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AMPLIFY

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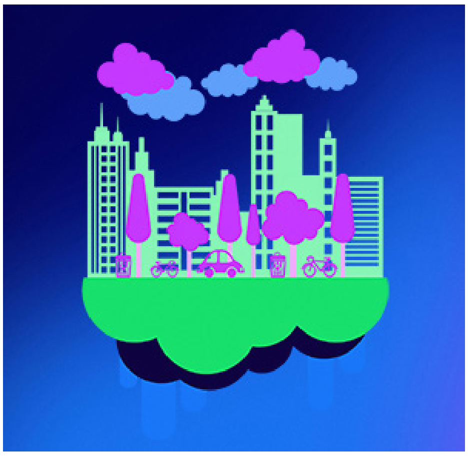
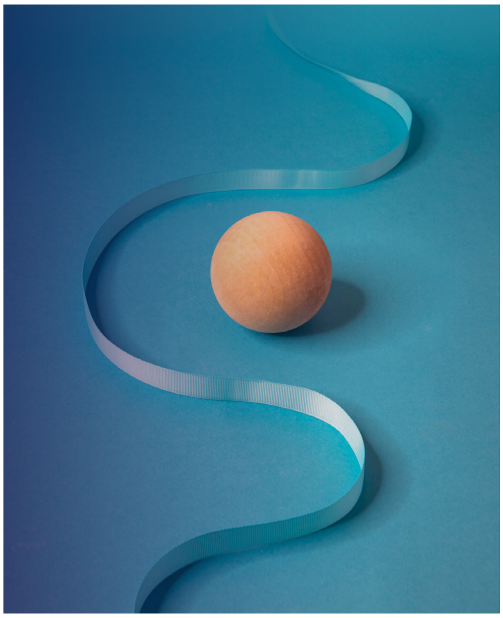
Anticipate, Innovate, Transform

Sustainable Urban Mobility

CONTENT





SUSTAINABLE URBAN MOBILITY

BY ANI MELKONYAN-GOTTSCHALK, GUEST EDITOR

In recent years, transportation and mobility systems have become extremely vulnerable to disruptions caused by geopolitical instabilities, intensified global trade, increased urbanization, changes in migration patterns, new business models across transport and mobility chains, and climate disasters. Meanwhile, urban transportation systems led to a substantial increase in urban energy demand, accounting for almost 30% of energy consumption globally, mostly of fossil fuels. Urban road transport accounts for 40% of all CO2 emissions and up to 70% of other pollutants, including nitrogen dioxide and particulate matter.[1]

This highlights the importance of investments in renewable energy infrastructure, public transport infrastructure, improved battery technology, and multinational cooperation to generate new technologies in the domain. A wide range of innovative technologies such as blockchain, big data, Internet of Things, augmented reality, AI, autonomous driving, and digital twins are being implemented to decarbonize transportation and mobility systems. Another technological innovation, mobility as a service (MaaS), has the potential to revolutionize the urban mobility paradigm, triggering a societal shift toward more sustainable travel behaviors.

Our first article in this issue of *Amplify* addresses the hurdles faced by MaaS implementations and what cities can do to overcome them. François-Joseph Van Audenhove and Hans Arby look at recent MaaS trends and detail four causes for slow progress: lack of demand, offerings that don't match demand, suboptimal enablement, and lack of viable business cases. The answer, they believe, lies in cities setting priorities to help extract value at the system level. Van Audenhove and Arby advocate for a comprehensive framework that includes framing dimensions (e.g., mobility patterns and system characteristics and creating the right conditions for mobility service providers) and enabling dimensions (e.g., integration support, regulations that allow open collaboration, and systems to ensure learnings from experimentation are extracted and shared). "One size fits all" is not the answer for MaaS, write the authors. Rather, comprehensive approaches and increased collaboration between public and private stakeholders are needed.

These types of shared services (e.g., car sharing) also need corresponding dynamic pricing mechanisms, which is the topic of our second article, by Christian Müller, Jochen Gönsch, Louisa Albrecht, and Max Staskiewicz. Given the convenience of free-floating car-sharing systems (customers can pick up a car and drop it off anywhere in a given area), they could contribute substantially to reducing road density and CO2 emissions. The difficulty is the imbalance of vehicle distribution caused by uneven travel patterns, and the authors propose mitigating this with an anticipative customer-centric pricing approach. Their data-driven model predicts future vehicle movements and the expected profit of each vehicle, then uses machine learning and AI to combine various data sources. This results in different prices for the same vehicle for different customers, depending on their location, thus rebalancing cars in the pickup/drop-off zone without the operator having to relocate cars (adding emissions). According to the authors, an extensive computational study and a case study showed the approach outperforms all benchmarks, saves providers operational costs, and improves sustainability via clear decarbonization benefits.

> **ANY INTERACTION BETWEEN SOCIETAL BENEFITS & SUSTAINABLE URBAN MOBILITY, SUCH AS PUBLIC HEALTH ASPECTS, SHOULD BE EXAMINED HOLISTICALLY**

ALIGNING AVAILABLE TECHNOLOGIES WITH SUSTAINABILITY GOALS

The decarbonization process enabled by advanced technologies and respective pricing schemes often goes further than reductions in greenhouse gas emissions: it aligns with broader societal goals such as climate adaptation, social equity/inclusion, and institutional transitions. Thus, effective and socially acceptable decarbonization strategies need to limit costs for industries and households (low abatement costs), be administratively manageable (low administrative costs), promote the development and deployment of new technologies (stimulate innovation), and contribute to broader socioeconomic goals, including the United Nations Sustainable Development Goals (UN SDGs).

Any interaction between societal benefits and sustainable urban mobility, such as public health aspects, should be examined holistically, including considering the urban built environment. This has been done by Kerstin Kopal and Dirk Wittowsky, who authored our next piece. As integrated as these functions are, public health concerns are usually included too late or not at all in urban planning processes today. The authors use a survey on walkability conducted in 2021 in Essen, Germany, to show how cities can identify key relationships between the built environment and healthy mobility behavior. The goal is to promote active mobility interventions by city planners; along the way, Kopal and Wittowsky describe how walkability data can be used by stakeholders like real estate companies and public transportation operators.

Public transportation planning systems must also consider ways to create dense, mixed-use zones close to transportation hubs. In our fourth article, Sk. Riad Bin Ashraf, Denis Daus, and Tobias Kuester-Campioni delve into transport-oriented development (TOD) by describing a proposal to municipal authorities in Dortmund, Germany, to help the city achieve its sustainable development objectives. Although Dortmund has a comprehensive public transportation system, it's not convenient enough to discourage private car use, especially given the city's urban sprawl. The proposal includes adding micromobility hubs at major transit points; installing AI-based adjustable bus routing;

adding pedestrian- and bicycle-friendly infrastructure; and adding high-density, mixed-use development near transit hubs. Finally, the authors point to TOD projects in India, China, Indonesia, and Australia that can serve as examples for urban planners as they work on their sustainable development objectives.

THE ROLE OF SUMPS IN ACHIEVING NET ZERO

The complex evolution of urban mobility planning concepts, pricing systems, technologies, and policies means that cities, governments, and organizations have undertaken a variety of initiatives to shape modern societies' sustainable urban mobility future.

Starting in 2009, the European Commission endorsed an action plan on urban mobility to promote and support local, regional, and national governments. The related white paper "Roadmap to a Single European Transport Area — Towards a Competitive and Resource-Efficient Transport System" was published in 2011. In December 2013, the European Commission developed an urban mobility package advising European cities to develop a sustainable urban mobility plan (SUMP). SUMPs are designed to satisfy the mobility needs of modern urban society while connecting the urban-rural continuum for better quality of life.

SUMPs strengthen current planning practices by considering the essential principles of integration, participation, and evaluation. They include urban freight distribution, urban access regulations, deployment of an intelligent transportation system, and road traffic safety. In our final contribution, Andrea Lorenzini explains how SUMPs can help local and regional authorities meet targets set out in the European Green Deal.

Six laboratories (in Belgium, Romania, the UK, Lithuania, Italy, and Greece) were set up to show how cities can develop the next generation of SUMPs and "put mobility at the heart of sustainable urban transformation." These labs are finding a need for strong coordination and collaboration at the local and regional levels (including cross-sectoral links), and Lorenzini describes what this could look like.

For example, in Lucca, Italy, the local public authority is involved in high-level planning, has legal responsibility for urban infrastructure and health, and runs daily operations to control urban logistics processes and ensure compliance with defined rules related to environmental impacts (e.g., traffic congestion and pollution).

Lorenzini points out that achieving net zero carbon by 2025 will require radical changes in transport and governance, followed by a periodic realignment of local planning objectives, partnerships, and frameworks with the high-level policy goals set at EU, national, and regional levels.

This issue of *Amplify* highlights the potential for technologies and new actors to develop mobility services so innovative that they can transform the current system into a more widely accepted, sustainable, resilient, and integrated model.

REFERENCE

[1] "Sustainable and Smart Urban Transport." European Parliament, January 2021.

About the guest editor

ANI MELKONYAN-GOTTSCHALK

Ani Melkonyan-Gottschalk is Professor for Sustainability and Socio-Technical Transformation at TU Clausthal. Previously, she was Professor and Executive Director of the Centre for Logistics and Traffic at the University of Duisburg-Essen, Germany. She has been involved in research and teaching for over 15 years in the areas of sustainable economies and frameworks for transitioning toward both sustainable and smart governance. Prof. Dr. Melkonyan-Gottschalk's expertise spans various domains, including sustainable and circular economies, smart and sustainable urban regions, sustainable supply chain management, the interconnectedness between resource and food systems, mobility and logistics systems, digital and innovative business ecosystems, and sustainable and inclusive governance models. She leads international, transdisciplinary research groups overseeing projects such as "Innovative Logistics for Sustainable Lifestyles," "Competence Network of Industrial and Rural Interlinkages," and "Innovative Citrus By-Products Supply Chain in the Mediterranean Area." These initiatives entail conducting comprehensive sustainability assessments across the entirety of modern services, both in stationary and online commerce while simultaneously exploring innovative business models related to sharing and circular economies. Through projects such as "Economic Assessment of Environmental Impact" funded by NASA, "Climate Mitigation and Adaptation Strategies" for the cities of Duisburg and Essen, "Essen — Green Capital City of Europe, 2017," and the Mercator Foundation–funded project "NEMO — New Emscher Mobility," Prof. Dr. Melkonyan-Gottschalk actively collaborates with local governmental authorities and industrial partners to develop collaborative decision support systems aimed at facilitating sustainable transition strategies. She has been published in more than 30 scientific publications and four monographs. Prof. Dr. Melkonyan-Gottschalk earned a bachelor's degree in economics and a master's degree in mathematical modeling from Yerevan State University, Armenia, and a PhD in environmental sciences from the University of Duisburg-Essen. She can be reached at ani.melkonyan-gottschalk@tu-clausthal.de.

IS MAAS DELIVERING ON ITS PROMISE?

PRAGMATIC INSIGHTS & PERSPECTIVES

Authors

Francois-Joseph Van Audenhove
and Hans Arby

Mobility as a service (MaaS) has the potential to deliver more sustainable, resilient, and human-centric mobility for the world, but significant barriers remain. Based on our experience as strategy consultants advising cities and public/private MaaS operators, vendors on the development of MaaS concepts and solutions, and entrepreneurs driving MaaS deployments, we're taking a fresh look at these hurdles and what cities can do to overcome them.

MaaS aims to encourage the use of more sustainable transport modes, moving the world away from individual car use "by default." MaaS promises seamless access to a wide array of mobility options to meet differing needs alongside increased simplicity and convenience in planning, booking, payment, getting information, and access to services for all passengers (see Figure 1, next page). From the perspective of cities and authorities, in addition to encouraging more sustainable mobility patterns and improving accessibility, MaaS could allow system-level asset optimization. For mobility service providers (MSPs), a MaaS framework could lead to better customer engagement, more tailored offerings, and reduced customer-acquisition costs.

WHERE IS MAAS TODAY?

Many MaaS implementations to date have been limited to one-size-fits-all travel planners (i.e., not focused on specific use cases), with a limited number of MSPs being fully integrated in terms of ticketing and payment and others only partly integrated.

However, we are seeing some interesting trends, including a general move away from business-to-customer (B2C) models that are financed with private capital toward a government-to-customer (G2C) one led by public transport authorities or operators. The difficulties behind the MaaS B2C model are well illustrated by the fate of MaaS Global (the most prominent example of this model). After several attempts to shift its business model, MaaS Global filed for bankruptcy in March. Although most G2C schemes are still "walled gardens" in terms of data sharing, there are signs of a shift toward open, public MaaS platforms accessible to third parties, as pioneered in Vienna, Austria, (Upstream Mobility) and now in the Netherlands (Rivier) and possibly later in Brussels, Belgium.

Business-to-employee (B2E) models have seen some positive evolution over the past two years, especially in Western and Central Europe triggered by fiscal incentives, and several vendors and B2C players are pivoting to this model. We are also seeing a rise in MaaS B2C models targeting specific use cases with better returns, such as tourist MaaS (e.g., Alpine Pearls) and rail/aviation MaaS (e.g., Doco by Renfe in Spain and AirAsia MOVE).

> **A MAAS FRAMEWORK COULD LEAD TO BETTER CUSTOMER ENGAGEMENT, MORE TAILORED OFFERINGS & REDUCED CUSTOMER-ACQUISITION COSTS**

CONSUMERS	• Improved customer experience by providing freedom to move through multiple mobility options based on preferences & circumstances • Triggering movement from ownership to usage, as well as reduction in overall mobility budget
CITIES/AUTHORITIES	• Ability to orient behavior toward more sustainable mobility patterns (e.g., mass transit, walking, new mobility) • Increased accessibility & inclusiveness • System-level optimization of flows & assets
MOBILITY SOLUTIONS PROVIDERS	• Real-time optimization of each mobility offering • Expanded access to all mobility needs expressed; reduced acquisition & customer support costs • Additional channel for user engagement

Figure 1. The MaaS promise — enhance the attractiveness of the shared mobility system (source: Arthur D. Little)

Another B2C variant involves mobility services offered as an integrated feature of another set of services, such as insurance, rent (business to tenant), banking (sometimes called "mobility as a feature"), or within super apps. Some promising rural MaaS applications focus on accessibility, in which the business case is more about cost savings for regional authorities than new revenue streams.

There have been positive efforts to evolve regulations, standards, and codes of practice to accelerate MaaS deployment and ease relationship management across various stakeholders, including Multimodal Travel Information and Multimodal Digital Mobility Services in Europe. Nevertheless, expansion has been slow overall, and MaaS-powered trips still represent only a tiny proportion of mobility trips worldwide.

We must conclude that, up to now, MaaS has not delivered on its promise. In terms of the Gartner hype curve, MaaS is probably close to the Trough of Disillusionment (see Figure 2). Whether, and how, it can climb the Slope of Enlightenment is the key question.

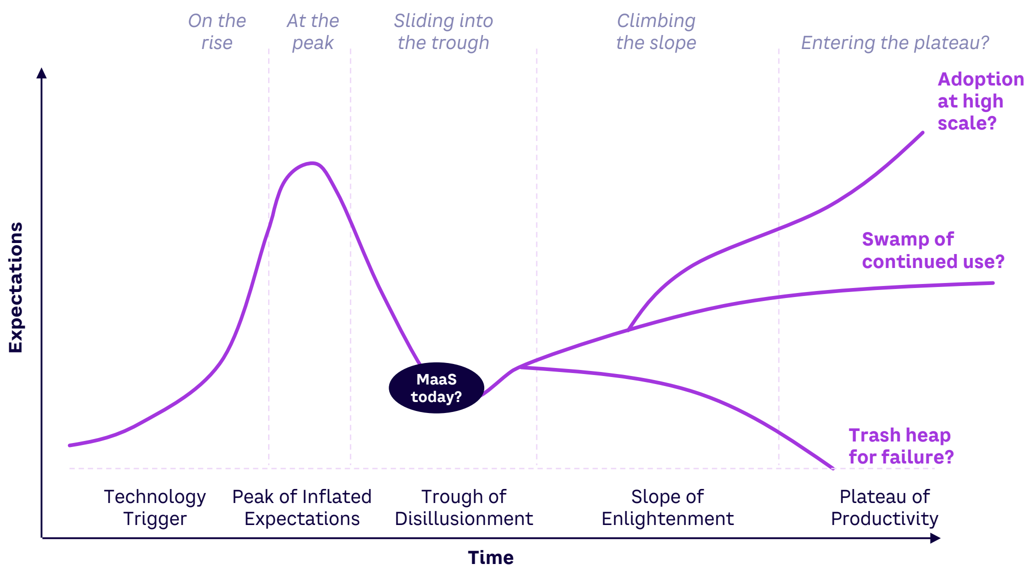


Figure 2. Where MaaS currently falls on Gartner technology hype curve (source: Arthur D. Little)

WHAT ARE THE ROOT CAUSES OF SLOW PROGRESS?

When attempting to verify the impact of MaaS, we run into two problems: (1) a lack of large-scale implementations to date and (2) a lack of proper evaluation of pilots and current operations that are not sharing data. From our experience, we have analyzed the possible root causes for MaaS falling short of its promise. These causes fall into four categories (see Figure 3):

1. **Lack of demand for MaaS.** Demand for good public transport is high, but it does not cover all the needs of users (e.g., door-to-door travel). Another rare example with high demand — and willingness to pay — is micromobility, especially e-scooters, e-bikes, and bikes. The percentage of intermodal trips in cities (using different modes in one journey) is typically less than 5%, excluding walking, but there seems to be strong demand for multimodal life (using different modes for different journeys), which is something that MaaS can facilitate, leading to higher demand.
2. **MaaS offerings not matching demand.** Here, one of the main failings is insufficient investment in the necessary physical solutions and infrastructure to provide the required service and customer experience, in addition to the digital components of MaaS. A second issue is that the accessibility, reliability, relevance, and pricing of the included mobility services are often not attractive enough individually, and a MaaS offer can only be so much more attractive than its components. Finally, MaaS offerings are often too generic, failing to match specific customer use cases.
3. **Suboptimal enablement.** The lack of collaboration between traditional public transport operators (PTOs), MaaS providers, and third-party MSPs is a major barrier to MaaS deployment. Few PTOs have opened their systems for third-party ticket reselling, and even fewer allow reselling of monthly passes or flexible tickets/subscriptions. Current regulations don't support such collaboration.
4. **Lack of viable business cases.** Apart from specific use cases, the business case for MaaS operators is challenging due to low margins and difficulties in building sufficient volume. The lack of volume and high levels of competition also make it challenging for MaaS vendors, limiting their ability to invest. Apart from micromobility players, most MSPs don't see the value in being integrated into MaaS services: it involves having to give up precious margins, and the current MaaS scope does not necessarily cover their customers' needs. There's money to be found in the economy of car ownership, which is something that MaaS still needs to tap into — subscription-based services can create value for all parties, but these are currently a hard sell.

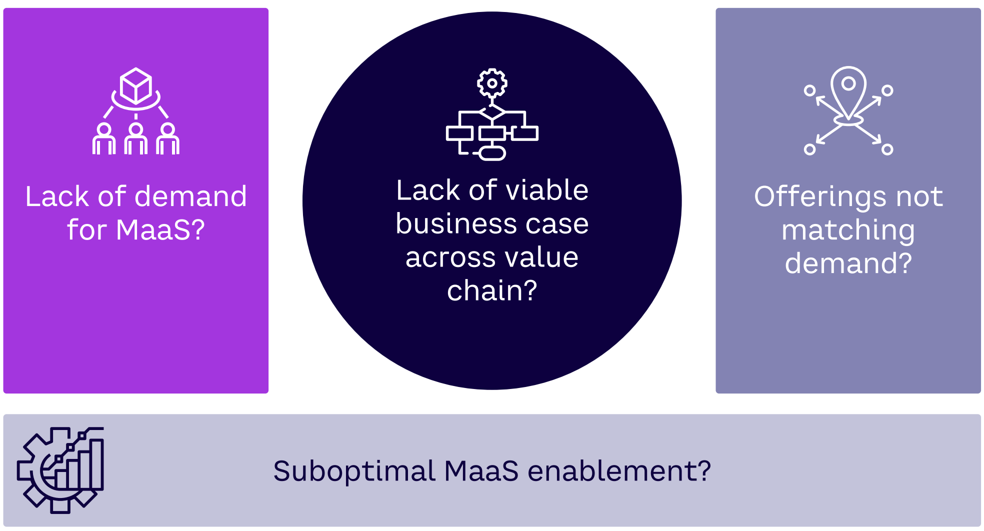


Figure 3. Root causes of barriers to MaaS progress (source: Arthur D. Little)

WHAT CAN CITIES & AUTHORITIES DO?

Moving ahead requires a more comprehensive approach to framing and enabling a virtuous mobility system powered by MaaS, as well as increased collaboration between public and private stakeholders.

Cities and authorities cannot bring about such a system on their own, but they play a key role in setting priorities to help fully extract value at the system level. Working out how to prioritize efforts in a tight funding environment is difficult. The Arthur D. Little (ADL) MaaS 360 review framework identifies six dimensions that together can drive progress (see Figure 4). They include:

- Framing dimensions such as reviewing mobility vision, strategy, and funding considering mobility patterns and system characteristics, creating the right conditions for MSPs, investing in infrastructures, and promoting/ensuring the progressive deployment of MaaS offerings that cater to relevant customer use cases.
- Enabling dimensions such as technical development and support, regulations that allow open collaboration across players and incent more sustainable behaviors, and programs that ensure learnings from experimentation are extracted and shared to foster continuous improvement.

CONCLUSION

Although MaaS has yet to deliver on its promise, there are huge benefits ahead that justify continuous efforts. As with most innovations, first steps are taken by targeted use cases, not one-size-fits-all offerings. Progress will require a more comprehensive approach to frame and enable a virtuous mobility system powered by MaaS, as well as increased collaboration between public and private stakeholders. Cities, transport authorities, and PTOs have a significant role to play in extracting value at the system level and unlocking MaaS's full potential.

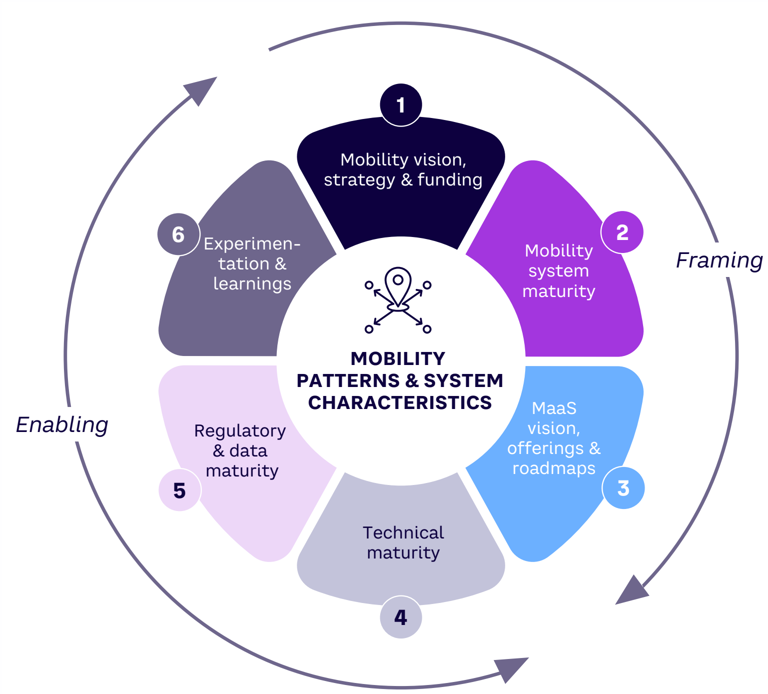


Figure 4. Arthur D. Little's MaaS 360°review framework

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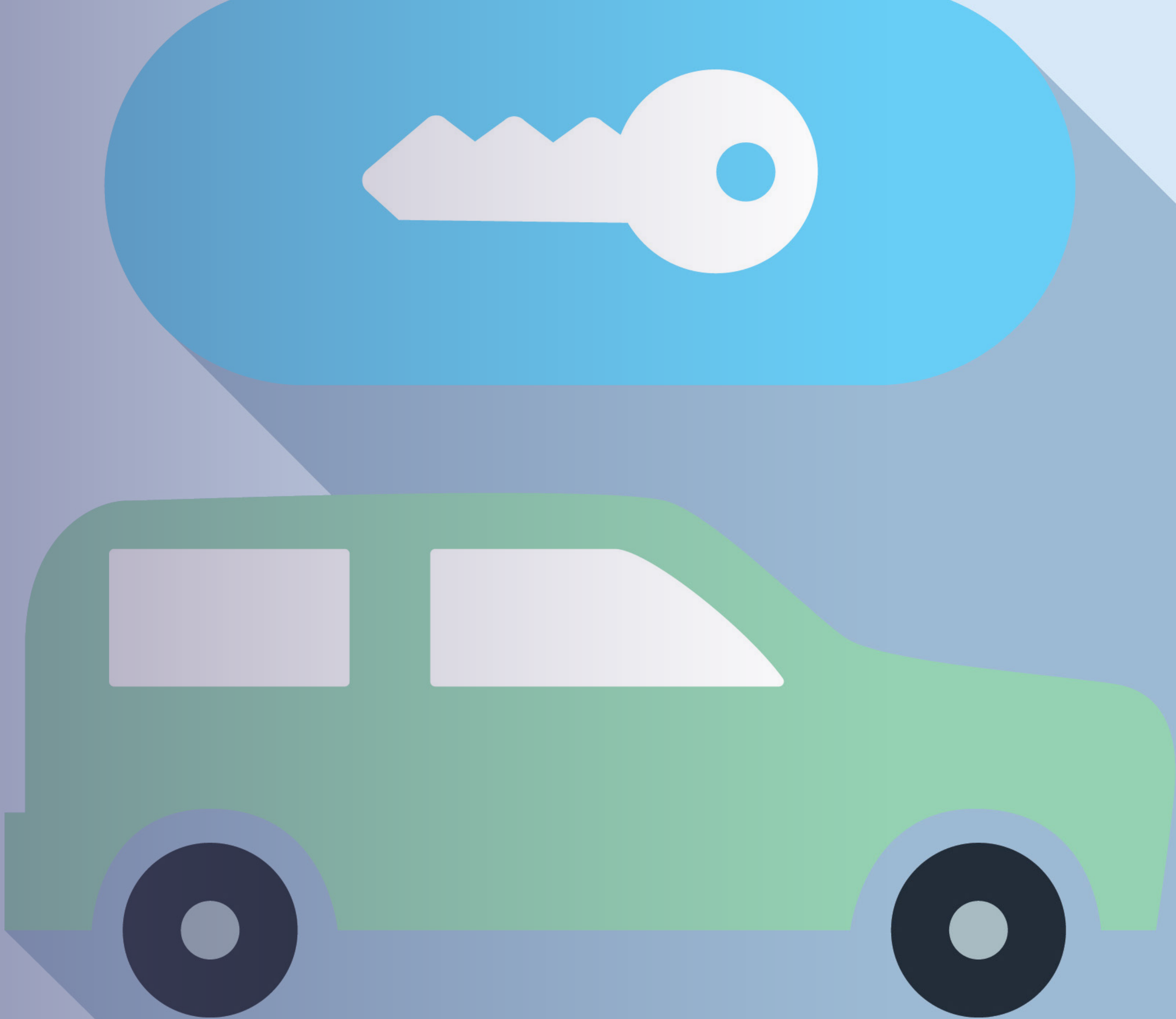
DYNAMIC PRICING FOR CAR-SHARING SYSTEMS REDUCES CO2 EMISSIONS



Authors

Christian Müller, Jochen Gönsch,
Louisa Albrecht, and Max Staskiewicz

The importance of sustainability in the mobility sector is coming to the forefront of the global agenda, driven by the urgent need to reduce CO2 emissions. Sustainable mobility concepts can minimize environmental impact and significantly improve quality of life in urban areas by promoting transportation modes that consume fewer resources and produce lower emissions.[1]

The transportation sector significantly contributes to environmental and societal issues, particularly through the use of private vehicles. Air pollution, noise, congestion, and the extensive use of valuable urban space for parking are just some of the adverse effects of traditional transportation systems. These issues underscore the need for more sustainable and efficient mobility concepts.

Given the global climate crisis, reducing CO2 emissions in the transportation sector is crucial. To achieve the goals of the Paris Agreement and avert the worst impacts of climate change, effective measures must be taken now. This requires new transportation concepts and the promotion of environmentally friendly, sustainable mobility forms.

Traditional mobility faces numerous challenges, including inefficiencies, congestion, and an inability to meet the growing demand for urban mobility with existing road capacities. These challenges require innovative solutions that improve efficiency and promote sustainable transportation infrastructure.[2]

One aspect of sustainable mobility is vehicle-sharing systems, which ensure that the last mile is covered. These systems increase the use of existing vehicles and reduce the total number of cars by replacing private cars. Vehicle-sharing systems contribute even more to a sustainable strategy if they are electric (significantly reducing CO2 emissions).

In this article, we focus on car-sharing systems and distinguish between one-way/free-floating and two-way car-sharing systems. In one-way car-sharing systems, the customer can pick up the car at one station and drop it off at any other station, or at the same station. In free-floating car-sharing systems, the customer can pick up the car and drop it off anywhere in the business area. In two-way car-sharing systems, the customer must drop the car at the same station where they picked it up. We focus on free-floating systems as the most flexible and convenient alternative to private cars, facilitating more efficient vehicle use and potentially reducing road density and thus CO2 emissions.

> **GIVEN THE GLOBAL CLIMATE CRISIS, REDUCING CO2 EMISSIONS IN THE TRANSPORTATION SECTOR IS CRUCIAL**

BALANCING WITH RELOCATION

Free-floating car-sharing providers face a major challenge: the imbalance of vehicle distribution caused by uneven travel patterns. This results in an accumulation of cars at popular destinations and a lack of cars at popular origins. As a result, the system can no longer meet demand and may lose customers. One solution to this imbalance is relocation.

We distinguish between operator-based and user-based relocation: *operator-based relocation* involves relocation of vehicles by employees; *user-based relocation* is performed by customers who are incentivized by pricing. Operator-based relocation has several drawbacks: it causes additional CO_2 emissions during relocation, increases operational costs, and is inefficient because vehicles are blocked during this relocation time. In contrast, user-based relocation does not generate additional CO_2 emissions or operational costs.

This article focuses on the development of a profit-maximizing dynamic pricing model for free-floating car-sharing systems. Our approach is customer-centric and leverages stochastic dynamic programming to anticipate future vehicle locations, rentals, and profits. By considering customer locations and disaggregated choice behavior in price optimization, we can accurately capture the effects of price and walking distance on the likelihood of vehicle selection by the customer. This origin-based, anticipative, dynamic-pricing approach not only enhances profitability, it helps providers overcome the major challenge of free-floating car-sharing systems.[3]

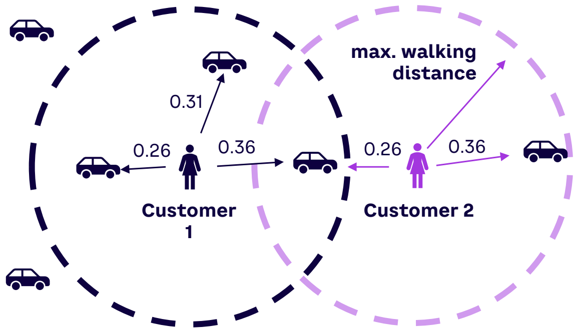


Figure 1. Illustration of customer-centric dynamic pricing

DYNAMIC PRICING & MODELING

This section describes an anticipative customer-centric pricing approach developed in a joint project with German car-sharing company Share Now. The core idea is to avoid imbalances not through relocation, but by using intelligent, customer-centric, dynamic pricing to incentivize customers to achieve a more balanced distribution of vehicles (sometimes called "user-based relocation").

The approach is based on a complex, data-driven model that considers the interplay between supply and demand in a business area, predicts future vehicle movements and the expected profit of each vehicle, and uses machine learning and AI to combine various data sources (e.g., vehicle GPS data, anonymized demand data).

The innovative aspect of this pricing approach is that it is customer-centric and dynamic. This is not the case with the pricing approach of other vehicle-sharing providers. Customer-centric dynamic pricing means that when a customer opens the provider's mobile application to rent a vehicle, the price optimization incorporates the customer's location as well as detailed (sometimes called "disaggregated") choice behavior to precisely capture the effect of price and walking distance on the customer's probability of choosing a vehicle.[4]

In contrast to other approaches, customer-centric pricing can result in different prices for the same vehicle for different customers, depending on their location. Figure 1 shows two customers opening the application at different locations. Both have a similar maximum walking distance (meaning they only consider cars within their respective walking distance). Both customers consider the car at the intersection of both walking areas. The system shows Customer 1 a price of €0.36 per minute; Customer 2 sees a price of €0.26 per minute.

Two other features distinguish this approach: (1) it is origin-based, meaning that prices are differentiated by origin location and origin time, which reflects the situation of many car-sharing providers, such as our practice partner Share Now; and (2) it is anticipative, as it stochastically predicts the impact of the current pricing decision for future profit using approximate dynamic programming.

The provider operates a fleet of cars spread across a business area with the objective of both maximizing profits and being as sustainable as possible. We consider a planning horizon of one day, in which the model is solved each time a customer arrives. Thus, each customer who opens the application receives prices for the cars. Each time the application is opened, the provider dynamically optimizes the prices in real time.

If the customer arrives, the provider knows the current vehicle distribution and potentially reachable vehicles for the customer (vehicles within the specified walking distance). Prices for reachable vehicles are then calculated based on the location of the customer, probability of the customer choosing a vehicle, and current vehicle distribution. The probability of choosing a vehicle is a function of price and distance to the vehicle, which is determined by an advanced customer-choice model.

MODEL & ALGORITHM

The model calculates optimal prices by calculating expected profit after a customer arrives. The profit-maximizing has two parts. First, it calculates the expected profit if a customer arrives, opens the application, and chooses a vehicle. This expected profit is divided into two parts: (1) the expected profit for the current rental the customer has chosen and (2) the approximate expected future profit generated by the entire system after a vehicle has been chosen. The second part of the equation considers the expected profit if the customer does not choose a car and disappears.

To improve tractability, we approximate the values for expected future profit. The challenge is to find a suitable approximation; ours is based on the simplification that the overall profit obtained until the end of the day is additive to the future profits of the cars. Thus, the expected future profit after the car has been chosen is approximately the sum of the values (expected profit) of the remaining idle vehicles plus the value of the chosen vehicle. The expected future profit when no car was chosen is approximately the sum (expected profit) of all idle cars.

To determine the values of the cars, we need historical data with information about the location of various cars, the time when they were picked up, and the profit they generated until the end of the day. Thus, for each car in the historical data, we have data about when and where it was picked up and how much profit the corresponding rental generated, as well as when and where each car was dropped off.

Using this historical data, we filter out the car values that are spatially and temporally similar (e.g., within 500 meters of the current location of the evaluated car, represented by the semicircle in Figure 2). To calculate the value of the gray idle car in Figure 2, we consider all idle car values in the spatial and temporal vicinity in the historical data (all crosses within the semicircle). We then weight the historical car values according to their spatial and temporal similarity.

For example, to evaluate the gray idle car, we consider the purple and black crosses within the semicircle, which represent different car values of idle cars at different times and locations. The car value of the first black cross is given a higher weight because it is closer in space and time to the gray idle car than the first purple cross. If the gray car departs, the vehicle is evaluated analogously.

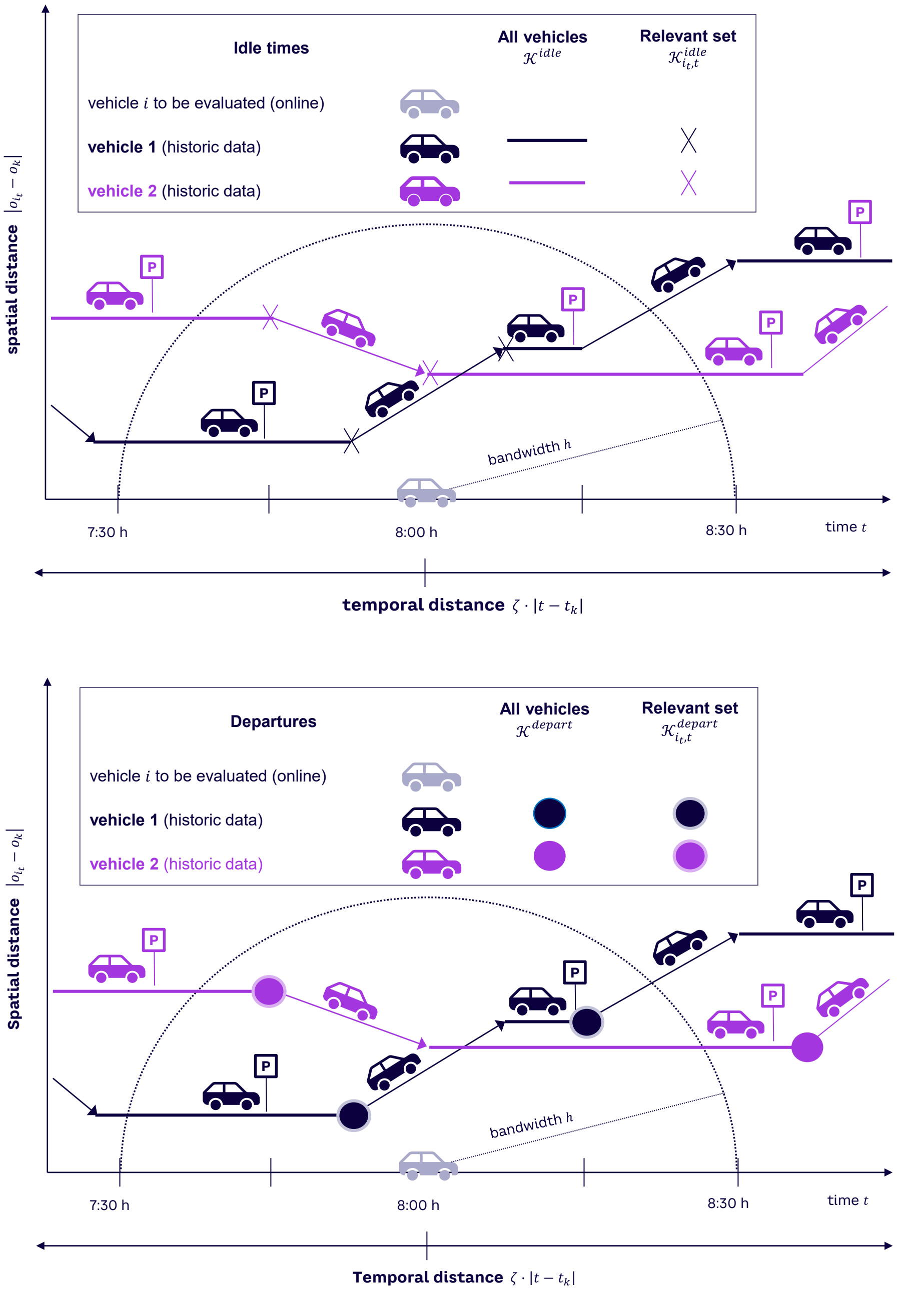


Figure 2. Illustration of historical data considered for evaluation of vehicle i (top: idle vehicle, bottom: departing vehicle)

RESULTS

To illustrate the benefits of our dynamic pricing approach (C-ANT) over other benchmarks, we carried out several computational studies and a case study using Share Now data from the city of Vienna, Austria. We considered three benchmarks. The first is a unit price (BASE). Thus, the provider does not differentiate the price. The second is customer-centric myopic pricing (MYOP), which does not consider the expected future profit. The third is non-customer-centric (i.e., location-based) anticipative dynamic pricing (L-ANT).

In an extensive computational study, we examined the developed approach and the benchmarks in realistic settings with varying business area and fleet sizes as well as varying demand patterns and overall demand levels, indicated by the demand-supply-ratio (i.e., the maximum period demand divided by the fleet size).

SETTING

We assumed a planning horizon of one day. The demand patterns we used replicate what is observed in practice: demand intensity varies over the course of the day with two peaks. There is also a spatial variation of demand (e.g., between the city center and outer areas). Across all settings and demand preferences, we considered three or five possible prices (in the case study), as car-sharing providers aim for a transparent, easy-to-communicate pricing mechanism. These prices are predefined based on typical prices in practice.

PROFIT IMPACT

We divided the results into two categories: profit and sustainability implications. The numerical results of our computational study show the C-ANT approach provides the highest profit for all settings and demand levels.

When compared to MYOP, we found that anticipative approaches (C-ANT and L-ANT) result in a higher fluctuation of prices across the business area. This is because they can consider future vehicle distribution and rentals in their pricing approach, allowing them to incentivize user-based relocations by varying prices in time and space.

For instance, in all peripheral areas, relatively low prices are set in the morning to incentivize customers to drive vehicles to the center, where demand is comparatively high. Furthermore, taking situation-specific customer information into account enables our approach to better adapt incentives to the customer's choice behavior.

Due to its ability to anticipate the spatiotemporal demand asymmetries and incentivize user-based vehicle relocations, C-ANT leads to a distribution of vehicles that is better aligned with demand. Immediately before the afternoon peak at 17:30, C-ANT manages to have more vehicles in the center of the business area where demand is strongest at this time compared to the benchmarks.

Regarding possible interdependencies between vehicle distribution and profits, we concluded that very low prices, especially in the outer areas during morning hours, can be successfully used as a customer incentive and can lead to higher profits later in the day when the vehicle distribution is better synchronized with demand.

The results of the numerical study and the case study confirm the benefits of the customer-centric dynamic pricing approach, which outperforms all considered benchmarks significantly, particularly with regard to realized profits and the spatial distribution of vehicles. An analysis suggests that the anticipation of future states and profits, together with the implementation of customer-centricity, is the main driver of its performance.

SUSTAINABILITY

Although profit maximization is the objective of the optimization problem and the most important metric from the perspective of car-sharing providers,[5] the customer-centric dynamic pricing approach can make a significant contribution to a provider's sustainability performance due to the reduced need for operator-based relocations.

Profit maximization does not have to be traded against sustainability considerations, as both targets can be considered by anticipating spatiotemporal demand variation in pricing, incentivizing customers to drive from low-demand to high-demand locations. The incentivization of user-based relocations via a customer-centric anticipative dynamic pricing approach improves profitability compared to alternative approaches while reducing the need for operator-based relocations. Providers not only save operational costs incurred by additional staff and equipment, they can reduce CO2 emissions and fuel consumption caused by "unnecessary" rentals or relocations.

To summarize, the customer-centric anticipative dynamic pricing approach for free-floating car-sharing systems performs considerably better in comparison to existing approaches in terms of relevant performance metrics and potential for improving sustainability.

THE SYSTEM IN PRACTICE

Share Now started with unit pricing for identical vehicles. In 2019, as a first step, it implemented static pricing, where the price is a function of the time and location of the rental's origin. To do so, it used either a predecessor's approach or our approach.

Next, Share Now wanted to implement dynamic pricing. It tested the customer-centric dynamic pricing approach in its digital twin, and the results were consistent with our findings. Back then, Share Now was a Mercedes Benz-BMW joint venture. After its recent sale to Stellantis, Share Now has some different preferences, so the dynamic pricing approach has not been implemented. We believe the process will restart this year.

The advantage and practicability of customer-centric dynamic pricing is that it does not have to be adapted for geographic regions or sharing providers (e.g., scooter sharing, bike sharing) because it is based on historical data of the geographic region or provider and thus implicitly considers the characteristics of the sharing system or geographic features. It can easily be transferred to other vehicle-sharing providers or regions.

CONCLUSION

This article described a profit-maximizing dynamic pricing model for free-floating car-sharing systems to counter the uneven distribution of vehicles, thus increasing the system's sustainability and efficiency by incentivizing user-based relocations.

After a customer opens the provider's mobile application, the system calculates the optimal prices. The probability of choosing a vehicle is a function of price and the customer's distance to the vehicle. We approximated the overall expected future profit by the sum of the expected future car profit. To determine the approximated future car profit, we used historical car values, which we weighted according to their spatial and temporal similarity.

In an extensive computational study as well as a case study, we demonstrated that our new pricing approach significantly outperforms all benchmarks. These results show that integrating anticipation and customer-centricity into dynamic pricing in car sharing leads to significant profit improvement across all settings and demand preferences.

Compared with the benchmarks, the anticipative customer-centric dynamic pricing approach leads to a vehicle distribution that is more balanced and better synchronized with demand (e.g., it raises prices in an area in the early morning if it anticipates a shortage of vehicles around noon).

The incentivization of user-based relocation via a customer-centric dynamic pricing approach improves profitability compared to alternative approaches while reducing the need for operator-based relocation. Regarding the objective to align future demand and supply, user-based relocation offers a favorable alternative to operator-based relocation in terms of both economic and environmental concerns.

From a sustainability perspective, user-based relocation not only helps providers save operational costs incurred from additional vehicles and staff, but it also reduces CO_2 emissions and fuel consumption generated by "unnecessary" operator-based relocations.

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SUSTAINABLE URBAN DYNAMICS:

SYNERGIES BETWEEN BUILT ENVIRONMENT, MOBILITY & PUBLIC HEALTH

Authors

Kerstin Kopal and Dirk Wittowsky

In recent decades, policy makers and local authorities have ignored the negative effects of predominantly car-oriented urban structures on people and the built environment. The design and distribution of transport infrastructure, as well as the modal split between various transport modes, play a critical role in determining overall health outcomes for society and individuals.[1]

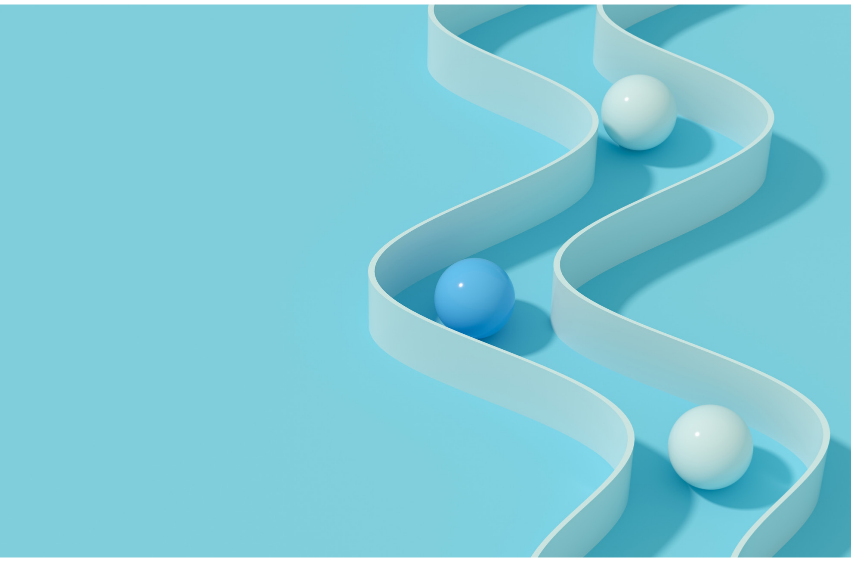
The interaction between the built environment, mobility, and public health has a huge impact on the role of the city in shaping the well-being of its inhabitants.[2] Simply put, the built environment (urban infrastructure, architectural design, and green and blue spaces) serves as a fundamental template for individual mobility patterns. The built environment, for instance, influences the daily lives of urban inhabitants in terms of walkability and accessibility to various daily amenities and modes of transport.[3] The spatial dynamics of urban mobility are shaped by the configuration of the transportation system, while the design and safety of public spaces affect leisure time use in the urban landscape. Consequently, individual mobility behavior is a complex interaction between subjective perceptions and the objective availability of mobility options.[4]

Motorized private transport and air traffic remain the primary sources of pollutant emissions. The consequences of these emissions have a significant impact on both climate and human health. According to the World Health Organization (WHO), air pollution is one of the biggest threats to health, with 8.8 million people dying prematurely each year.[5] Many cities are already experiencing heat islands due to densities and a lack of natural air exchange.[6] Despite this, mobility patterns have remained largely unchanged in Germany over the past 20 years.[7]

Historically, the protection of human health has played an important role in urban planning and has even been one of the starting points for planned development. Since the Middle Ages, there have been fire-safety regulations and restrictions on the use of tanneries due to dense development.[8] The Athens Charter, which aimed to improve hygienic conditions during the industrialization era, demonstrated the link between urban planning and health by focusing on improving ventilation and lighting in neighborhoods through the separation of work and living functions.[9]

> **SIMPLY PUT, THE BUILT ENVIRONMENT SERVES AS A FUNDAMENTAL TEMPLATE FOR INDIVIDUAL MOBILITY PATTERNS**

Unfortunately, public health concerns are usually included too late or not at all in the planning process today.[10] It seems that public health and urban planning have drifted apart. This lack of health-promoting structure means that many people do not have access to low-threshold, attractive opportunities for physical activity, including the simplest form of exercise: walking.[11] Due to car-oriented street environments, walking is often limited and unsatisfying,[12] and leaving health aspects out of the urban planning process has resulted in a wide disparity in health outcomes.[13]



The WHO's Health in All Policies (HiAP) approach was adopted to bring back the link between urban planning and public health. It aims to integrate public health into all sectors and levels of public service. As a result, health issues such as prevention, health promotion, and healthcare are integrated into the disciplines of mobility and urban planning. The need to link public health and urban planning is also evident at the normative level, such as construction regulations.[14]

Sustainable urban development promotes a holistic approach that has led to an increase in the popularity of sustainable transportation options, such as walking and cycling. Although walking and cycling have predominantly positive effects on the environment and human health, these modes of transportation don't fit into the daily mobility behavior of many people.

The concept of "walkability" describes neighborhoods that are easily accessible by foot or bike. This approach has a holistic impact, benefiting many areas. For example, more active lifestyles can reduce health costs and the incidence of noncommunicable diseases, such as heart disease and obesity.[15,16]

Active lifestyles and longer life expectancies also have a positive impact on the economy. For example, the German Institute of Urban Affairs found that employees who walk or cycle to work take a third fewer sick days per year and have a significantly lower body mass index.[17] Similarly, pedestrian traffic occupies less space than motorized traffic, so areas such as streets or parking lots can be redesigned and transformed into recreational green spaces. The creation of green spaces and the reduction of motorized traffic help improve climate and air quality.[18] A well-developed pedestrian infrastructure in the city center can also lead to more casual shoppers and increased purchases. City centers appear more attractive and safer to people when they are vibrant. Pedestrian areas are designed for strolling and lingering. Jan Gehl, a Danish architect and urban designer, put it this way: "Man is man's greatest joy."[19]

DATA EXAMPLE: UNDERSTANDING WALKABILITY

This article focuses on an empirical approach to identify relationships between the built environment and healthy mobility behavior to provide impetus for the development of active mobility interventions. Studies show that public health and the promotion of active and healthy mobility will be important for the design of future urban systems to reduce healthcare costs and create attractive urban districts. To plan strategic urban and transport systems, we must develop interdisciplinary databases and multilevel indicators.

An online survey was conducted in July 2021, with participants selected from an access panel weighted by age, gender, and residential location. The sample comprised 500 people 18 years of age or older living in Essen, Germany. The questionnaire consisted of 57 questions covering the following topics:

- Sociodemographics
- Health status
- Mobility options
- Physical activity patterns
- Quality of the environment
- Mobility behavior and activity radius
- Attitude and mobility culture
- Future vision

The study area was the city of Essen in the Ruhr region, the most densely populated part of Germany. Essen currently has 595,598 inhabitants living in 50 districts. Healthy and sustainable urban and mobility planning is becoming increasingly important in Essen, which suffers from the effects of car-dominated urban planning.[20]

The gender distribution of the data was 60.6% female and 39.4% male. The age distribution was diverse, with the majority in the 30-39 age group (23.6%). Most participants had completed high school (73%) and were employed (67%). Health status was good, with 44.6% reporting good health and 36.2% reporting very good health. The majority had a healthy weight (33.4%) or pre-obesity (25.6%). A significant proportion of the sample had a driver's license (84.4%). In terms of mobility, participants reported an average of 3.8 trips per day, with an average of 5,882 steps taken on foot per day. The household vehicle fleet consisted mainly of cars (1.1 average) and bicycles (1.4 average).

When respondents answered questions about their living environment, activity radius mapping was a key tool in understanding perceptions about and influences of the built environment. Participants placed pins on maps to mark their place of residence, workplace, and three preferred recreational areas. Coordinates were truncated to ensure anonymity.

The residential and work locations are shown in Figures 1 and 2 as examples. The distribution of places of residence shows a decline from north to south (see Figure 1). However, with the Baldeneysee (a lake in the south) and the urban forest (just above the lake), it is also clear that the southern part of Essen offers less residential space and serves primarily as a local recreation area. The majority of respondents live in Frohnhausen, followed by Rüttenscheid, Altenessen-Süd, and Südviertel. The information is concentrated in the northern and central parts of Essen, both in terms of residences and places of work. About 14% of the respondents work outside the city of Essen.

As stated, activity radius mapping plays an important role in identifying the influences of the built environment on people's health and mobility behavior. This is also applicable to certain indices that can be used as indicators for necessary interventions in urban planning, such as walkability. Walkability can also be calculated by collecting data on the built environment alongside subjective perceptions.

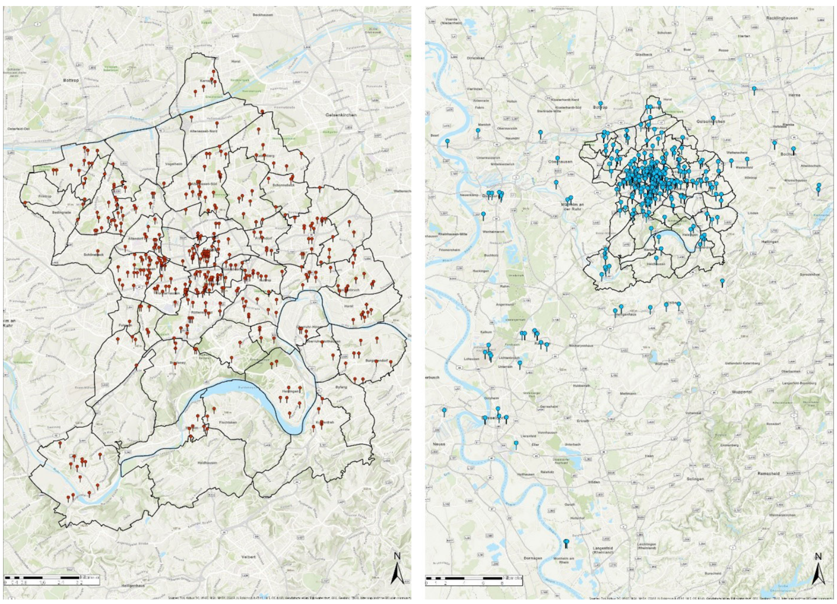


Figure 1. Place of residence (left) and place of work (right); n = 329

This study collected items of objective walkability (14 items), subjective walkability (18 items), and accessibility (7 items) to quantify a representative walkability indicator. The items were questions about the walkability of the neighborhood (e.g., "How satisfied are you with the possibility of walking in your neighborhood?"; "How many minutes does it take to walk to your nearest transit stop?"). There were five predefined responses to these questions, each with a scale of 1 to 5. The scores were summed, and the mean was calculated to obtain the walkability index.

In our study, we calculated the walkability for every district in Essen. The results are shown in Figure 2. In the walkability index, 5 is the highest possible score. In this sample, the range of walkability is 2.95 to 4.24. The overall walkability for the city of Essen is 3.61, which is in the upper-half of the index, indicating that Essen has good overall walkability. The most walkable districts in Essen appear to be Byfang and Haarzopf. Rüttenscheid, Schuir, Heidhausen, and Bochold seem to have the worst walkability in this sample, but the index is still quite high, with 2.95 for Schuir and 3.40 for Heidhausen. The indices for Frintrop and Vogelheim could not be calculated because none of the study participants live in these areas.

Except for a few outliers, there is a decline from south to north, with the southern districts of Essen rating higher than the northern districts. This trend can also be seen in the standard land values of the city of Essen, which are often used as an indicator of attractiveness.[21] Furthermore, neighborhoods located on the outskirts of a city tend to have lower walkability compared to those in the city center. This is because grocery stores, schools, and transit stops are often difficult to reach on foot or by bike in rural areas.

Another interesting piece of information is the data on the ratings of the individual indicators that make up the walkability index. The best rating for the city of Essen was given to the indicator "presence of sidewalks," and the worst rating was given to the indicator "drivers exceeding the speed limit in the neighborhood."

In the most walkable district, Byfang, several indicators received the highest score of 5, including "connectivity of streets" and "presence of green spaces." The lowest score in Byfang was for "pedestrian crossings and traffic lights on busy streets." In Schuir, the district with the worst walkability, the item "neighborhood as a place to live and feel good" got the highest rating, and the item "satisfaction with traffic noise in the neighborhood" got the worst.

Based on these findings, the walkability index is a valuable tool for improving the built environment relative to physical activity. As shown, it can measure walkability for an entire city and at the district level. The data set could also be used to analyze individual streets.

THE WALKABILITY INDEX IS A VALUABLE TOOL FOR IMPROVING THE BUILT ENVIRONMENT RELATIVE TO PHYSICAL ACTIVITY

Walkability indices can also be used by real estate companies and public transportation operators. For example, accessibility impact can be determined based on property prices or the acceptance of public transport usage. Accessibility planning is also crucial for evaluating urban areas for investments or to estimate mobility justice. It could also be used by property owners to estimate the value of their property or explain trends in economic performance.[22]

The data shows that mobility and urban planning experts should take a more integrated approach to the design of public spaces. A built environment that promotes physical activity and good health can be linked to walkability and mobility behavior. Behavioral measures at the neighborhood level are an additional way to promote the desired change in mobility patterns and the integration of physical activity into everyday life.

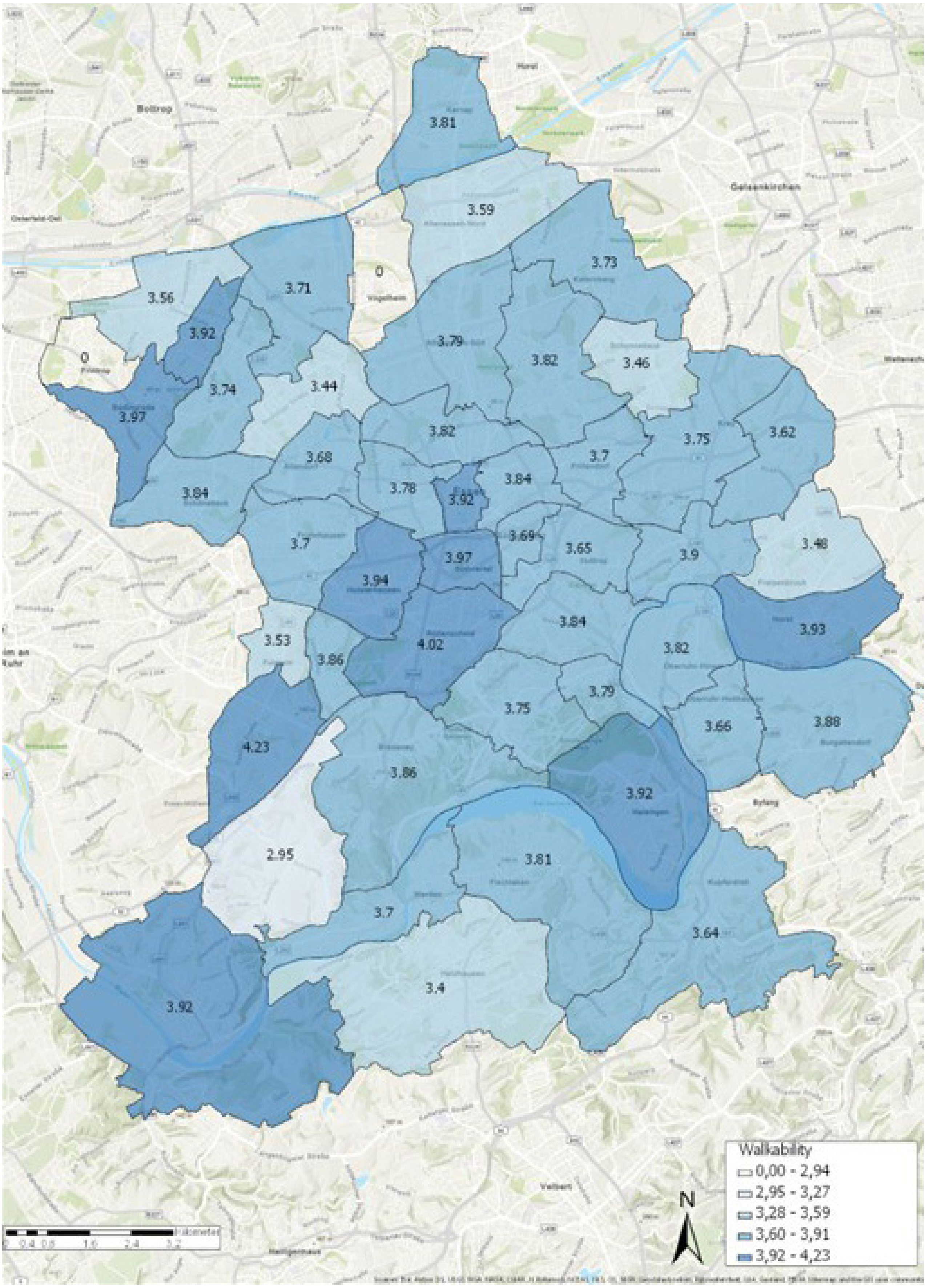


Figure 2. Walkability by district

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CRAFTING A TRANSPORT-ORIENTED CITY FOR SUSTAINABLE LIVING

Authors

Sk. Riad Bin Ashraf, Denis Daus, and Tobias Kuester-Campioni

Europe and other highly developed areas are experiencing a growing interest in transport-oriented development (TOD), which focuses on creating dense, mixed-use zones close to public transportation hubs. TOD encourages a transition from reliance on cars to more sustainable forms of mobility.[1] It also aligns with the overarching objectives of sustainable urban development, including improving urban transportation quality, promoting economic growth, and strengthening environmental sustainability.[2]

This article describes a TOD framework proposal to municipal authorities and urban planners in Dortmund, Germany, to help the city achieve its sustainable development objectives. Dortmund was chosen for several reasons:

- Most of its infrastructure was built to support coal mining and heavy industry in the 20th century. With coal mining ending, it has experienced dramatic economic and social restructuring.
- These wide-ranging changes involve infrastructure, economy, and environment.
- Despite restructuring and change, the city remains vibrant and is capable of reinventing itself.

Dortmund urgently needs innovative urban design that includes sustainable transportation options. Research shows that modern urban development relies heavily on sustainable urban mobility — combining effective, environmentally friendly transportation systems with urban planning to improve quality of life and minimize environmental impacts.[3] Sustainable mobility is crucial for tackling issues such as traffic congestion and pollution and optimizing urban-area use.[4]

TOD emphasizes high-density, mixed-use developments near public transportation to improve urban mobility and land use. It is essential for mitigating urban sprawl and traffic congestion, enhancing the quality of life for city dwellers and promoting environmental sustainability.[5,6] TOD has proven effective in reducing traffic congestion in Iranian cities and increasing public transport accessibility and feasibility in South African cities.[7,8]

THE STATE OF TRANSPORT & HOUSING IN DORTMUND

In Dortmund, private cars are considerably more convenient and flexible than public transportation systems, strengthening people's dependence on them.[9] Although Dortmund's public transportation system is comprehensive, accessibility is a significant concern, especially in the evening.

> **SUSTAINABLE MOBILITY IS CRUCIAL FOR TACKLING ISSUES SUCH AS TRAFFIC CONGESTION & POLLUTION & OPTIMIZING URBAN-AREA USE**

Additionally, urban sprawl has made providing public transportation to all parts of the city and surrounding areas difficult. Regular services are often not economically feasible in peripheral regions with low population density.[10] Integrating various types of public transportation, such as buses, trams, and trains, is essential to a smooth commuting experience. However, a lack of coordination between the various modes diminishes the appeal of public transit to everyday commuters.[11]

Dortmund's public transit faces significant efficiency challenges. Indeed, the city has undergone a years-long remodeling of its train system infrastructure, leading to delays and unreliable service. This discourages locals from using public transportation, leading them to prioritize private car transportation. The extensive use of private vehicles owing to urban sprawl and convenience conflicts with the necessity for sustainable, efficient, and interconnected public transportation networks. A comprehensive strategy is needed to harmonize urban development and transportation planning to establish a more sustainable, accessible, and efficient urban setting.

There are also some housing-related issues. For example, several residential compounds containing multi-apartment options (built in the 1960s and 1970s) lack mixed-use functions and are therefore less than desirable. Some are vacant and currently undergoing a redesign, presenting an opportunity to turn them into more popular living spaces.

The Hannibal, for example, a concrete construction located in Dortmund Dorstfeld-South, has been vacant for years and faces an uncertain future. It could become a TOD pilot showcasing mixed-use living with multifunctional facilities and green spaces. Its durable construction opens the possibility of a refit rather than demolition, in keeping with the city's sustainability goals.

PROPOSED INITIATIVES

Creative ideas and sustainable urban design are needed to transform Dortmund into a model TOD city. The pillars of the proposed initiative include improving public transit systems, building autonomous and pedestrian/bicycle-friendly transit infrastructure, and establishing high-density mixed-use zones with renewable energy solutions.

ENHANCED PUBLIC TRANSIT SYSTEMS

Proposed improvements to Dortmund's public transit include:

- **Micro-mobility hubs at all major transit points.** These hubs provide services such as e-bikes, e-scooters, and compact cars that cater to last-mile connectivity (see Figure 1).
- **Dynamic bus routing.** Installing AI-based adjustable bus routing will save travelers time by modifying routes in real time based on current traffic conditions and user demand.
- **Virtual transit networks.** An online software application will let users request immediate shuttle ride services. These shuttles close existing gaps in public transit by operating adjustable routes.

AUTONOMOUS & PEDESTRIAN/BICYCLE-FRIENDLY INFRASTRUCTURE

Proposed infrastructure plans include:

- **Smart crosswalks.** Smart crosswalks include lights and sensors that notify nearby motorists when pedestrians are crossing. They can also modify the timing of lights according to pedestrian traffic to improve safety.
- **Cycling highways.** Connecting critical zones of the city with cycling-specified "highways" helps ensure a fast, safe travel experience for those on bicycles.

Figure 1. Micro-mobility hub

HIGH-DENSITY, MIXED-USE DEVELOPMENTS NEAR TRANSIT HUBS WITH RENEWABLE ENERGY SOLUTIONS

Proposed initiatives include:

- **Mixed-use developments.** Constructing mixed-use developments that combine commercial, residential, and relaxation spaces within walking distance of transit hubs can dramatically decrease private car use.
- **Community-based energy systems.** Visionary approaches to renewable energy solutions include rooftop solar panel systems and kinetic energy tiles that capture energy from people passing through the walking zones for each community in these areas.

> **CREATIVE IDEAS & SUSTAINABLE URBAN DESIGN ARE NEEDED TO TRANSFORM DORTMUND INTO A MODEL TOD CITY**

LEVERAGING COLLABORATIVE & TECHNOLOGICAL STRATEGIES

Dortmund's TOD initiatives require community participation, sustainable technology adoption, and significant infrastructure building. These strategies will ensure the integration of local needs/preferences with cutting-edge solutions for a future-proof urban landscape. They include:

- **Interactive community workshops.** City planners should speak with residents, businesses, and local stakeholders to gather input on transit and development proposals.[12] Ideally, these workshops will use augmented/virtual reality simulations to help participants visualize the impact of the proposed changes.
- **Online feedback platforms.** There is a need to develop online platforms where residents can provide feedback and suggestions on TOD projects.[13] This ongoing dialogue ensures that the community's voice will be heard throughout development.
- **Local advisory panels.** It is important to establish advisory panels comprising residents and business owners; these panels can be critical in decision-making, ensuring that TOD initiatives align with community interests.[14]

The overall impact of TOD from the triple-bottom-line (social, environmental, economic) point of view is shown in Table 1.

LEARNING FROM SIMILAR TOD PROJECTS

To help Dortmund achieve its sustainable development objectives, we can draw on several examples from around the world:

- **Transport routes and residential development** were prioritized in Kolkata, India, demonstrating how urban planning can improve an area by enhancing transit-point infrastructure.[15] Dortmund could likewise stimulate connectivity around its existing public transportation hubs.
- **By using a data-driven TOD approach,** China's Shanghai has experienced noticeable public health improvements and more efficient transportation facilities.[16] Dortmund's TOD initiatives might similarly be refined by using data analytics, helping its initiatives more closely match the city's needs.
- In Jakarta, Indonesia, **devotion to network management** provides a strong, convincing case for the effectiveness of interconnected frameworks.[17] Dortmund could benefit from this TOD model, as it leverages private/public collaboration to expedite the implementation process.
- Palembang, Indonesia, is an excellent example of how a **low-carbon city concept** can be incorporated into TOD while focusing on the environmental elements of urban development.[18] Understanding how the TOD model can help preserve the environment is something Dortmund is eager to include in its urban planning concept.

IMPACT ANALYSIS	KEY INSIGHTS	SOURCE
Economic growth & development prospects	TOD stimulates job growth in the construction, urban planning, and public transportation sectors. Enhanced accessibility increases commercial activity and creates jobs in retail/service sectors.	Cervero, Robert, and Michael Duncan. "Transit's Value-Added Effects: Light and Commuter Rail Services and Commercial Land Values." *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1805, No. 1, January 2002.
	Proximity to efficient public transport increases property values, attracting investment in local businesses and residential areas.	Wenwen, Zhang, et al. "The Impact of Transit-Oriented Development on Housing Value Resilience: Evidence from the City of Atlanta." *Journal of Planning Education and Research*, Vol. 41, No. 4, July 2018.
Social benefits	TOD encourages social interactions and community cohesion through pedestrian-friendly spaces and mixed-use developments.	Milan, Blanca Fernandez. "How Participatory Planning Processes for Transit-Oriented Development Contribute to Social Sustainability." *Journal of Environmental Studies and Sciences*, Vol. 6, January 2015.
	Improved accessibility benefits all community members, including the elderly, children, and those with mobility challenges, fostering inclusivity and promoting equal opportunities.	Chen, Jun. "The Impacts of TOD on Sustainability Based on the Livability Prism Model." *Applied and Computational Engineering*, Vol. 6, June 2023.
Environmental impact	TOD reduces reliance on private vehicles, decreasing greenhouse gas emissions and improving air quality.	Cervero, Robert, and Cathleen Sullivan. "Green TODs: Marrying Transit-Oriented Development and Green Urbanism." *International Journal of Sustainable Development & World Ecology*, Vol. 18, No. 3, June 2011.
	Reduced car use contributes to a significant decrease in a city's overall carbon footprint.	Robinson, Bryan. *African Special Economic Zones*. Springer, 2022.

Table 1. Impact analysis of TOD from the triple-bottom-line point of view

- Melbourne, Australia, studied **how to "intensify" the city**. Australian cities tend to be low-density and car-dependent, and Melbourne is no exception. The study seeks how "transit-related problems and opportunities at different scales interconnect to form synergies and alliances both between projects and scales," an exploration Dortmund city planners would likely benefit from.[19]

The case studies from Australia and China, in particular, are in climate zones similar to Dortmund's, making them interesting from an infrastructure-planning and cultural viewpoint. Although Dortmund is in the very early stages of the TOD process, it is nonetheless progressive because TOD is not widely known in Germany.

RECOMMENDATIONS & CONCLUSION

Dortmund's TOD framework includes enhancing the public transportation system, developing autonomous and pedestrian/bicycle-friendly infrastructure, and creating high-density mixed-use urban spaces that utilize renewable energy. Recommendations for policy makers and urban planners include:

- **Strategic placement of transit hubs.** Policy makers must carefully organize the strategic arrangements of transit hubs to increase connectivity and enhance progress.
- **Data-driven decision-making.** There should be a data-driven strategy in place for the ongoing assessment process and modification of TOD initiatives.
- **Community engagement.** It is important to constantly include the community's viewpoints during the project's planning stages to ensure the alignment of the developmental process with the preferences of local people.
- **Sustainability integration.** TOD project planning should integrate a sustainable environment to encourage eco-friendly activities and green urban areas in the city.
- **Enforce law consideration.** It is vital to review building codes and land-use planning to achieve high-rise developments.

In effect, other European cities could use Dortmund's plan as a blueprint for efficiently combining transport and housing development. Highly populated cities will likely enhance public transport connectivity; lower-density cities may focus on establishing advanced transit hubs with easy-to-use structures. Modifications will be needed to match the specific needs of each city. Still, TOD delivers a flexible approach to urban development — one that is adaptable to the changing needs of urban residents as cities grow.

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NAVIGATING THE LONG-TERM TRANSITION TOWARD NET ZERO CITIES

Author

Andrea Lorenzini

Cities often struggle to successfully develop strategies for implementing policy measures; reasons for this struggle include public and political acceptability, funding and legislative issues, administrative restrictions, and skills shortages.[1] This is especially true for the transport sector as it works to meet the goals and targets set out in the European Green Deal. The concepts are quite different from the urban planning strategies of the last two decades and require city planners to use forecasting and backcasting models and to develop cross-sectoral master plans. These skills are not prevalent in smaller cities and disappear altogether in rural and peripheral areas.[2,3]

Recognizing this, the European Commission included two methodologies in its 2013 urban mobility package: sustainable urban mobility plans (SUMPs) and sustainable urban logistics plans (SULPs).[4] A SUMP is a consolidated methodology to help local and regional authorities improve accessibility of urban areas by providing high-quality, sustainable transport to, through, and within the urban area. Essentially, it contains actionable guidelines for comprehensive and sustainable urban mobility planning.

The guidelines have gone through several evaluations, revisions, and targeted extensions since they were first published. The focus of SUMPs seems to be changing from an approach that would lead to the implementation of a transport system enabling sustainable mobility to a planning strategy leading to the decarbonization of the transport sectors. Today, the focus should be on specific SUMP measures or related policies, rather than on a comprehensive package of measures and interventions needed to deliver the zero-carbon target.

Starting in 2019, the CIVITAS SUMP-PLUS project helped towns and cities analyze their existing governance arrangements in an effort to bridge implementation gaps and break down the barriers preventing the development of effective strategies and policy actions. Most sites identified a lack of cooperation schemes and frameworks as a barrier, and these have now been substantially mitigated via a variety of engagement tools.

CIVITAS SUMP-PLUS also created six laboratories to equip “cities to develop the next generation of SUMPs and put mobility at the heart of sustainable urban transformation.”[5] The labs are located in Antwerp, Belgium; Alba Iulia, Romania; Greater Manchester, UK; Klaipeda, Lithuania; Lucca, Italy; and Platanias, Greece.

The Manchester laboratory has clearly demonstrated the importance of stakeholder participation in achieving policy objectives.[6] For example, a working group with members from both Transport for Greater Manchester and the National Health Service was a catalyst for the integration of cross-sector links into Greater Manchester’s transition pathway and the alignment of decarbonization strategies across health and transport sectors.[7] It also drove an analysis of the alignment of healthcare and transport strategies and how these could be enhanced to form a joint, long-term transition pathway. The outcomes fed the development of Manchester’s Five-Year Environment Plan[8] for health and transport decarbonization and harmonization of decision-making processes. Its health and transport decarbonization group is committed to delivering the Green Plan.[9] In three years, stakeholders involved in this group will work together to monitor and update the plan.

Klaipeda successfully achieved the objectives laid out in its Economic Development Strategy and Action Plan[10] on public transport renewal, in conjunction with the plan for the city development. Core and supporting measures for the redesign of the public transport network (particularly for the development of the planned bus rapid transit) have been identified, despite some initial difficulties due to the discussions on which core measure should be prioritized for the city's future plans. Measures were accompanied by a specific financial strategy, including an estimate of implementation costs and related funding sources.

Platanias demonstrated that small and medium-sized cities can successfully develop a SUMP. The one created by the city helped it overcome mobility challenges, secure funding for sustainable mobility projects, and draft a plan that includes prioritization of actions and milestones to be achieved between now and 2035. Alba Iulia was also able to define a set of measures to be prioritized with related supporting measures.

NEW OPPORTUNITIES FOR CROSS-GOVERNANCE POLICIES & ACTIONS

Engagement tools and activities have the potential to improve organizational frameworks and promote cross-boundary cooperation among entities, as presented in CIVITAS SUMP-PLUS's "Results of City Laboratories Evaluation."[11] The problem is that multilevel and cross-sectoral governance usually do not share common objectives, interests, or priorities, due to a lack of coordination and/or dialogue among the various groups. Strong coordination and collaboration at the local and regional levels, including cross-sectoral links, are needed.

European cities can overcome governance fragmentation (and its related uncoordinated policies and objectives) by (1) strengthening integration at the metropolitan and regional levels and (2) shifting specific transport competencies from the national level to regional and local levels. Regional governments can get closer to the citizens if municipality-based engagement strategies are successfully developed and pursued.

To achieve this, SUMPs should focus on integration and coordination with existing territorial planning and transport instruments at the local level while interfacing with the policies and plans of upper governance levels, including:

- Cross-sectoral synergies with EU directives and national plans (e.g., transport, mobility, land use, infrastructure, digitization, energy).
- Cross-sectoral synergies with regional plans and strategies (e.g., spatial development, environment, infrastructures).
- Cross-sectoral synergies at the local and municipal level, such that mobility and transport plans are integrated with other planning tools. This integration should consider the societal and environmental goals set by the EU framework, as well as common objectives of the urban governance level. This will help ensure that plans for smart city strategy, local development, environment, air quality, and so on, are aligned.

Participatory structures can then be successfully delivered to facilitate bottom-up strategy developments as well as tailored local implementations of transport and mobility policies. This is a time-intensive process, due to the difficulties in mapping relevant actors, conducting co-creation events, and so on, but it's critical for the citizen engagement needed for a successful decarbonization transition.

The sharing of experiences, through cross-fertilization exercises, networking activities, and knowledge sharing, can contribute to a common learning process on the transition pathway for the decarbonization and subsequent improvements. Ideally, policies and strategies will be developed at the local and regional level and then managed, interconnected, and coordinated with other European regions (see Figure 1).

FOSTERING PUBLIC & PRIVATE COOPERATION

A key aspect emerging from the SUMP-PLUS project is the will to improve cooperation and integration between the public and private sectors. New forms of partnerships and business models have emerged as a main pillar in the transition toward decarbonized cities. The mobility market contains a broad spectrum of transport and logistics services, enabling technologies, and digital solutions that allows effective and efficient management of the various processes related to mobility, traffic, and public transport.

There are a number of design, planning, and implementation options available to operators and other actors (e.g., public/private organizations, planners, managers, value-added service providers, and users). For example, a variety of actors is assessing new ways to set up partnerships with the public sector. Cities are growing more comfortable letting public/private operators be proactive in the mobility context, provided the city sets the overall rules of the game (i.e., managing the city regulatory frameworks and responsibilities).

Antwerp and Lucca are good examples of cities that successfully developed a participatory process for collaborating with private companies. Through its Marketplace for Mobility, Antwerp has been very successful in encouraging private providers to launch in the city and pilot their services.[12] In the past few years, several discussions about the various ways cities can support partnerships took place. The main drivers for this have been infrastructure provision, data sharing, and funding support.

Lucca set up an "innovation call" to select the most sustainable logistics companies (which it calls "Inspirers") for participating in logistics roundtables and presenting innovative projects

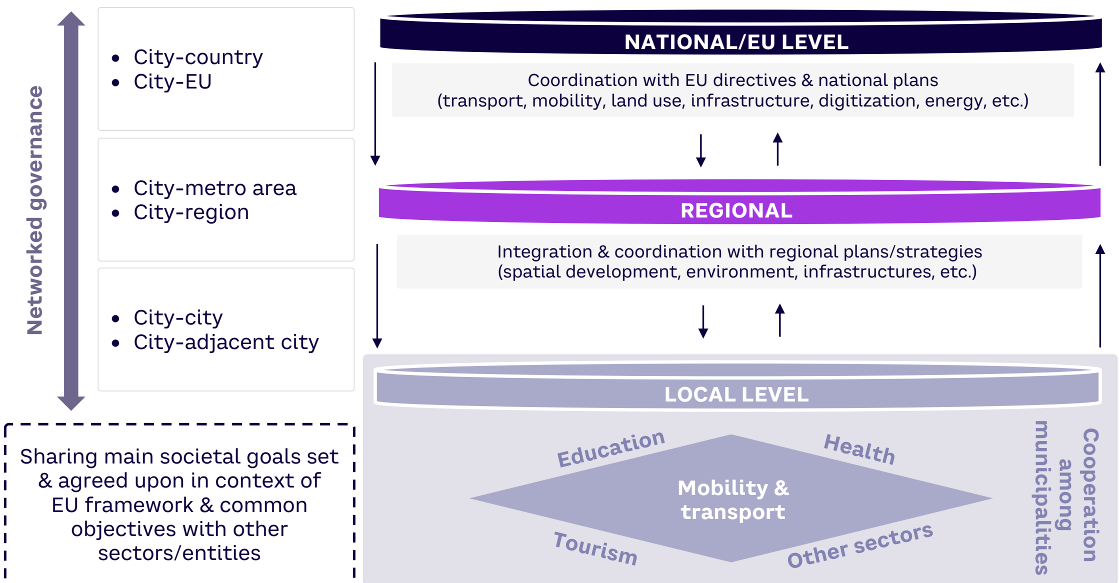

Figure 1. Opportunities for cross-governance policies and actions

on sustainable logistics.[13] Inspirers gained greater visibility, and this increased their willingness to behave sustainably and be involved in the discussion with an institutional representative. What's more, the sustainability ranking is beginning to drive "old" companies to change.

CREATING NEW PARTNERSHIP FORMS & BUSINESS MODELS

Collaborative and participatory framework(s) that enable various mobility actors to cooperate in offering innovative services play a strong role in the decarbonization of the transport sector. Integrated service bundles or solutions packages tailored to user groups go a long way in helping towns and cities successfully meet their decarbonization goals.

In Antwerp, these frameworks and solutions help meet the mobility and transport needs of workers, students, tourists, families with children, and the elderly. They enable reliable options for door-to-door journeys as well as practical alternatives to owning and/or using a car in the various transport environments of a functional urban area (metropolitan center, peripheral and suburban areas, and rural surroundings).[14]

In Lucca, the role of the local public authority, especially at the municipal level, is central not only for the legal responsibility of urban infrastructure and health but also at the planning level for identifying measures and facilitating engagement and dialogue among various stakeholders. This holds true at the day-to-day operation level as well for controlling urban logistics processes and ensuring compliance with defined rules related to environmental impacts (i.e., traffic congestion and pollution).

To better grasp the political and financial preconditions for success of urban mobility transition, it is important to flesh out various approaches to regulate shared mobility and logistics services (e.g., adaptive regulation, risk-based regulation, regulatory sandboxes) and to assess or adapt policy instruments (e.g., laws, directives, taxes, calls for bids) and financial models that have been shown to facilitate the adoption of new services (see Figure 2).

It is essential to analyze the regulatory and financial challenges linked to the implementation, monitoring, and enforcement of services and/or solutions (e.g., interoperability, cooperation models); the barriers for their deployment (e.g., existing legal frameworks); and the risks brought by the solutions (e.g., transport unaffordability or poor accessibility for vulnerable user groups) and adjust the regulatory and organizational frameworks accordingly.

City authorities should create a schedule for frequent assessment of the performance and achievements of the links and partnerships established. Based on the results, changes to existing frameworks can be confirmed or adjusted. The partnerships showing the most successful results can be promoted further.

TRANSITIONING TO ZERO-EMISSION CITIES

Cities across Europe are focusing on which mobility measures (for both people and freight) and measure-specific enabling actions are needed, given each city's current legislative powers, institutional capacities, and financial resources. The time frame — net zero carbon by 2025 — will make it difficult to achieve the radical changes in transport and governance required. Cities must carefully evaluate the cross-sectoral constraints and requirements associated with mobility measures that will achieve this target, necessitating a transition based on a strategic vision for the city 10, 20, and 30 years from now (see Figure 3).

Decarbonization requires a focus on transport packages that effectively and efficiently reduce greenhouse gas emissions. SUMP development should align with climate objectives, so measures must be adapted accordingly (or dropped and replaced by other means to coherently ensure all SUMP objectives).[15]

It is essential to ensure long-term political buy-in and acceptance while implementing measures to start achieving long-term targets. For example, substantial measures should be implemented to create the public transport efficiency, affordability, and reliability needed for a sustainable city; this will require continuous funding during successive political administrations.

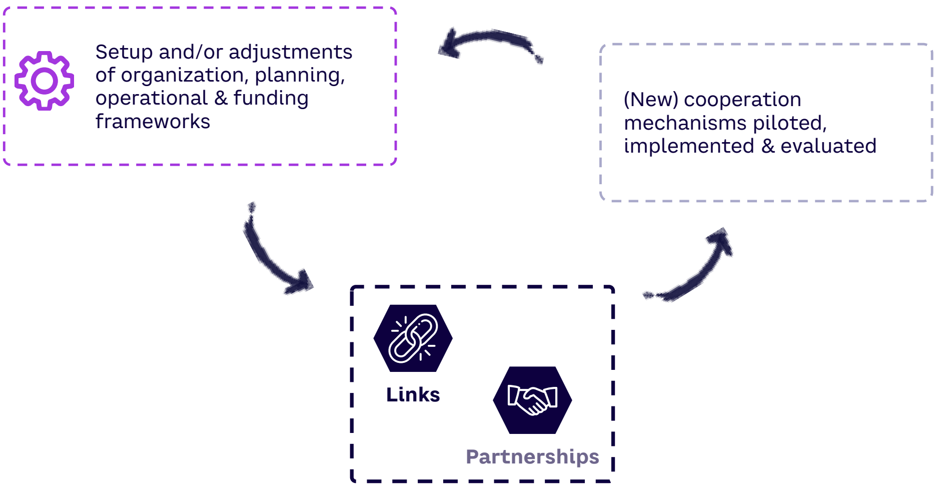

Figure 2. Assessing partnerships and cross-sectoral links versus existing frameworks

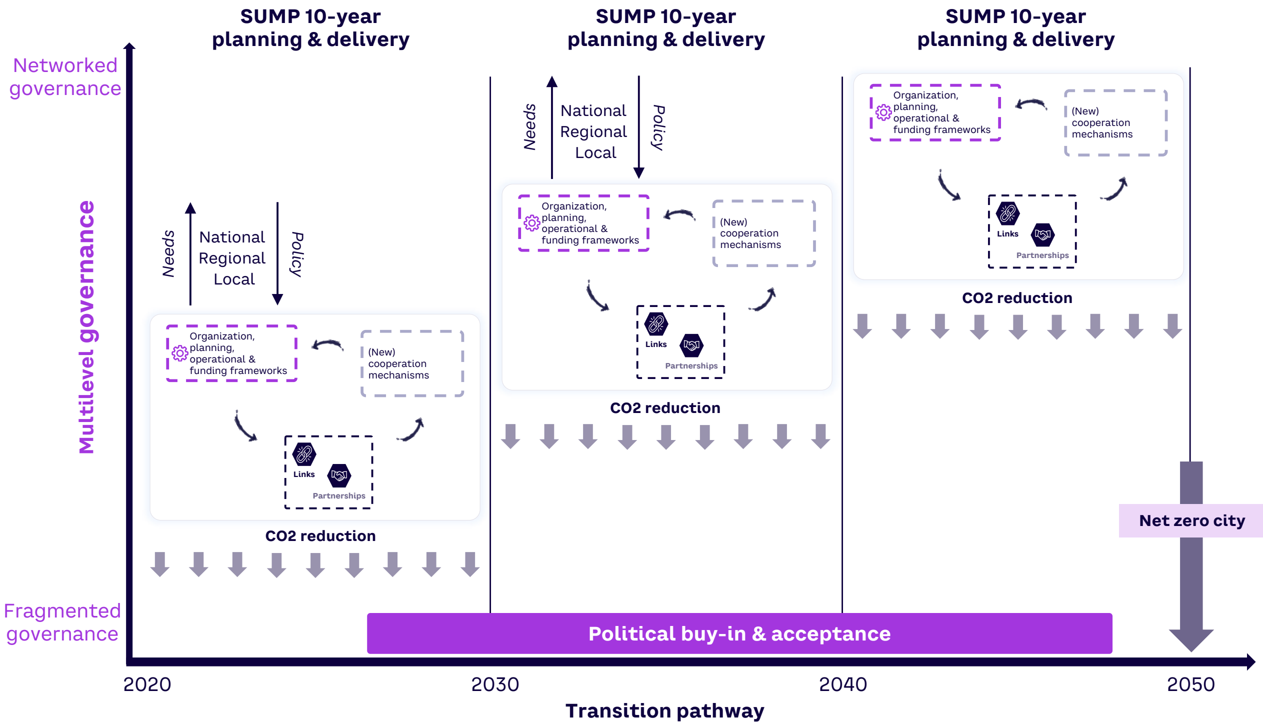

Figure 3. Suggested process to manage the transition toward zero-emission cities

Upon agreeing on the vision, the city should thoroughly assess the policy, funding, and governance requirements needed to reach its long-term targets. City leaders must frequently evaluate whether the mobility strategies and policies they put in place are efficient (and socially acceptable) in delivering a transport system that meets environmental, social, and economic requirements; is cohesive with overall city development; and is sufficient to meet the net zero target.

During implementation of the transition strategy, governance structures and related arrangements should be set up, increasing the level of cooperation between city departments, local and regional entities, and other actors (public and private). This should result in a networked governance that periodically (e.g., every 10 years) realigns local planning objectives, partnerships, and frameworks with high-level policy goals set at EU, national, and regional levels.

With new frameworks in place, both private companies and public operators can be proactive, proposing new solutions for the mobility and logistics chain by filling gaps between their role in the service chain and the seamless integration of new solutions, contributing to the transition to a low/zero-carbon economy.

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