REPORT

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MOBILITY DEMAND MANAGEMENT: A CRITICAL TOOL TO INFLUENCE MOBILITY BEHAVIOR

Further insights into
"The Future of Mobility 5.0"

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EXECUTIVE SUMMARY

As urbanization, pollution, and congestion continue to rise, sustainable urban mobility has become a critical need. This report builds upon insights from the 2024 Arthur D. Little report "The Future of Mobility 5.0." This follow-up report focuses on mobility demand management (MDM) as a key strategy for optimizing urban transportation systems. MDM aims to influence travel behavior to reduce car dependency, mitigate congestion, and prevent urban sprawl, ultimately improving accessibility and livability in cities.

MDM works by encouraging a shift away from private vehicle use and promoting sustainable modes of transport, such as public transit, shared mobility, cycling, and walking. It integrates a mix of regulatory tools, pricing policies, land use planning, and travel incentives to shape how, when, and why people travel, thus reducing overall demand for car usage. By strategically managing travel demand, MDM helps reduce the strain on transportation networks and enhances the environmental and social sustainability of urban areas.

This report explores the practical application of MDM, providing real-world examples of successful strategies. It includes a comprehensive cost-benefit analysis of various MDM levers, assessing the financial feasibility and practical impacts of different interventions. The analysis highlights how cities can combine behavioral change with infrastructure planning to create a more efficient and sustainable urban mobility system.

While expanding physical infrastructure remains important, this report emphasizes that solely increasing road capacity or transit services can lead to induced demand, where improvements actually encourage more car use. Instead, MDM promotes smarter management of existing infrastructure, directing traffic away from peak periods, supporting carpooling, and encouraging the use of nonmotorized transport like walking and cycling. By focusing on behavior modification alongside infrastructure improvements, MDM provides a holistic, balanced approach to solving urban mobility challenges.

In summary, MDM presents an innovative way to optimize urban transportation systems, reduce traffic congestion, and support environmental sustainability — all while improving quality of life in modern cities.

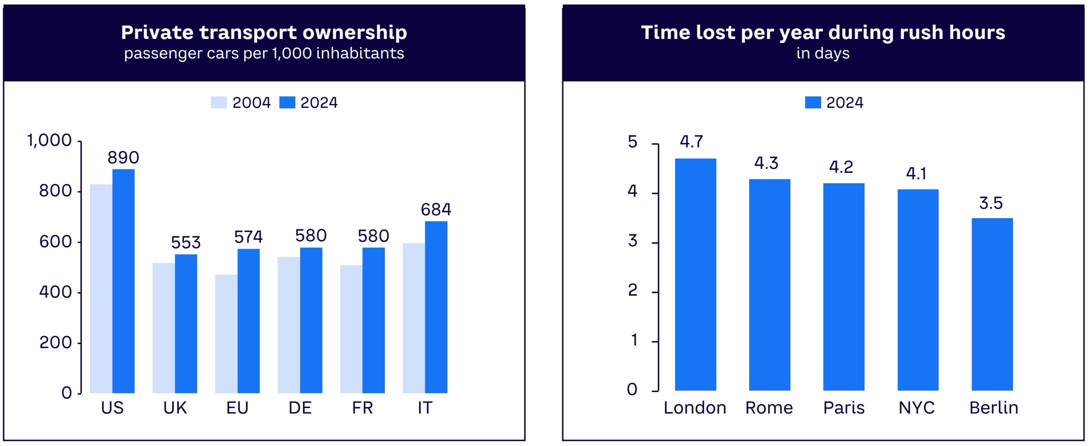
1. BACKGROUND & APPLICATION

Transportation systems have become a crucial factor in sustainable urban planning. As modern cities face increasing challenges related to traffic congestion, pollution, and urban sprawl, the need for innovative solutions has never been more pressing. Simply expanding physical infrastructure is no longer sufficient. MDM is one of the most effective strategies to meet these challenges.

MDM is a comprehensive approach designed to influence traffic levels (sometimes referred to as "traffic evaporation") and shape transportation choices. This approach optimizes the efficiency and sustainability of urban mobility systems by reducing the reliance on private vehicles and promoting alternative modes of transport like public transit, shared mobility, cycling, and walking.

The rise in motorized individual transportation, primarily in private cars, has contributed to various adverse effects in urban environments. It has limited space in cities, due to the additional roads and parking required, and has increased time spent in traffic congestion (see Figure 1). MDM can mitigate these challenges by redistributing travel demand across more sustainable modes of transport and optimizing the use of existing infrastructure. Through the application of MDM, cities can reduce reliance on cars, enhance mobility, and improve quality of life for residents.

Figure 1. Increasing transport ownership and time lost in rush hour congestion (in hours)



Source: Arthur D. Little, TomTom Traffic Index

UNDERSTANDING MDM APPLICATION

MDM aims to modify travel behavior through a combination of policy interventions, planning frameworks, and incentive structures. These measures are designed to reduce car dependence, encourage alternative modes of transportation, and improve the overall efficiency of urban mobility systems. MDM integrates regulatory tools, pricing policies, land use planning, and personal travel management techniques to influence how, when, why, and how much (in total kilometers) people travel.

As ADL's "The Future of Mobility 5.0" report explored, expanding physical infrastructure alone (i.e., building more roads or expanding transit infrastructure) often leads to induced demand, where improved infrastructure encourages more car use, resulting in little or no reduction in congestion. Instead, MDM provides a proactive approach by focusing on smarter management of existing resources.

Key interventions include:

- Redirecting travel away from peak periods
- Supporting carpooling and other shared mobility services
- Encouraging public transit ridership and nonmotorized forms of transport like walking and cycling

MDM PROVIDES A PROACTIVE APPROACH BY FOCUSING ON SMARTER MANAGEMENT OF EXISTING RESOURCES

MDM offers a proactive approach to urban mobility that drives modal shift, encourages socioeconomic benefits, and supports environmental sustainability. While many of these benefits (particularly those related to socioeconomic equity and the environment) are widely recognized, MDM also delivers less visible but significant economic and other advantages (see Figure 2). Malevolent reasons, such as social envy for car ownership and mobility control (to enforce political stability and limit freedom of civilian movement), are not further considered. By prioritizing behavioral change over infrastructure-heavy solutions, cities can better optimize their existing transportation systems, alleviating congestion, reducing environmental impacts, and minimizing external costs (e.g., pollution and traffic-related injuries).

Figure 2. Reasons for MDM application

Social utility	Environmental	Economic	Other *(not considered)*
▪ Reduce/redistribute travel demand or travel times ▪ Drive modal shift ▪ Increase mobility safety ▪ Increase (reduce) public space/ counteract system constraints	▪ Reduce CO_2 emissions within cities ▪ Decrease noise pollution ▪ Improve air quality in high-risk areas	▪ Increase tax revenue on state or federal level ▪ Increase communal revenue streams ▪ Qualify for federal grants ▪ Indirect financial benefits through better health	▪ Social envy ▪ Mobility control (for political stability or control [e.g., minimize social mobility, limit travel distances or movement between certain areas])
Mostly publicly communicated		Mostly publicly hidden	

Source: Arthur D. Little

2. FRAMEWORK FOR IMPACT & FEASIBILITY

EVALUATING MDM LEVERS

MDM aims to influence travel behavior by addressing both the overall demand for movement (how much and when people travel) and the allocation of trips across different transport modes (influenced by time or price sensitivity). To effectively manage demand, MDM interventions can be grouped into three main categories:

1. **Regulatory guidelines** — rules or restrictions designed to actively manage when, where, and how mobility occurs
2. **Land use and strategic planning** — shaping the physical and spatial conditions of urban areas to reduce travel needs and support sustainable transport
3. **Personal travel management** — targeting individual behavior through incentives, information, and services that encourage more efficient and environmentally friendly travel choices

Each of these levers plays a role in optimizing travel behavior.

MDM AIMS TO INFLUENCE TRAVEL BEHAVIOR BY ADDRESSING BOTH THE OVERALL DEMAND FOR MOVEMENT AND THE ALLOCATION OF TRIPS ACROSS DIFFERENT TRANSPORT MODES

3. COST & BENEFIT ANALYSIS

LEVER ASSESSMENT

To evaluate the effectiveness of different MDM levers, we conducted a structured cost-benefit analysis across 40 selected strategies (see Figure 3). The analysis followed a two-step process:

1. Initial evaluation of each lever's performance
2. Cross-calibration to determine their relative effectiveness

Insights from international mobility experts, including policy leaders, C-level executives, and advisors, guided the evaluation across six standardized criteria.

Cost assessment

1. **Direct implementation costs** — up-front expenses required to implement each lever
2. **Direct operating costs** — ongoing costs to maintain and manage each lever
3. **Indirect externalities** — broader costs (e.g., long-term economic impacts or potential disruptions during implementation)

Benefit assessment

1. **Environmental benefits** — the lever's potential to reduce emissions and enhance sustainability
2. **Economic benefits** — gains in efficiency, reduced congestion, and cost savings
3. **Social benefits** — improvements to public health, safety, liveability, and equitable access to transportation

Following the initial evaluation and cross-calibration, the 40 levers were assigned an overall score, which resulted in an overall ranking.

Figures 3a-3c show these rankings using color codes from red (high cost/low benefit) to green (low cost/high benefit). This process allowed for a prioritized ranking of levers based on their total cost-effectiveness, considering economic, social, and environmental factors. (Note: the rating/ranking does not focus on the reduction/change of modal split by itself.)

COST & BENEFIT MATRIX

Figure 4 visually represents the cost-effectiveness of various MDM levers, plotting them based on cost (high to low) and benefit (low to high). This approach allows for an easy comparison of strategies and helps identify those that offer the most favorable cost-to-benefit ratio.

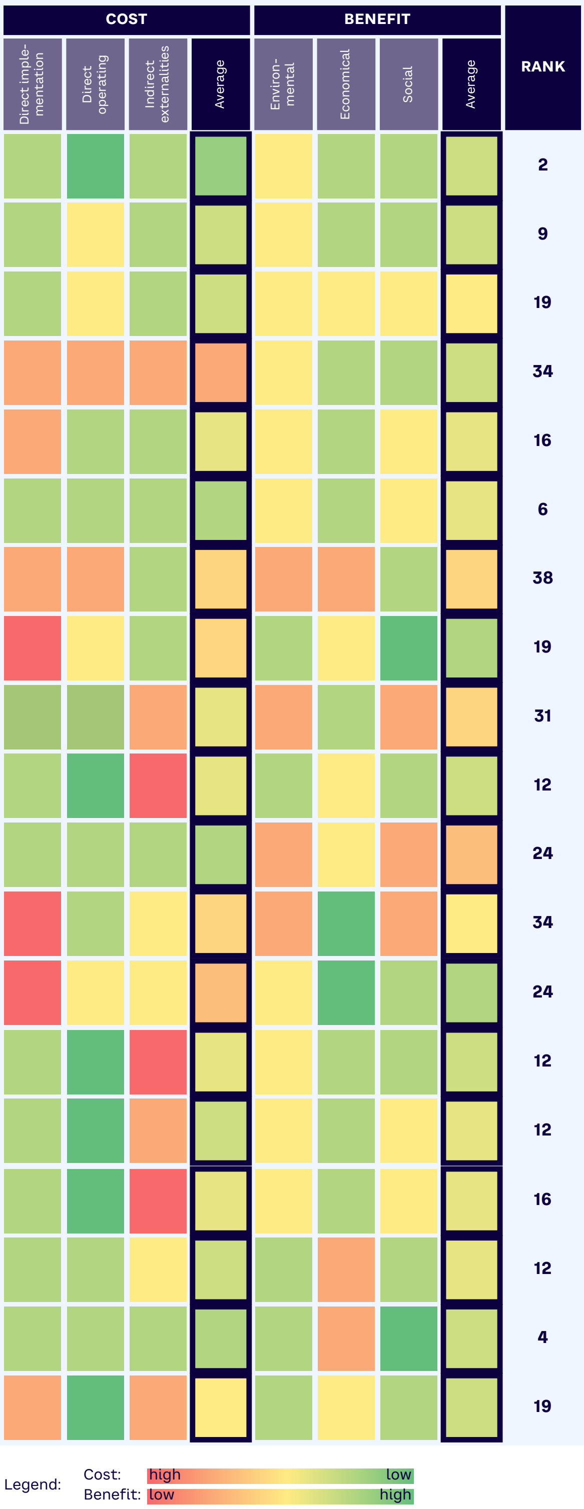
Certain levers offer high benefits while incurring relatively low costs. These "sweet spot" levers fall into three categories:

1. **Regulatory guidelines.** Levers like peak hour speed limits, emergency lane usage during peak hours, freight transport vehicles entry and movement restrictions, high-occupancy vehicle (HOV) and express lanes, low-/zero-emission zones (including low-traffic neighborhoods [LTN]), parking regulations/pricing, and dynamic tolling systems rank highly due to their significant impact on reducing congestion and pollution.
2. **Land use and strategic planning.** Effective infrastructure development guidelines, land use models, site-based approaches (e.g., schools and commercial areas), and intermodal hubs also rank highly because of their ability to improve overall transportation efficiency and accessibility.

3. **Personal travel management.** Key levers such as apps for sustainable mobility (with gamification features), smart parking solutions (potentially integrated with electric vehicle charging), marketing and nudging campaigns, and navigation-support applications (e.g., MaaS platforms) provide substantial benefits by encouraging more sustainable travel choices.

While the exact ranking of these levers may differ depending on the specific urban environment, many of the top-rated interventions are widely applicable, making them cost-effective solutions for improving urban mobility and sustainability. In the next chapter, we expand on our assessment results.

Figure 3a. MDM lever cost-benefit analysis (regulatory guidelines)



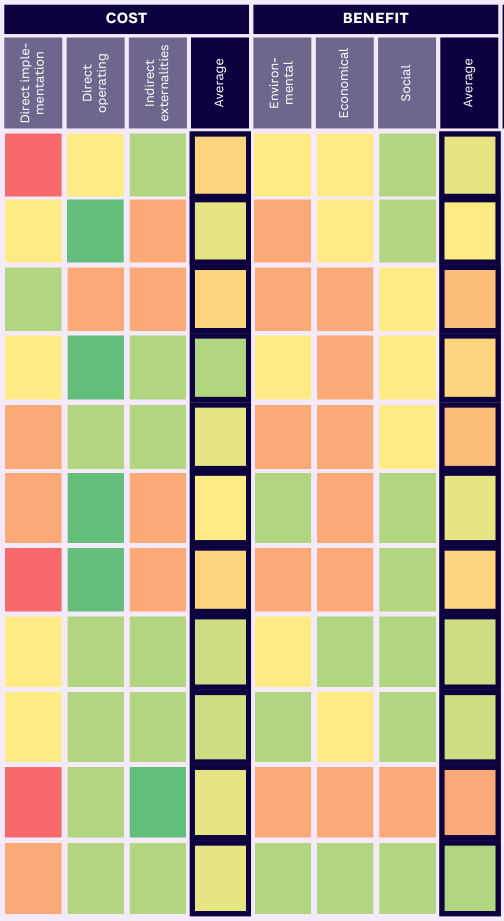
Regulatory guidelines	RANK
1 Peak hour emergency lane usage Allowing vehicles to use emergency lanes during peak traffic hours to reduce congestion (use in suburban areas)	2
2 High occupancy vehicle (HOV) & express lanes Dedicated lanes for vehicles with multiple passengers and/or express traffic to encourage carpooling & reduce congestion (use in suburban areas)	9
3 Priority lanes Designated lanes for specific types of vehicles (e.g., buses, taxis, or bicycles) to improve traffic flow & promote alternative transportation modes (use in urban areas)	19
4 Reversible lanes Lanes that change direction depending on traffic flow & time of day to optimize road capacity & reduce congestion	34
5 Dynamic (congestion) speed limits Adjusting speed limits in real time based on traffic conditions to optimize traffic flow & reduce congestion	16
6 Peak hours speed limits Implementing lower speed limits during peak traffic hours to optimize traffic flow, reduce congestion & enhance safety	6
7 Coordination of road detours/closures Efficient management & communication of road detours & closures to minimize disruption & optimize traffic flow during construction, maintenance, emergencies, or events	38
8 Intelligent traffic signal management Implementing advanced traffic signal control systems equipped with sensors, algorithms & real-time data analysis to optimize traffic signal timing & coordination	19
9 Dynamic or peak hour parking pricing Adjusting parking prices based on demand or during peak hours to manage parking availability, reduce congestion & encourage alternative transportation modes	31
10 Limiting parking space availability Limiting available parking spaces to discriminate against individual motorized car transport	12
11 Parking pricing for commercial zones Implementing parking pricing strategies in commercial zones to manage parking availability, support local businesses & encourage alternative transportation modes	24
12 Tolling system (static) Implementing system to charge drivers for using specific infrastructure to manage traffic demand, generate revenue & encourage alternative transportation modes	34
13 Dynamic tolling system Implementing system that adjusts toll rates based on real-time traffic conditions to manage traffic demand, reduce congestion & encourage alternative transportation	24
14 Increased vehicle registration fees Implementing higher vehicle registration fees to discourage car ownership, generate revenue for transportation infrastructure & encourage alternative transportation modes	12
15 Vehicle use tax (fuel, carbon) Implementing taxes on fuel or carbon emissions associated with vehicle use to manage traffic demand, reduce emissions & fund transportation initiatives	12
16 Vehicle tax Implementing taxes on vehicle ownership or registration to manage traffic demand, fund transportation initiatives & incentivize use of alternative transportation modes	16
17 Low emission zones (incl. LTN) Implementing designated areas within urban areas where access is restricted to vehicles meeting certain emission standards, typically targeting older, more polluting vehicles	12
18 Freight transport vehicles entry/movement restrictions Implementing restrictions on entry & movement of freight transport vehicles within urban areas to manage traffic congestion, improve safety & reduce emissions	4
19 (Limited) car-free zones Designating certain areas within urban centers where vehicular access is restricted or prohibited, allowing only pedestrian, cycling & public transport traffic	19

Source: Arthur D. Little

Figure 3b. MDM lever cost-benefit analysis (land use & strategic planning)

Land use & strategic planning

#	Lever	Description	Rank
20	Park & ride facilities	Establishing park & ride facilities on outskirts of urban areas, where commuters can park vehicles & transfer to public transportation to complete journey into city center	31
21	Dynamic curbside management	Implementing policies or strategies to reduce availability of parking spaces, such as converting parking spaces into alternative uses (e.g., pedestrian zone, green spaces, parks)	24
22	On-street parking ban during peak hours	Implementing measures to ban on-street parking during peak traffic hours in urban areas, where vehicles are prohibited from parking along designated streets during specified times	40
23	Bicycle parking	Establishing designated bicycle parking in urban areas to promote cycling as a mode of transportation by providing safe, convenient & accessible parking for cyclists	19
24	Intersection improvements	Reducing number of conflict points & improving junction design of intersections (e.g., implementing gridlocks & box junction enforcement; yellow gridlines on intersections)	33
25	Improved bicycle lane network	Implementing measures to expand/enhance bicycle infrastructure to create a safe & accessible network for cyclists within urban areas by providing dedicated lanes separated from vehicular traffic	24
26	Road network expansion	Implementing measures to expand road infrastructure to accommodate growing mobility demands within urban areas by constructing new roads, highways, or arterial routes	38
27	Infrastructure development guidelines/land use models	Establishing holistic guidelines, standards & policies for infrastructure development (long-term) & land use to ensure that projects are planned, designed & executed in a manner that promotes sustainable mobility, enhances livability	9
28	Site-based approach	Implementing holistic concepts (following a decentralized approach) for tailored mobility solutions for specific sites (e.g., schools, commercial shopping areas & working districts within urban areas)	9
29	Traffic management center	Implementing a holistic citywide, centralized facility equipped with advanced technology to enable real-time monitoring, managing & coordinating of traffic flow & incidents within urban areas to identify potential improvement measures	36
30	Intermodal mobility hubs	Orchestrating designated locations where different modes of public & private transportation converge, incentivized by the city to facilitate seamless transfers between various transport services	6



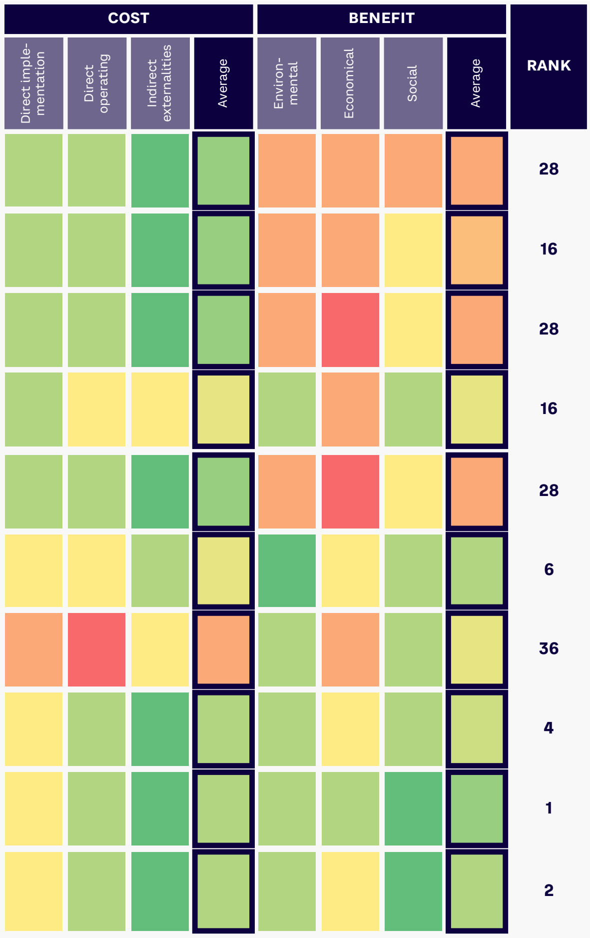
Legend: Cost: high – low; Benefit: low – high

Source: Arthur D. Little

Figure 3c. MDM lever cost-benefit analysis (personal travel management)

Personal travel management

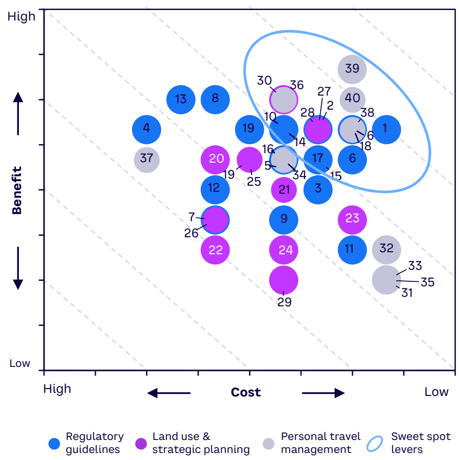
Lever	Rank
31 Car-free days Organizing car-free days where private vehicle usage is restricted or discouraged to promote alternative transportation modes & raise awareness about sustainable mobility options	28
32 Flexible employment & personal travel patterns Implementing policies/incentives to encourage employers & employees to adopt staggered work hours, allowing individuals to start/end workdays at different times to reduce peak-hour congestion	16
33 Remote work Encouraging or mandating remote work arrangements where employees perform job duties from locations other than traditional workplace (e.g., home or coworking spaces)	28
34 Staggered work hours within public institutions Implementing policies or incentives to stagger operating hours of educational institutions (e.g., schools & universities) to reduce congestion during peak commuting hours	16
35 Remote learning Implementing remote learning programs where students participate in educational activities & classes remotely from locations other than traditional classrooms, often facilitated by digital technologies	28
36 Marketing & nudging Utilizing various marketing & communication tools to promote & encourage adoption of sustainable mobility practices & initiatives (e.g., public transit, carpooling, cycling, walking, telecommuting)	6
37 Public transportation (mobility pass offers) Offering incentives or subsidies to encourage use of public transportation (e.g., discounted or free mobility passes, transit vouchers, or employer-sponsored transit benefits)	36
38 App for sustainable mobility comp. (gamification) Rewarding use of sustainable transport option by offering financial incentives to user (e.g., vouchers, financial discounts), similar to reward points collection system	4
39 Smart parking management Developing smart mobile app for real-time parking information, reservations & payments using sensors & data analytics to optimize parking usage, cut search time & ease traffic congestion	1
40 Navigation support applications Forming cooperations with existing navigation applications that provide real-time routing, traffic updates & alternative transportation options to users; provide city-specific data to optimize travel routes, minimize congestion & facilitate efficient & sustainable mobility choices	2



Legend: Cost: high — low; Benefit: low — high

Source: Arthur D. Little

Figure 4. Ranking MDM levers vs. costs and benefits



Regulatory guidelines
1 Peak hour emergency lane usage
2 HOV & express lanes
3 Priority lanes
4 Reversible lanes
5 Dynamic (congestion) speed limits
6 Peak hour speed limits
7 Coordination of road detours/closures
8 Intelligent traffic signal management
9 Dynamic or peak hour parking pricing
10 Limiting parking space availability
11 Parking pricing for commercial zones
12 Tolling system (static)
13 Dynamic tolling system (incl. congestion charging)
14 Increased vehicle registration fees
15 Vehicle use tax (fuel, carbon)
16 Vehicle tax
17 Low-emission zones (incl. low-traffic neighborhoods)
18 Freight transport vehicles entry & movement restrictions
19 (Limited) car-free zones

Land use & strategic planning
20 Park & ride facilities
21 Dynamic curbside management
22 On-street parking ban during peak hours
23 Bicycle parking
24 Intersection improvements
25 Improved bicycle lane network
26 Road network expansion
27 Infrastructure development guidelines & land use models
28 Site-based approach (schools, commercial shopping areas, working districts)
29 Traffic management center
30 Intermodal mobility hubs

Personal travel management
31 Promote car-free days
32 Promote flexible employment & personal travel patterns
33 Promote remote work
34 Implement staggered working hours within public institutions (e.g., schools, city offices)
35 Promote remote learning
36 Marketing & nudging
37 Incentives for PT (mobility pass offers)
38 App for sustainable mobility comp. (gamification; sustainable mobility nudging)
39 Smart parking management
40 Navigation support applications (journey planner/MaaS)

Source: Arthur D. Little

4. ASSESSMENT RESULTS

COMPARING MDM LEVERS

Each of the 40 MDM levers was ranked based on a cost-benefit analysis, considering both implementation costs and potential societal benefits across environmental, economic, and social dimensions (refer back to Figure 4).

The top-ranked lever, **smart parking management**, offers high benefits at a relatively low cost. With a benefit score of 4.2, it emerges as the most effective MDM lever, making it an efficient solution for optimizing urban mobility.

Cities like Barcelona have successfully implemented such systems, which provide real-time data on available parking spaces, reducing search time for drivers, decreasing congestion, and enhancing overall urban mobility efficiency. One app provides real-time data on the availability of off-street parking spaces, covering approximately 80,000 spots across nearly 300 car parks. Another app caters specifically to professional drivers, offering real-time information on parking availability and enabling users to activate parking sessions directly from their mobile devices. This solution is particularly useful in urban goods distribution areas and bus zones, further optimizing parking efficiency for targeted user groups.

Other highly ranked levers include **navigation support applications and peak hours emergency lane usage.** Navigation support applications scored 4.0 in both benefit and cost categories, while peak hours emergency lane usage achieved a benefit score of 3.7 and a cost score of 4.0. Navigation-support applications contribute to improved traffic flow by providing real-time routing and updates, enabling drivers to avoid congestion dynamically.

However, the effectiveness of utilizing emergency lanes during peak periods as a congestion-relief strategy has been questioned. Its success depends on strict enforcement, public adherence, and clear communication. In practice, physical and institutional constraints may limit its implementation, and in some instances, the anticipated benefits may not fully materialize. Moreover, this measure has been associated with potential negative externalities, reflected in its lower externality score. Concerns include reduced accessibility for emergency vehicles and possible compromises to overall road safety. Additionally, by increasing effective road capacity, this approach may unintentionally encourage higher car usage, leading to increased air and noise pollution levels that could diminish its environmental and social benefits.

Another relatively high-ranking lever is **marketing and nudging**, which received an overall average score of 3.7. This lever promotes sustainable mobility by employing strategies such as gamification and providing incentives to encourage eco-friendly behaviors like walking, cycling, or using public transit. However, nudging extends beyond gamification, encompassing a wider array of subtle interventions designed to influence decision-making and foster long-term behavioral change. For instance, nudging can involve providing real-time feedback on the environmental impact of travel choices, setting default options that prioritize sustainable modes (e.g., highlighting public transit as the first choice in navigation apps), or using visual cues (e.g., clear signage for bike lanes or pedestrian pathways) to make sustainable options more intuitive and accessible. By combining these behavioral prompts with gamified incentives, this lever not only incentivizes individual action but also generates valuable data to inform urban mobility planning.

Initiatives like Bologna's Bella Mossa illustrate the effectiveness of such approaches, demonstrating how marketing and nudging can drive significant shifts in travel behavior. These strategies support cities in advancing their sustainability and mobility goals by aligning individual incentives with broader environmental objectives.

Infrastructure development guidelines/land use models represent another high-impact lever, offering significant social, environmental, and economic benefits despite their high implementation costs.

In our assessment, this lever received an average score of 3.67, reflecting its strong potential. Strategic, long-term infrastructure and land use planning is essential for optimizing urban functionality while balancing mobility and livability goals. These guidelines integrate health, environmental, and spatial considerations, promoting sustainable development and accessible transport. By managing transport demand and improving public spaces, cities can pursue holistic urban planning that enhances both mobility and quality of life.

Marketing & nudging — Bella Mossa, Bologna, Italy

The city of Bologna's Bella Mossa initiative utilized gamification to reduce private car usage and promote cleaner modes of transport. Integrated with the BetterPoints app, Bello Mossa rewarded users for each sustainable trip with points redeemable for discounts at local businesses. This approach incentivized new users while reinforcing eco-friendly habits among existing sustainable travelers. During the first six months of 2017, 15,000 participants logged over 900,000 sustainable trips, covering 3.7 million km.

Feedback was overwhelmingly positive, with 73% of participants reducing car usage and 77% walking more often. Beyond individual behavior change, the app also provided valuable data for urban mobility planning, helping public authorities improve infrastructure and further promote sustainability goals. This example illustrates how marketing and gamification can drive significant behavior shifts toward sustainable mobility, making it a valuable lever in urban mobility demand management.

Infrastructure development guidelines/land use models — Ljubljana, Slovenia

An exemplary case of the implementation of infrastructure development guidelines/land use models can be found in Ljubljana, Slovenia, where the city's Sustainable Urban Mobility Plan (SUMP) has transformed urban mobility and livability. Through a strategic, participatory approach, the city has reclaimed 100,000 square meters of pedestrian space by closing the city center to motorized vehicles, resulting in a 620% increase in pedestrian areas. This bold reallocation of space has significantly enhanced walkability and revitalized the urban core.

The introduction of free electric Kavalir vehicles has further improved accessibility, particularly for the elderly and people with limited mobility. Since 2008, these vehicles have transported 900,000 passengers, offering a convenient, sustainable alternative to cars within the pedestrian zone.

In addition, the BicikeLJ bike-sharing system, launched in 2011, has become a popular mobility option, recording 2.8 million rides to date. This system has contributed to a broader shift toward active and low-emission transport.

Public transportation improvements have also been notable. Since 2010, city bus use has increased by 19%, while regional bus journeys have risen by 34% since 2013. These gains have been supported by the introduction of new compressed natural gas buses and real-time information systems, which have improved service efficiency, environmental performance, and user experience. Ljubljana's example illustrates how integrated planning, supported by inclusive policies and technological innovation, can lead to substantial improvements in mobility, sustainability, and urban quality of life.

In contrast to lower-ranked levers like **reversible lanes** and **static tolling systems, dynamic tolling systems** offer a more promising solution despite their higher costs. While both static and dynamic tolling systems are relatively low-cost options (scoring 2.67 and 2.33, respectively), the benefits of dynamic tolling significantly surpass those of static systems. Dynamic tolling is more effective because it adjusts road pricing in real time, based on traffic conditions, time of day, and congestion levels. This flexibility allows for better management of urban traffic by encouraging drivers to modify their travel times, choose alternative routes, or switch to public transportation when congestion is high. Furthermore, the revenue generated by dynamic tolling systems is often reinvested into infrastructure improvements, which enhances transportation networks and supports long-term urban mobility goals.

The assessment results highlight that low-cost, high-benefit levers — particularly those leveraging smart technologies and dynamic, demand-driven interventions — offer the greatest potential for managing urban mobility effectively. For example, dynamic tolling systems demonstrate how a single, well-designed measure can alleviate congestion, promote sustainable mobility, and generate revenue that can be reinvested into transportation infrastructure.

However, the true potential of MDM lies in the ability to integrate multiple levers into a cohesive strategy. By addressing various dimensions of urban mobility simultaneously, cities can achieve significant, transformative outcomes. Importantly, the evaluation of these measures must consider different perspectives: depending on the stakeholder or policy goal, priorities such as accessibility, social equity, or environmental impact may need to be emphasized.

Dynamic tolling systems

Real-life examples show that dynamic tolling systems can significantly reduce congestion and generate revenue for reinvestment in transportation infrastructure. In Stockholm, Sweden, a tolling system introduced in 2007 and upgraded to a dynamic pricing model in 2016 led to a 47% reduction in vehicle traffic between 2006 and 2014. With an initial investment of US $236.7 million, the system now generates $155 million annually. This revenue is reinvested into roadway improvements and the expansion of public transport, offering viable alternatives for drivers.

Similarly, Singapore's Electronic Road Pricing (ERP) system adjusts tolls in real time based on traffic conditions, resulting in a 10%-15% reduction in traffic during operational hours. The system required an initial $110 million investment and incurs $18.5 million in annual operating costs, yet it generates $100 million annually, which is reinvested into transportation infrastructure.

These examples illustrate the effectiveness of dynamic tolling systems in easing congestion and supporting sustainable mobility. By generating revenue that is reinvested in infrastructure and offering public transport alternatives, dynamic pricing emerges as a powerful tool for managing urban mobility demand.

5. MDM STRATEGIES IN ACTION

While individual levers can have the desired benefits, they are best used within a comprehensive mix of regulatory, infrastructure, and personal travel management levers implemented to tackle the unprecedented demand for mobility. This chapter outlines three overarching MDM strategies in action in Paris, Stockholm, and London. These cities leveraged their strategies to successfully manage mobility challenges while also setting the foundation for long-term improvements in urban transportation. In addition, we explore the key obstacles to MDM implementation and the considerations necessary to overcome them to ensure that mobility solutions are equitable, practical, and widely accepted.

MDM DURING THE 2024 PARIS OLYMPICS

Strategy & content

For the 2024 Olympic Games, Paris adopted a comprehensive MDM strategy to accommodate millions of visitors while minimizing traffic disruptions and environmental impacts. By leveraging a mix of regulatory, infrastructure, and personal travel management levers, the city successfully managed mobility challenges during the Games. Several measures were so effective that they have been retained post-event, contributing to Paris's long-term urban mobility objectives.

Paris significantly enhanced its public transit network to accommodate the increased demand for the Olympics. As a result, it boosted Metro and train frequencies by 15% while increasing the Réseau Express Régional commuter network services by 23%. The city also added 4,500 trains to the Transilien network and introduced 10 new bus lines connecting Olympic venues.

These measures reduced reliance on private vehicles, ensuring efficient transport for visitors and residents.

To further promote sustainable travel, Paris expanded its micromobility options. The city added 5,000 e-bikes to its bike-sharing system, bringing the total to 15,000, and installed 3,000 additional bike parking spaces at train stations. The city also installed temporary bike stations near key Olympic sites, making it easier for people to use bicycles for last-mile connectivity. This investment in cycling infrastructure encouraged a significant shift from car dependency to active mobility.

Another component was the introduction of 185 km of dedicated transportation lanes on major roadways, such as the Boulevard Périphérique and key highways like the A1 and A13. These lanes prioritized official vehicles, public transport, and emergency services, facilitating swift and reliable transport during the Games. Simultaneously, real-time traffic management systems and navigation applications provided live updates, helping drivers avoid congestion and optimizing traffic flow across the city.

Key MDM levers applied

- **Incentives for public transport use** — increased metro and train frequencies, added new bus routes, and improved public transit connectivity
- **Improved bicycle lane networks** — expanded cycling infrastructure with additional bike-sharing options and parking spaces
- **Priority lanes** — created dedicated transportation lanes for public transit and official vehicles to ensure efficiency
- **Intelligent traffic signal management** — utilized real-time traffic management and navigation systems to optimize traffic flows.

Legacy & long-term impact

The success of these initiatives during the Olympics led Paris to retain several measures as part of its long-term mobility strategy. The increased frequency of metro and train services has become a permanent feature, providing residents with more reliable and accessible public transportation. Similarly, the expanded bike-sharing system and additional bike parking spaces continue to encourage sustainable commuting habits. Certain dedicated transportation lanes, initially reserved for Olympic use, have been repurposed to prioritize buses and emergency vehicles, improving traffic flow and safety.

These measures ensured a successful Olympic Games and set a new standard for sustainable urban mobility in Paris. The city's ability to integrate a mix of mobility levers demonstrates how thoughtful planning can address short-term challenges while delivering long-term benefits. By retaining and building upon these initiatives, Paris has reinforced its commitment to creating an efficient, environmentally friendly, and accessible transportation network (for further insights, see the Viewpoint "Paris 2024 Olympics.")

MDM TO REDUCE TRAFFIC IN STOCKHOLM

Strategy & content

Stockholm has been a pioneer in MDM, demonstrating how a mix of regulatory measures, public transit improvements, and technological innovations can significantly reduce car traffic and shift modal share. Introduced in 2006, Stockholm's congestion charging system, paired with investments in public transportation and complementary dynamic traffic management, has set a benchmark for effective urban mobility planning.

At the heart of Stockholm's strategy was the introduction of a congestion charging system that levied time-differentiated tolls on vehicles entering and leaving the city center. This regulatory lever disincentivized car usage during peak hours while encouraging drivers to adjust travel times, switch to public transportation, or explore alternative routes.

The system's effectiveness was enhanced by investments in Stockholm's public transport network, ensuring a viable and attractive alternative for commuters.

Stockholm also utilized dynamic traffic management technologies to optimize road usage. Real-time traffic monitoring allowed for adjustment of tolls and the dissemination of live updates to drivers, further reducing congestion. Investments in park-and-ride facilities around the city's periphery offered an additional incentive for drivers to transition to public transit for the remainder of their journey.

Key MDM levers applied

- **Congestion charging** — implemented time-differentiated tolls to discourage car use during peak hours
- **Dynamic traffic management** — enabled real-time adjustments to toll rates and optimized traffic flows
- **Park-and-ride facilities** — incentivized modal shifts by providing convenient transit alternatives
- **Increased public transit services** — improved connectivity and frequency to accommodate new demand

Legacy & long-term impact

Stockholm's results were striking. Car traffic entering the city center decreased by 20%, a reduction that has been sustained over time. Additionally, CO2 emissions within the congestion zone dropped by 10%-15%. Public transit usage increased significantly, with many commuters shifting from cars to buses and trains due to improved service quality and convenience.

The success of Stockholm's congestion charging system has gone beyond reducing traffic congestion. Revenue generated from the system has been reinvested into public transport infrastructure, further enhancing accessibility and sustainability. The city's ability to integrate complementary MDM levers has created a lasting impact on urban mobility, making Stockholm a global leader in sustainable transportation.

MDM TO DECREASE CONGESTION IN LONDON

Strategy & content

London has long been at the forefront of MDM, using bold regulatory measures like congestion charges and environmental zones to tackle car dependency and traffic congestion. Introduced in 2003, London's Congestion Charge, paired with the Ultra Low Emission Zone (ULEZ) launched in 2019, has significantly shifted modal share while reducing vehicle-related emissions.

The Congestion Charge, one of London's earliest MDM levers, applied a flat fee to vehicles entering central London during peak hours. This measure reduced car traffic and generated revenue for public transit improvements. Building on this success, ULEZ further discouraged private vehicle use, particularly for older, polluting vehicles. Together, these regulatory measures reshaped travel patterns and promoted sustainable mobility.

London also invested heavily in public transport and active mobility options. The city expanded bus services, introduced real-time tracking systems for users, and developed an extensive cycling infrastructure, including cycle superhighways. Marketing and nudging campaigns encouraged residents to adopt public transit, cycling, and walking as viable alternatives to car travel.

Key MDM levers applied

- **Congestion charging** — discouraged car use in central areas during peak hours
- **Low-emission zones** — incentivized cleaner vehicles and alternative transport modes
- **Public transit enhancements** — improved bus and train services to support modal shifts
- **Marketing and nudging** — promoted behavioral change through targeted campaigns
- **Improved bicycle lane networks** — expanded cycling infrastructure to reduce car dependency

Legacy & long-term impact

The Congestion Charge initially reduced car traffic in central London by 15%-20%, while the ULEZ contributed an additional 12% reduction in vehicle distance traveled. Bus ridership increased by 6% in the first year of the Congestion Charge, with further growth supported by subsequent investments. Cycling trips increased by 154% from 2000 to 2019, reflecting the success of active mobility initiatives.

London's integrated MDM approach has created a lasting shift in travel behavior. Revenues from the Congestion Charge and ULEZ have been reinvested into public transport and active mobility projects, further enhancing sustainability. By combining regulatory measures with infrastructure improvements and behavioral nudging, London has set a global standard for managing urban mobility demand while addressing environmental goals.

OBSTACLES IN IMPLEMENTATION

These examples illustrate MDM's potential to achieve transformative results when implemented strategically. However, while these use cases highlight the effectiveness of combining multiple levers, they also underscore the challenges that cities face when attempting to adopt similar strategies. Challenges can occur if (1) trade-offs between different costs and benefits are not balanced or aligned to the specific needs of the geographic area of implementation, or (2) if MDM is used solely to "decrease" rather than "redirect" demand, thereby limiting mobility for parts of society.

Key challenges that can significantly impact MDM's success include:

- **Political and public resistance.** Many MDM measures, particularly those involving restrictions or additional costs (e.g., congestion pricing or parking fees), often face opposition from both the public and policymakers.

Congestion pricing schemes, for example, are sometimes perceived as unfair, particularly by drivers and businesses that rely on road access. Gaining public and political buy-in for such measures requires careful communication, the provision of adequate alternatives, and the demonstration of long-term benefits. Access to nonresident users of the mobility system is often complex – communication of the measures to foreign drivers or visitors is a challenge.

- **Equity concerns.** Certain MDM interventions, such as vehicle-use taxes or low-emission zones, may disproportionately affect lower-income individuals, who are more likely to rely on older vehicles or live farther from city centers and face transport poverty issues. To address these concerns, cities must carefully design MDM policies that balance environmental objectives with the need for inclusive, affordable transportation options for all socioeconomic groups.
- **Lack of preparation and impact modeling.** In some cases, the implementation of MDM measures suffers from insufficient preparation or inadequate modeling of their impacts. This can result in unintended consequences, such as economic disruptions or a lack of behavioral change. Effective MDM strategies require thorough impact assessments and data-driven planning to predict and manage their effects accurately.

LEVERS ARE BEST USED WITHIN A COMPREHENSIVE MIX OF REGULATORY, INFRASTRUCTURE, AND PERSONAL TRAVEL MANAGEMENT IMPLEMENTED TO TACKLE THE UNPRECEDENTED DEMAND FOR MOBILITY

6. FUTURE DIRECTIONS FOR MDM

The future of MDM lies in harnessing technology and data analytics to develop more targeted, responsive, and personalized solutions. Moving beyond individual levers, future strategies will focus on integrated, real-time systems that dynamically adapt to evolving urban mobility needs. Key emerging trends include:

- **Data-driven design, monitoring, and adaptation.** The advancement and application of digital tools will enable more precise tailoring of demand management solutions to local contexts. This includes continuous monitoring and the ability to fine-tune interventions to minimize unintended consequences and maximize effectiveness.
- **Autonomous vehicles (AVs).** The integration of AVs into urban transportation systems could significantly improve road space utilization by reducing parking demand and enhancing traffic flow. AVs may also support more efficient public transit by operating in coordination with other mobility services. (See Chapter 2.6, "Autonomous mobility," in "The Future of Mobility 5.0" report.)
- **MaaS.** MaaS platforms, which integrate various transportation modes (e.g., buses, trains, ride sharing, and bike sharing) into a single, user-friendly platform, are gaining momentum. By simplifying access to multiple transport options, MaaS encourages a shift from private car use to shared or public transportation. These platforms offer a seamless experience by combining real-time information, booking, and payment across modes, making sustainable transport more convenient and appealing. (See Chapter 2.5, "Mobility as a service," in "The Future of Mobility 5.0" report.)
- **Digitalization of circulation plans and geofencing.** The growing use of digital tools allows cities to dynamically manage and restrict traffic in specific areas or time frames. Smart circulation plans, enhanced by geofencing technology, enable regulation of vehicle access based on factors such as environmental impact, time of day, or vehicle type, improving traffic efficiency and reducing emissions. These technologies are especially useful in sensitive zones like schools and city centers or during major events.

Looking ahead, the convergence of these technologies will enable more agile and efficient mobility systems, where interventions are not only informed by data but also automatically adjusted in real time based on conditions, user behavior, and broader sustainability goals.

CONCLUSION — A SCALABLE TOOL FOR CITIES

MDM is a vital tool for creating sustainable, efficient, and equitable urban transportation systems. By reducing reliance on private vehicles and shifting travel demand toward more sustainable modes of transport, MDM enables cities to tackle congestion, lower emissions, and improve accessibility in a targeted, resource-efficient way. Rather than focusing solely on expanding infrastructure, MDM emphasizes behavioral change through regulatory measures, land use planning, and personal travel management. As demonstrated in real-world applications, such as the Paris 2024 Olympics, well-designed MDM strategies can deliver measurable impact at scale.

While some interventions may have high up-front costs, the long-term benefits (including improved mobility, better air quality, reduced congestion, and enhanced public health) can be substantial — however, only if the negative externalities are managed and mobility is not limited. Therefore, the MDM lever cost-benefit analysis discussed in this report emphasizes the importance of selecting strategies tailored to local needs, combining regulatory policies, infrastructure enhancements, and behavioral incentives to promote more sustainable transportation choices.

Looking ahead, the future of MDM will depend on harnessing emerging technologies and data-driven insights to more effectively manage transportation demand and further shift travel behavior toward sustainable mobility in an increasingly urbanized world.

MDM EMPHASIZES BEHAVIORAL CHANGE THROUGH REGULATORY MEASURES, LAND USE PLANNING, AND PERSONAL TRAVEL MANAGEMENT

FUTURE OF MOBILITY LAB

The Future of Mobility (FoM) Lab is Arthur D. Little's (ADL's) contribution to tackling the mobility challenge. With this lab, ADL aims to support mobility actors in shaping the extended mobility ecosystems of tomorrow and facilitating an open dialogue between mobility stakeholders. The FoM Lab gathers under the same roof as cross-industry and cross-functional professionals to support governments, authorities, mobility solution providers (public and private), and investors in shaping their roles in future mobility ecosystems. Supporting cities and investors in selecting, sourcing, improving, and engaging with micro, shared, and active mobility solutions providers and supporting the latter in improving their operations are among the key services offered to our clients.

POLIS

Founded in 1989, POLIS is the leading network of European cities and regions working together to develop innovative technologies and policies for local transport. POLIS aim is to improve local transport through integrated strategies that address the economic, social, and environmental dimensions of transport. To this end, POLIS supports the exchange of experiences and the transfer of knowledge between European local and regional authorities. POLIS also facilitates the dialogue between local and regional authorities and other mobility stakeholders such as industry, research centers and universities, and NGOs. POLIS fosters cooperation and partnerships across Europe with the aim of making research and innovation in transport accessible to cities and regions and to facilitate dialogue and exchange between local authorities, the transport research community, and the industry. POLIS also strives to provide decision makers with the necessary information and tools for making sustainable mobility a reality.

Arthur D. Little has been at the forefront of innovation since 1886. We are an acknowledged thought leader in linking strategy, innovation and transformation in technology-intensive and converging industries. We navigate our clients through changing business ecosystems to uncover new growth opportunities. We enable our clients to build innovation capabilities and transform their organizations.

Our consultants have strong practical industry experience combined with excellent knowledge of key trends and dynamics. ADL is present in the most important business centers around the world. We are proud to serve most of the Fortune 1000 companies, in addition to other leading firms and public sector organizations.

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