POLITECNICO MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE

EXECUTIVE SUMMARY OF THE THESIS

A ROADMAP TO A 15-MINUTES CITY MOBILITY

TESI MAGISTRALE IN MOBILTY ENGINEERING

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1. Introduction

In the last years there has been a change in the cities' vision which was the consequence of the awareness acquisition that today's cities establishment involves incredible waste of resources and dangerous levels of pollution.
Transportation is certainly one of the major causes of cities pollution and, despite countermeasures such as electrical conversion and public transport increase have been taken in recent years, data show that pollution level is still dangerous, people still depend very much on their cars, city centres still have congestion issues and traffic is forecast to increase, particularly that related to freight transportation [1].
However, another measure that should be considered to make a difference in the same direction can be found in urban planning.
The pandemic highlighted how innovative measures need to be tailored to ensure that urban residents can cope and continue with their basic activities, including cultural ones, even during a lockdown. The 15-minutes city concept responds to this need and many local authorities in the world are considering applying this model to their cities. The implementation of the 15-minutes model, though, requires a change in the way people move inside the city. The aim of this work is then to define a way to a redesign of city transportation services combined with the replanning of the land usage proposed in the 15-minutes model.

2. Challenges

To achieve the proposed aim of this work, it was fundamental to understand what the 15-minutes concept is and what is needed for its realisation. The 15-minutes concept is an urban planning model that aims at organising a city so that residents can reach all basic services (Table 2.1) within 15 minutes by foot or by bike, making the city more human sized and sustainable. The 15-minutes concept is also about social development, aiming at creating an environment of integration and sense of community. The 15-minutes model lies on four pillars: *(1) density*, meant as residential density that justifies the presence of basic quality services; *(2) proximity*, meant as the vicinity of services that is fundamental for inviting people to walk or ride a bike and to facilitate that social interaction which creates the sense of community; *(3) diversity*, meant both in the diversity of services, which must not be centralised in one part of the city, but also meant as cultural diversity, which, coupled with the sense of community, aims at creating an environment of integration; *(4) digitalisation*, to make services even more accessible and efficient [2][3].

Table 2.1: Basic Services

Supply	Work	Education	Health	Leisure	Living	Mobility
Grocery shops (Greengrocer, Bakery, Butcher) Hardware shops (Stationary, Clothes, Shoes, Mobile phone) Amenities (Hairdresser, Laundry) Supermarket Post Office	Local employment opportunities Coworking spaces Wi-fi and High-Speed internet	Nursery school Kindergarten Elementary School Middle School Library	Doctor Dentist Clinic Pharmacy	Park Playground Bars & Restaurants Recreation facilities	Affordable housing Housing diversity	LPT Stop Safe Cycling Network Walkable Streets Charging Facilities Last mile Sharing docks

Once it had been understood what the 15-minutes concept is, the following step was to understand what the challenges to its realisation could be, according to the different characteristics of the cities in the world, particularly regarding the ability to move on foot and by bike, as the 15-minutes model requires. Using benchmarks such as those of Paris, Melbourne, and Bogotá, where the 15-minutes concept is being implemented, it was possible to understand that obstacles to walking or to using soft mobility modes even for short trips are not just cultural awareness and habits or the lack of options.

The first challenge is given by geomorphology, which requires a different planning of neighbourhoods to meet proximity requirements, according to whether their territory is flat or uphill. Services must be closer in an uphill territory to be reached within a 15-minutes' walk or bike ride, than they must be in a flat territory.

The second challenge is given by the city development along time, particularly regarding the advent of cars, which affects the density and proximity requirements. This second challenge was highlighted by the representation on QGIS of high-resolution population density maps, using humanitarian datasets (data.humdata.org), and services distribution maps, obtained with OpenStreetMap data.

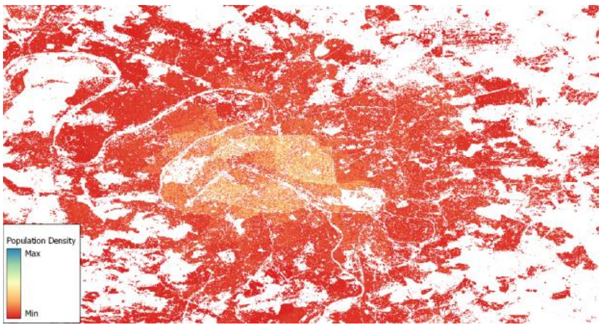

Figure 2.1: Paris' population distribution

Figure 2.2: Melbourne's population distribution

Figure 2.1 and Figure 2.2 show that Paris' population is very much concentrated (yellow) in the municipal area, and it becomes less dense (red) and slightly sprawled in the metropolitan area, while Melbourne's population has an almost constant concentration and is very much sprawled, given the lower density of red dots with respect to Paris' metropolitan area.

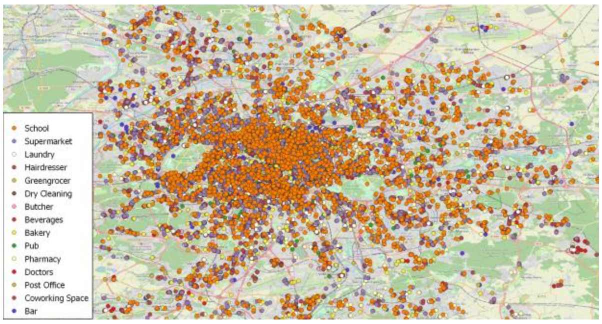

Figure 2.3: Main services in Paris

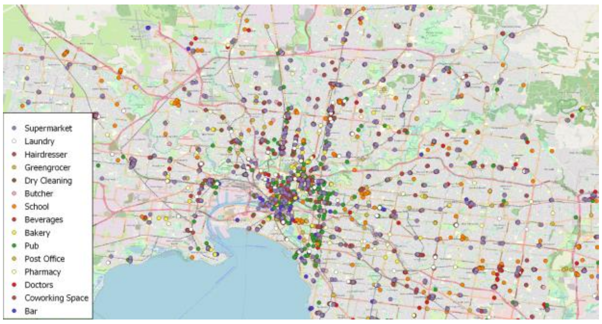

Figure 2.4: Main services in Melbourne

Intuitively, services' distribution and density in Melbourne (Figure 2.4) reflects that of population and comparison with Paris is dramatic (Figure 2.3). Such a difference should not be a surprise, since Melbourne's urban development pattern was shaped by car-oriented policies, unlike many European historical centres. As such, it consists of a low-density zonal type of development with separation of basic urban functions such as housing, working, entertainment, shopping etc.

The comparison between Paris and Melbourne is the proof that car advent made distances much greater and cities very sprawled and shows how in densely populated cities, such as municipal Paris, the level of services' proximity is very high, and people are more likely to walk to reach their destinations. Accessibility, in fact, increases when the mixture and density of land use increases, bringing our destinations closer to where we begin, and makes vehicle ownership less of a need.
On the contrary, in sprawled cities, such as Melbourne or Paris' metropolitan area itself, the services' proximity is low. The result of such development is that privately owned vehicles are more likely to be used, especially where collective transport connection is not guaranteed.

3. Methodology

The next step was to define a transport system that allowed to overcome the above-mentioned challenges, and guaranteed sustainable cross-city mobility, while preserving that characteristic of accessibility that is required by the 15-minutes model. In fact, the 15-minutes model aims at eliminating the unnecessary and unwanted trips, but, at the same time, it does not aim at confining residents to their own neighbourhoods.
By reviewing literature, five fields were identified to characterise such transport system: Transit Oriented Development, Traditional Infrastructure renovation, Shared Use Mobility, Neighbourhood Logistic and Smart Infrastructure Development.
By using a case study, instead, with which a hypothetical execution of these fields and 15-minutes model was attempted in the city of Monza with QGIS (Figure 3.1), it was defined how to act upon the five areas and achieve the new transport system.

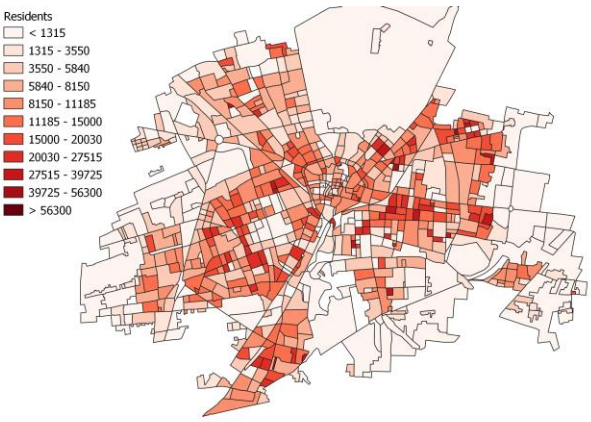

Figure 3.1: Monza's census zones densities

3.1. Transit Oriented Development

Transit Oriented Development (TOD) was selected to meet density and proximity requirements. TOD promotes denser, mixed-used development around public transport services, enabling a large-scale shift away from reliance on private vehicles [4]. Thus, first of all, possible neighbourhoods were identified accordingly to the TOD vision, by placing their gravity centre in correspondence of a station or a public transport stop that already exists or is planned to be built (Milan's M5 will be prolonged to Monza), so to have a barycentric concentration of services, including mass transit, while ensuring that the greatest amount of population and territory is covered by the sheds. In the example (Figure 3.2), the neighbourhoods were identified by tracing isochrones corresponding to a 15-minutes' walk from the gravity centre.

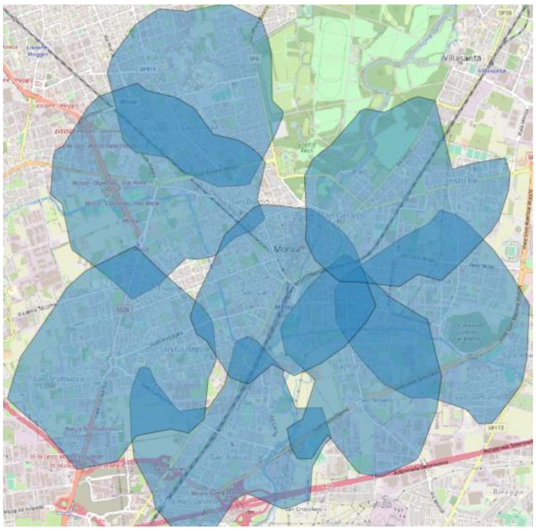

Figure 3.2: Possible 15-minutes neighbourhoods in Monza

Realising TOD is a long-term undertaking, and it is possible that 15-minutes concept requirements are not immediately met. Then, in the medium term the neighbourhoods can be developed with infilling, for population densification, or with the repurposing of existing buildings for mix-use and the recovery of abandoned ones, if services are lacking. In a TOD vision, large scale infill should be placed around the gravity centre to justify barycentric service's concentration and higher transportation frequency.

3.2. Traditional Infrastructure

The purpose of Traditional Infrastructure renovation is to raise the level of walkability and cyclability in the city and make public transport more competitive with respect to private vehicle. With the case study,

renovations were identified in traffic moderation, road diet (or conversion) and the implementation of a viable bike lanes network.
Traffic moderation includes a series of infrastructural intervention such as repaving and installation of furniture elements that guarantee a good level of protection for pedestrians while allowing them to easily occupy the street and induce vehicles to keep speed very low. This already happens in historical city centres, but in the case study the concept has been spread to the rest of the city.
In the short-term it is possible to create new Limited Traffic Zones (LTZs) inside the neighbourhoods (Figure 3.3), where parking on the curb could be forbidden to allow its differentiation, in favour of wider sidewalks, bike lanes or dehors.
In the medium-term, instead, the LTZs can be turned into Moderate Traffic Zones (MTZs), by implementing the previously mentioned infrastructural interventions.

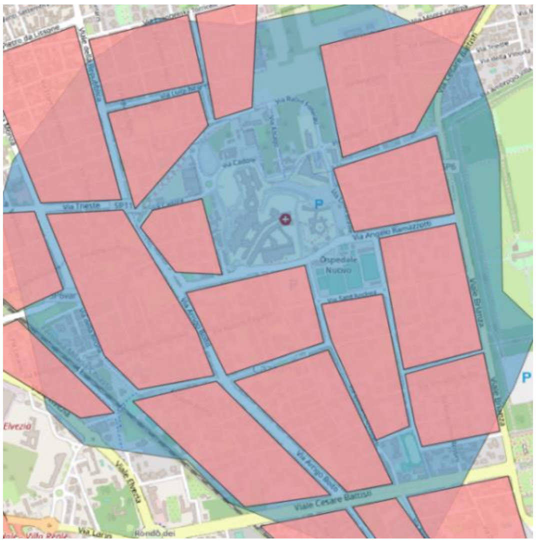

Figure 3.3: LTZs identification in Neighbourhood

The zones were identified following the streets' typology, using main streets as a perimeter, where neighbourhood crossing traffic will flow.
On these main streets, road conversion could be applied in order to turn car lanes, in the short term, and curb parking, in the medium term, into transit lanes or bike lanes.
The realisation of MTZs, where part of the curb can be destined to bike lanes, and the conversion of main streets' lanes into bike lanes can result into an extended bike lane network which can be made more usable, by planning a velopolitain, which uses the same scheme of metros around the world, with coloured lines connecting different areas of the city. In Figure 3.4 is an example of velopolitain implementation in Monza, where the red line is already existing and new bike lanes (green and blue) integrate the existing network (black), creating new lines that serve routes that are not covered by LPT.

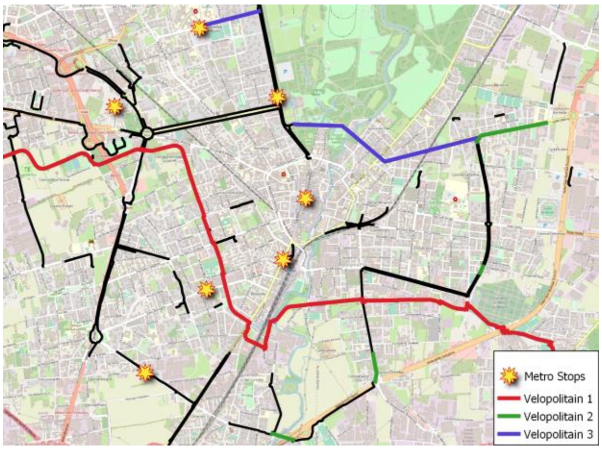

Figure 3.4: Possible velopolitain configuration in Monza

3.3. Shared Use Mobility

Shared Use Mobility (SUM) is meant to improve sustainability, guaranteeing cross city trips that are not granted by public transport and improving accessibility to services and mass transit. Car sharing, ride sharing, and e-hailing are those sharing services meant to fill the gaps of mass transit in the short-term, while decreasing the need for car ownership and allowing for a future land repurposing, such as car park conversion. Car sharing stations should be placed at the edges of MTZs, particularly on those sides where mass transit stops are lacking (Figure 3.5).
Bike-sharing is meant to make neighbourhood trips to services faster, and to work as a last mile mode or as an alternative mean of transportation for trips between neighbourhoods. Bike sharing docks should be placed at the edges of the MTZs were car sharing stations and transit stops are placed to increase their accessibility, and inside the MTZs in a way that maximises overall bike sharing accessibility (Figure 3.5).
Together with bike sharing, also neighbourhood shuttles, running on demand, can be implemented for neighbourhood trips for people with disabilities, the elderly or children going to school, particularly in uphill cities.

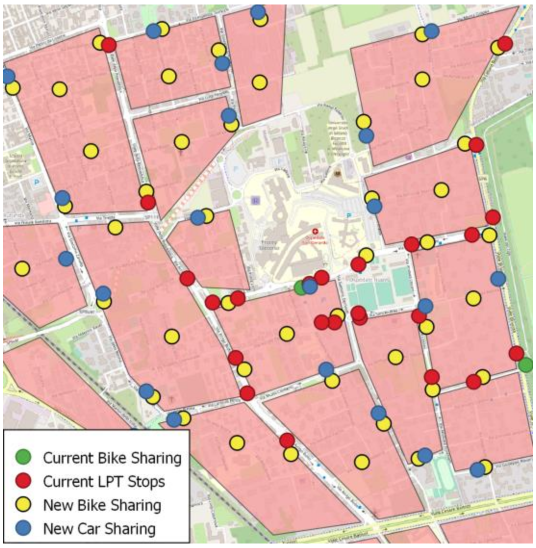

Figure 3.5: Sharing docks and LPT stops in Monza's neighbourhood

Transportation service providers tend to operate separately, and it can be difficult for a user to move across different modes. A multimodal route planning app, allowing to purchase tickets combining schedule-based transportation (buses, trains) with bike and e-scooter sharing and providing navigation, is not supported by current algorithms yet, but it is likely to be so in the medium-term, allowing for Mobility As A Service (MAAS) implementation.
In the long term, instead, the advent of level 4 and 5 autonomous vehicles is likely to increase the propensity to travel, influencing a mode shift toward cars. Through effective regulation and incentives, planning and programming, cities will encourage a proper use of Shared Autonomous Vehicles (SAVs). Also, by implementing automated bus lines with smaller vehicles (autonomous shuttles), more frequent service, and flexible routes that deliver passengers closer to their destination, MAAS will be taken to a higher level that will be completely seamless and capable to bring together disparate mobility modes.

3.4. Neighbourhood Logistics

Neighbourhood Logistic was identified to realise a last-mile logistic that is coherent with the 15-minutes model and could take advantage of its implementation.
In the short-term, cycle logistic represents a great opportunity for largely reducing pollution and congestion resulting from freight deliveries in cities, particularly considering the development of bike lanes that comes with the 15-minutes concept.
Cycle logistic would need little further infrastructure, namely, cycle logistic hubs that can be quickly installed at the edge of the LTZs so they can be supplied by electric vans overnight [5].
Immediate proximity to the delivery area is crucial, which means no more than 1.2 km away from transhipment hub or that the delivery radius around a transhipment hub does not exceed 500 m.
Considering an average walking speed of 4 km/h, a flat neighbourhood has a radius of 1 km, which means a surface that is four times as big as the area that a cycle logistic hub is supposed to cover. Thus, from a distance point of view, 4 hubs should be ideally placed in a 15-minutes neighbourhood (Figure 3.6).
Not just hubs, but also lockers could be installed in the short-term for each house, so to avoid "not at home" recipients and make delivery service more efficient.

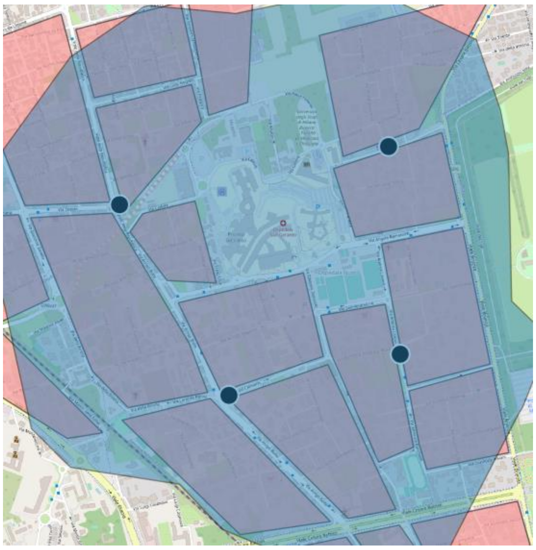

Figure 3.6: Cycle logistic hubs in neighbourhood

The upgrade of this type of logistic is represented by robot delivery. Although robots are already available for the purpose, further technological advancement is needed, especially for driving range. Meanwhile, private companies and public authorities have to jointly agree on the rules for safe and efficient operations on paths shared with pedestrians. Both these processes will require time; thus, robot delivery is not going to become a widespread reality soon.
Further in the future, autonomous vehicles could transport delivery robots, and even cargo drones, in a very barycentric point of the MTZs, where robots and cargo drones could be deployed for the very last-mile delivery. In this scenario, the autonomous vehicle would serve as a mobile hub which would eliminate the need for a permanent one and make the use of robots more efficient.

3.5. Smart Infrastructure

Finally, smart infrastructure development was identified to meet the digitalisation requirement of the 15-minutes model and increase the overall sustainability of the new mobility scheme. In fact, smart infrastructure development includes electrification, for local pollution abatement, and automation for congestion reduction, safer traffic circulation and collective transportation upgrade. Electrification is certainly the area in which research has progressed the most and has already spread in some countries in the world. Concerning the 15-minute project and transportation, charging facilities become one of the necessary services and should be placed in correspondence of parking lots, particularly those for shared cars that were previously identified. In fact, enhancement of electrification of shared fleets and public vehicles, which are used more intensively, would encourage a shift toward sustainable mobility and, since technology has already been developed, it should be achieved quickly.
Regarding automation, instead, the progress on the hardware has been very significant, but much still needs to be done. Forecasts state that although Level 3-4 vehicles will begin running on streets only in the medium-term. However, when they will be available, it will be possible for vehicles to drive cooperatively, exchanging status data (position, speed, events, …), disseminating their status information and allowing other vehicles to become aware of their presence and of eventual hazards detected on the road, and exchanging sensors data (objects, field-of-view, …), allowing road users to provide additional information gained through on-board sensors.
Further in the future, it will be possible to exchange intention data (intentions, trajectories, …), enabling cooperative driving phase among vehicles, for higher traffic efficiency, better fuel economy, and collision avoidance, and to exchange coordination data for synchronised driving trajectories, reaching fully autonomous drive with Level 5 vehicles [6].
Nonetheless, this progress will allow the implementation of SAVs, and may even bring to forbidding human driving, if full automation proves to be safe at 100%.

4. Conclusions

These steps are grouped according to the area they belong to in a Roadmap that summarises their temporal and logic sequence (Table 4.1). They are the result of a case study application, literature review and analysis of the projects undergoing in different cities of the world, and they are meant to be a standard for future cases of study applications.

Table 4.1: Roadmap

	SHORT TERM	MEDIUM TERM	LONG TERM
TRANSIT ORIENTED DEVELOPMENT	Neighbourhood Gravity Centre	Infilling Mixed-Use Buildings Reuse of vacant buildings and areas	–
TRADITIONAL INFRASTRUCTURE	Limited Traffic Zones LTZs Curb Side Differentiation Car Lanes into Bus & Bike Lanes	Moderate Traffic Zones Car Park into Bus & Bike Lanes Velopolitain	–
SHARED USE MOBILITY	Bike Sharing Car Sharing Neighbourhood Shuttle	Mobility As A Service	Autonomous Shuttles Shared CAVs Fully Seamless MAAS
NEIGHBOURHOOD LOGISTIC	Logistic Hubs Parcel Lockers & Boxes	Robot Delivery	Autonomous Vans Cargo Drones
SMART INFRASTRUCTURE	Charging Columns	Cooperative Driving	Fully Autonomous Driving

In the short-term, which can be counted in five years or less, the aim is to start the implementation of 15-minutes neighbourhoods, by placing their gravity centres, spread the habit of walking, by instituting Limited Traffic Zones with no curb parking, and sharing, by providing a good sharing service.
In the medium-term, approximately from ten to fifteen years from now, the first aim is to reduce overall movements and shorten their distance, by completing 15-minutes neighbourhoods' implementation with infilling, for population densification, or with the repurposing of existing buildings for mix-use and the recovery of abandoned ones, if services are lacking. The second aim is to raise the level of walkability, by turning the limited traffic zones into proper moderate traffic zones, where walking function prevails, and by making roads safer with technological development allowing for cooperative driving. The third aim is to move people away from the use of cars, by improving public transportation and cycling competitiveness, with infrastructural interventions, such as lanes and curb parking conversion, for higher frequency and punctuality of the former and higher safety and agility of the latter. Public transport and sharing services could be combined altogether with MAAS, making collective transport more convenient overall than private car use.
Finally, in the long term, twenty or more years form the time of this writing, the aim is to completely abandon car ownership, by providing a completely seamless mobility system with regulated shared autonomous vehicles and complementary public transport that could make use of autonomous shuttles.
The scheme also includes freight mobility, which can be thought as the photographic negative of people mobility. Logistics can take advantage already in the short term of a 15-minute neighbourhood development, if requirements are met, by

implementing cycle logistic, and even more so in the medium term, with bike lanes network expansion, reducing pollution and congestion. Cycle logistic needs little infrastructure development that can be quickly achieved and is represented by cycle logistic hubs and lockers to avoid “not at home” recipients. When legislation will be ready, the streets could also accommodate delivery robots, completing the cycle logistic service. In the future, though, robots themselves, combined with autonomous vans and cargo drones could make cycle logistic obsolete, but could provide more efficient delivery.

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A ROADMAP TO A 15-MINUTES CITY MOBILITY

TESI DI LAUREA MAGISTRALE IN
MOBILITY ENGINEERING

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Academic Year: 2020-21

Abstract

Much work is being done in order to achieve a less polluting, less congested and safer mobility. Action for these purposes has been taken in the direction of electrification and automation and lately in urban planning too. The world would certainly be less polluted, and streets would certainly be less congested and safer, if all walked more.

The 15-minutes programme is the standard that has been taken as a model for this kind of urban planning in different parts of the world. Cities such as Paris, Melbourne, Bogotá, and Barcelona are clearing the way towards this new conception of urban planning and lifestyle, although there are some differences in the strategies due to the characteristics of each city. Despite the idea behind the 15-minutes model being that all basic needs should be accessible within a 15-minutes' walk or bike ride, the program does not aim at confining people to their own neighbourhood. Cross city transfer will still have to be guaranteed, just in a different way than they are today.

In such a context, the goal of the thesis is to find a set of standard guidelines to implement a new transportation system that fits within a 15-minutes urban concept and focuses more on the ability of people to reach their destination, rather than on the movement of vehicles.

The new scheme was obtained by reviewing literature and strategies of those cities that are already implementing the 15-minutes concept and with a case study, the aim of which was apply the 15-minutes concept together with a new idea of transport to the city of Monza.

The case study highlighted challenges and problems that were used to define standard steps that are grouped in a roadmap and can be applied and customised to future cases of study.

The roadmap then aims at summarising what the steps to follow are and what their logic and temporal sequence is for the realisation of a transport system for a 15-minutes city.

Key-words: 15-minutes, mobility, roadmap.

Abstract in lingua italiana

Si sta facendo molto per ottenere una mobilità meno inquinante, meno congestionata e più sicura. A tal fine si è intervenuti nella direzione dell'elettrificazione e dell'automazione e ultimamente anche nell'urbanistica. Il mondo sarebbe sicuramente meno inquinato e le strade sarebbero sicuramente meno congestionate e più sicure, se tutti camminassero di più.

Il programma dei 15 minuti è lo standard che è stato preso a modello per questo tipo di pianificazione urbana in diverse parti del mondo. Città come Parigi, Melbourne, Bogotà e Barcellona stanno aprendo la strada a questa nuova concezione di pianificazione urbana e stile di vita, sebbene vi siano alcune differenze nelle strategie dovute alle caratteristiche di ciascuna città. Nonostante l'idea alla base del modello dei 15 minuti sia che tutti i bisogni di base dovrebbero essere accessibili in 15 minuti a piedi o in bicicletta, il programma non mira a confinare le persone nel proprio quartiere. Gli spostamenti attraverso la città dovranno comunque essere garantiti, solo in modo diverso da come lo sono oggi.

In tale contesto, l'obiettivo della tesi è trovare una serie di linee guida standard per implementare un nuovo sistema di trasporto che si inserisca in un concetto urbano di 15 minuti e si concentri maggiormente sulla capacità delle persone di raggiungere la propria destinazione, piuttosto che sulla circolazione dei veicoli.

Il nuovo schema è stato ottenuto rivedendo la letteratura e le strategie di quelle città che stanno già implementando il concetto dei 15 minuti e con un caso di studio, il cui scopo era applicare il concetto dei 15 minuti insieme a una nuova idea di trasporto alla città di Monza.

Il caso di studio ha evidenziato sfide e problemi che sono stati utilizzati per definire passaggi standard che sono raggruppati in una roadmap e possono essere applicati e personalizzati a futuri casi di studio.

La roadmap mira quindi a riassumere quali sono i passi da seguire e quale sia la loro sequenza logica e temporale per la realizzazione di un sistema di trasporto per una città da 15 minuti.

Parole chiave: 15-minuti, mobilità, roadmap

Contents

Introduction

In the last years there has been a change in the cities' vision to which COVID-19 pandemic has contributed very much. Cities that were partially or totally locked down experienced unprecedented challenges such as the shortage of basic supplies as food. A sizeable number of urban residents also faced unemployment as companies and institutions downscaled due to the low demand and supply of basic materials and services. The emergence of this pandemic exposed the vulnerability of cities in their current establishment and the need for a radical re-thinking, where innovative measures need to be tailored to ensure that urban residents are able to cope and continue with their basic activities, including cultural ones. Also, the awareness that today's cities establishment involves incredible waste of resources and dangerous level of pollution brought to the necessity for cities to become smart, so to be more liveable, resilient and self-reliant both in the short and long terms.

Smart cities are comprised by six key fields of smartness: smart governance, smart economy, smart mobility, smart environment, smart people and smart living [1]. Smart cities and intelligent transport systems are two closely related concepts that rely on the use of IoT (Internet of Things) for connecting physical items (e.g., vehicles, road infrastructure, etc.) in several application scenarios. Despite all the previous government efforts and research projects that tested smart mobility solutions and promoted integrated transportation systems, the 2017 Global Mobility report that evaluates transportation shows that:

1. People still depend on their cars. In Italy, over the span of forty years the number of people using their cars to travel has more than tripled (+9.7 million) and consistency of the fleet in circulation has grown from 28.4 million cars on the road in 1991, to 33.2 million in 2001and to 37.1 million in 2011 [2].
2. City centres still have big problems from traffic. The number of delivery vehicles in the largest 100 cities globally is foreseen to rise by 36% and congestion on streets, from all types of vehicles, is foreseen to rise by more than 21%, adding another 11 minutes to the daily commute of every car and bus passenger [3].

3. The increased traffic brings pollution, noise, and degradation of the urban environment. According to Francesca Racioppi [2], the transport sector is the largest contributor of nitrogen oxide emissions, accounting for 47% of total EEA 33 Member Country emissions in 2014. Transport also contributed 13% and 15% of total PM_{10} and $PM_{2.5}$ primary emissions, respectively, in the EU-28 in 2014. Particularly, road transport accounts for the vast majority of greenhouse gas emissions: approximately 73% in the EU, with passenger cars accounting for 44,4%. In the EU-28 road transport (including international shipping) accounts for the largest amount of transport energy consumption, equivalent to 73% of total demand in 2014. Emissions from delivery traffic is foreseen to increase 32%, emitting an additional 6 million tons of CO2. Studies show that in Rotterdam freight vehicles such as vans and trucks are disproportionately responsible for urban greenhouse gas (GHG) emissions (34% of all CO2) and air pollution (62% of NOx and 39% of PM10), even though they account for just 11.2% of overall traffic [3].

The pandemic, however, has become an opportunity to change. During lockdown, the use of almost all means of transport fell by 60% in Europe, the US and China. Private bicycles and walking were the preferred methods of citizens all over the world, passing from 21% to 59%. Surveys show that during the lockdown, about a third of the interviewees travelled at different times of the day to avoid the crowds and almost a quarter used public transport only in the presence of empty seats. Changes in consumer behaviour are evident, it remains to be seen whether these new habits are going to stay and what they will mean for future demand. In the short term it is estimated that these changes will lead to an increase in the use of individual mobility, namely cars, motorcycles, and scooters. Shared mobility will also remain popular in Europe, with the prospect for services such as individual ride-hailing to take hold in most countries, if accompanied by sanitation services. In the next 12-18 months, instead, the Boston Consulting Group foresees two potential scenarios: the confirmation of private mobility as the most used mode or the great return of public transport [4].

Public transportation cannot compete against private means especially in areas with disperse population, where the network and frequency of public transportation are not satisfactory and where all the green ways of transportation (walking and bicycle) have a limited impact on traffic. However, the compact and densely populated cities of East Asia, appear to be more promising for developing sustainable smart-mobility schemes based on mass transportation, whereas in the large but widely dispersed cities of the United States and Australia people still prefer private means of transportation and require a different approach. Large European cities stand in the middle, since they have a smaller population size, density, and area. They are usually built around a single city centre that promotes green mobility and is connected to the surrounding areas with metropolitan transportation networks.

The redesign of city transportation services, connected with a replanning of the land usage and the proper arrangement of business, commercial, residential, industrial, and other zones, could result in a more reliable establishment helping cities all over the world in solving the above-mentioned issues [5].

1. 15-Minutes Model

The model of the "15-minutes city" responds to that requirement for redesign to achieve a new, more reliable city establishment. Its aim is to minimise to need to move, by improving accessibility to fundamental facilities. According to Carlos Moreno at al. [6], an important point is that the way many modern cities are designed is often determined by the imperative to save time, yet so much time is wasted driving to work, in traffic jams, driving to a fundamental activity. The idea of the 15-minutes city answers the question of saving time by completely overturning it, suggesting a different rhythm of life.

To achieve this goal, the 15-minutes City must rest on four pillars, which were identified after observing the challenges that several cities around the world endured during the height of widespread COVID-19 cases and the resulting health measures and protocols aimed at mitigating the spread. As noted earlier, urban residents endured countless challenges, especially in accessing basic necessities that, in most cities, were poorly distributed. These pillars are *Density*, *Proximity*, *Diversity* and *Digitalisation* (*Figure 1.1*).

Figure 1.1 – 15-minutes model pillars [6]

1.1 Density

In the 15-minutes City concept, density is viewed in terms of people per square kilometre. In planning for a city that is sustainable, it is supported that it is paramount to consider the optimal number of people that a given area can comfortably sustain in terms of urban service delivery and resource consumption. In earlier planning models, where the emphasis was on creating ultra-high-rise buildings and offices, challenges arose, including the increased overconsumption of resources and over-reliance on fossil fuel energy to power buildings. As such, the emphasis here is on the optimal density that ultimately allows sustainability pursuits to be achieved on the economic, social and environmental frontiers. According to Andres Duany and Robert Steuteville [7], the 15-minutes city implies three levels of sheds. The 5-minutes' walk shed, a quarter mile from centre to edge, indicating the individual neighbourhood where the population may be provisionally calculated at 2,600. A 15-minutes' walk shed, three-quarters of a mile from centre to edge, which is the maximum distance that most people are going to walk, where weekly and daily needs are provided, and the population is approximately 23,000. The 15-minutes bicycle shed which gives access to major cultural, medical, and higher education facilities and where population may be calculated at 350,000. With these numbers it can be assumed as an overall suggestion that density should be approximately 5'200 residents/km^2.

1.2 Proximity

Proximity is viewed to be both temporal and spatial. Within the 15 minutes quickly accessible radial nodes, residents in each neighbourhood can readily access basic services, which can be divided in seven categories (*Table 1.1*): supply, work, education, health, living, entertainment, mobility.

Pozoukidou and Chatziyiannaki [8] suggest that the main difference in relation to other neighbourhood centred approaches is that 15 minutes cities intend to bring activities to the residents and not residents to activities, restoring the urban planning concept of proximity. To do so, C40 Knowledge Hub [9] proposes to reclaim vacant plots and underutilised space as well as repurposing parking for on-street greenery and parklets and upgrade existing spaces to better serve the needs of the city and community.

This dimension is critical not only in helping cities reduce the amount of time lost in commuting but also in reducing the environmental and economic impacts of such activity, while promoting social integration of individuals. According to Pozoukidou and Chatziyiannaki [8], it is estimated that indoor and external pollution causes 7 million premature deaths each year, with lower income groups being the most vulnerable and at risk on a daily basis. Therefore, policies to increase micro-mobility, reduce travel distances to meet basic needs, increase the use of mass transit, together with more accessible public green spaces, are necessary to manage carbon emissions and improve air quality. Regarding the social dimension, inclusive societies provide employment and housing for everyone to ensure economic prosperity that will in turn contribute to the reduction of crime, violence, and poverty. In economic terms, inclusion concerns the issue of providing equal opportunities to employment, education, lifelong learning, financial resources etc., and to ensure a fair share in rising prosperity. The spatial dimension, instead, concerns accessibility to affordable housing, transportation options, urban services and amenities and to the regulation and control of available land and housing stock.

Table 1.1 – Basic Services

Supply	**Work**	**Education**	**Health**	**Leisure**	**Living**	**Mobility**
Grocery shops (Greengrocer, Bakery, Butcher) Hardware shops (Stationary, Clothes, Shoes, Mobile phone) Amenities (Hairdresser, Laundry) Supermarket Post Office	Local employment opportunities Coworking spaces Wi-fi and High-Speed internet	Nursery school Kindergarten Elementary School Middle School Library	Doctor Dentist Clinic Pharmacy	Park Playground Bars & Restaurants Recreation facilities	Affordable housing Housing diversity	LPT Stop Safe Cycling Network Walkable Streets Charging Facilities Last mile Sharing docks

1.3 Diversity

This dimension is twofold: firstly, the need for mixed use neighbourhoods which are primary in providing a healthy mix of residential, commercial and entertainment components and secondly, diversity in culture and people.

According to C40 Knowledge Hub [10], to achieve mix use development it is necessary to update planning and zoning rules for new developments, by switching from conventional zoning to form-based codes and/or mixed-use zoning, for example. Form-based codes (FBCs) regulate the overall form and character of allowable buildings in a zone without specifying use, while conventional zoning separates buildings by use. Alternatively, cities can implement mixed-use zoning – on specific corridors or districts, or citywide – starting by identifying any existing provisions that prohibit mixed-use development. Zoning should also be done for medium density development, with more multi-family housing than single-family buildings and smaller block size to create better walkability. For instance, in 2020 Portland passed a comprehensive zoning reform to allow up to four homes on almost any plot under the Residential Infill Project and remove parking mandates. The reform re-legalises 'missing middle' housing types, and is designed to increase neighbourhood density, provide more housing choices and tackle the city's housing shortage. This way of zoning should promote infill, although the favoured type of compact development will depend on local market conditions, residents' preferences and the feasibility of different building types.

Regarding diversity in culture and people, C40 Knowledge Hub also suggests including public and/or collective social spaces in policies, such as those to introduce priority amenities in underserved neighbourhoods through permanent, flexibly used and temporary spaces, in order to promote inclusion, and adopt inclusive planning processes that benefit everyone [11].

In the pursuit of a 15-minutes City model, the adoption of mixed-use neighbourhoods is fundamental in ensuring that an optimal density and proximity of essential amenities are achieved, while also providing for development of walkable streets and bicycle lanes. This means investing in infrastructure that makes streets more pleasant, safe and accessible for pedestrians and cyclists, by creating wider sidewalks, more street crossings, secure bike parking, protected cycling infrastructure, reduced vehicle speed limits, traffic-light priority for pedestrians and cyclists, and more, reclaiming road space and on-road parking spaces [9].

Within the context of inclusiveness, streets must be designed to be accessible for all users, particularly children, wheelchair users, families with pushchairs/strollers, the visually impaired and other vulnerable users.

Interventions may include restricting use of cars in certain areas while providing more space to pedestrians of all ages, 30 km/h zones or Woonervens, where pedestrian mobility is not confined to zones pedestrian, but it can take place all the way, because vehicles always have to give up precedence and are obliged to proceed at walking pace [12].

1.4 Digitalisation

This dimension is very relevant especially in ensuring the actualization of the three other dimensions. For instance, through digital tools and solutions, it would be possible to ensure that biking experiences are enhanced by emphasizing solutions such as bike sharing and the deployment of sensors to ensure the safety and security of cyclists.

An integrated digital system should be designed to ensure the ease and affordability of multi-modal journeys. It should also enable easy payments, provide live transport updates, and be easily integrated with other modes, such as shared bike schemes. This is the goal of mobility as a service (MAAS), which focuses on a user-centric paradigm for demand orientation and seeks to offer a multimodal collective transport solution that is best from customer's perspective. Via digital platforms, customers are offered services on subscription in the form of mobility packages, or a more common pay-per-ride micro-transaction, and access to all the necessary services for their trips: trip planning, booking, ticketing, payment, and real-time information, since multiple actors cooperate through it [13].

Regarding proximity dimensions, digitalisation has been effective where services such as online shopping, cashless transactions and virtual communications and interactions amongst others are implemented and promoted. The digitalisation of public services allows residents to avoid unwanted trips, improves efficiency and lowers costs. Building on and learning from the rapid, widespread digitalisation of public services during the pandemic, cities can strengthen and expand online services further as part of a 15-minutes city strategy. This might mean, for example, upgrading digital healthcare apps to facilitate online diagnosis, providing online library-book renewals, or improving ease of access, reducing the need for commuting even further, as some services could be delivered within the comfort of homes or offices [14].

Digitalisation, especially during the COVID-19 pandemic, has made it possible for people to work from home and communicate, while reducing the need to travel from home to offices and other workplaces at the same time. A study conducted in Milan by Chiara Bisconti shows some of the benefits of smart working. The first one is the time saved in commuting, which is above 100 minutes on average. Smart working can generate a dilution over time of the use of public transport and a decrease in traffic peaks with great benefits for those who still need or want to move and great benefits in terms of emissions: a person working from home only once a week could save up to 135 kg of CO_2 over a year [2]. Furthermore, since smart working drastically reduces car use and distances, by increasing its adoption we will certainly have a decrease in the number of road accidents. It is clear that public and private places must be rethought to meet the needs of these workers who adopt such different ways. Coworking is an alternative to working in the traditional office or at home. These places allow to avoid the isolation that could result from excessive use of one’s home, creating relationships and offering the possibility of networking.

2. State of Art

There are a few examples of cities around the world that are implementing the 15-minutes project. In South America and Australia respectively, Bogotá and Melbourne are leading the way. In North America, Portland is the most advanced, followed by Ottawa, where a 25-year urban intensification plan to create a community of '15-minutes neighbourhoods' was approved in December 2019. Houston too is taking a polycentric approach to urban development, aligned with 15-minutes city principles and well suited to low-density, sprawling cities.

In China, Shanghai, Guangzhou and other cities have included 15-minutes Community Life Circles in their masterplans. Chengdu is another city taking a polycentric approach to urban development: it has a Great City plan to create a smaller, distinct satellite city in its outskirts, where everything will be within a 15-minutes walk of the pedestrianised centre and connected to current urban centres via mass transit.

In Europe, Paris and Barcelona are setting the examples, followed by other cities such as Milan, where the newly elected mayor Giuseppe Sala promoted the 15-minutes project during his campaign, and Madrid, which announced in June 2020 plans to pilot the Barcelona approach as part of its transition to a 'city of 15-minutes' to support the city's revival following the pandemic [15].

2.1 Paris

The vision of Paris "En Commun" strives for a carbon-free economy and a healthy life for its citizens. It concerns the area of Paris that is confined within the ring road, also known as "peripherique". The four axes of the strategy include the implementation of ecological measures, solidarity-centred ecological transformation, hyper-proximity and the commitment of citizens to the strategy. The 15-minutes concept falls under the hyper proximity axis, as an attempt to create a neighbourhood centred city where all inhabitants can cover most of their needs within 15 minutes, walking or biking, from their place of residence. Mayor Hidalgo suggested a "big bang of proximity," including massive decentralization, developing new services for each of the neighbourhoods and reducing traffic by increasing bike lanes into recreational spaces, new economic models to encourage local stores, building more green spaces and transforming existing infrastructure (*Figure 2.1*).

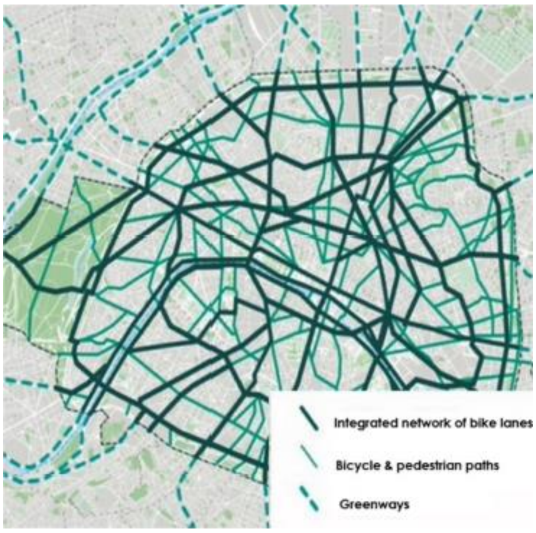


Figure 2.1 – Paris' bike lane network

For example, digital labs within sports centres or, in the evening, transforming schools into neighbourhood centres while respecting the golden rule of the 15-mins city: every square meter already built, should be put to multiple uses [16]. The notion of localising services and functions is evident throughout the plan. Initiatives such as "eat and buy local" promote the consumption of products that have been produced in the "basin" of Paris. In fact, the strategy proposes the creation of cooperatives like the "Agri-Paris" which acquires fresh food and other products from local producers and distributes them quickly and directly to the residents and neighbourhood markets of Paris. In addition, main roads through Paris will be inaccessible to motor vehicles, "children streets" will be created next to schools for term time, and the schools turned over to local residents during weekends and holidays [8].

2.2 Melbourne

The city of Melbourne, Australia, is currently working on the development of "20 minutes" neighbourhoods, aiming at completing the task by 2050. This long-term strategy seeks to accommodate the challenges posed by an ever-growing population and employment. These include providing affordable and accessible housing, ensuring adequate number and diversity of jobs, containment of urban sprawl, accessibility and adequacy of transport, mitigation of green-house emissions, and adaptation to climate change. The “20-mins neighbourhoods” include a series of 17 urban and social functions that should be accomplished within their jurisdictions [8]. *Figure 2.2* provides an overview of the proposed functions.

Figure 2.2 – Melbourne neighbourhoods’ features

A critical structural feature of the 20 mins neighbourhoods is the “neighbourhood activity centre” (NAC), which is the focal point of the neighbourhood (the Plan refers to them as high streets or specialized streets) and provide a variety of urban functions. Work undertaken in partnership with the Heart Foundation (Victoria) and across the Victorian Government identified the following hallmarks of a 20-minutes neighbourhood [17].

They must: (1) be safe, accessible, and well connected for pedestrians and cyclists to optimise active transport; (2) offer high-quality public realm and open spaces; (3) provide services and destinations that support local living; (4) facilitate access to quality public transport that connects people to jobs and higher-order services; (5) deliver housing/population at densities that make local services and transport viable; (6) facilitate thriving local economies.

2.3 Bogotá

A survey made in Bogotá by Luis A. Guzman et al. showed that nearly 22% of the respondents changed the preferred transport modes for shopping activities due to the pandemic. The prevalence of walking trips for shopping purposes highlights local shops' importance within house holds' close vicinity during the pandemic. A 65% increase in walking trips for performing health activities was identified in detrimental of trips by car, motorcycle, taxi, and public transport. Such a rocketing of the walking rate was due to inaccessible healthcare facilities, particularly for the low-income population. The results of the survey reinforce the importance of urban planning to allocate an adequate land use mix within the household vicinity to guarantee active transport access to shopping, sports, cultural, recreational, and health opportunities [18].

Barrios Vitales (Vital Neighbourhoods) build on the city's extensive street space reallocation for walking, cycling, cafes and other people-focused uses during the pandemic. The project was planned well before the sanitary emergency, but it gained more importance with the pandemic itself, and integrates a network of green corridors with pedestrian and cycle-priority roads, and uses traffic restrictions, tactical urbanism interventions and more to create people-centred mobility and thriving streets. In May 2021, Bogotá released a new draft land management plan which integrates a 30-minute city strategy and the Barrios Vitales approach. If approved, the POT will expand the city's metro and cable car/aerial tram lines to support longer trips, improve a 218 km network of pedestrian routes [19].

The Planning Secretariat assumes that proximity is determined by access to 4 variables: facilities (schools, hospitals, parks, etc.), economic fabric (workplaces and original vocation of the territories), public services and mobility and transportation. To address the disparity in time and well-being, proximity levels of the proposed neighbourhoods have been measured: 14 have levels of "positive proximity"; 6 of "intermediate proximity"; and 10 of "deficit proximity". The layout of a District will be marked by everything you can reach in 20 minutes by bike or public transportation [20].

2.4 Barcelona

The Superblocks program takes a step forward and becomes the model for the transformation of the streets of the entire city, with the aim of recovering for citizens a part of the space currently occupied by private vehicles. The goal is to create a healthy, greener, fairer, and safer public space that fosters social relations and the local economy. The Barcelona City Council has carried out a careful analysis of the city: citizen flows and mobility, neighbourhood facilities, green spaces, constructive and social fabric. With this overview, a street hierarchy was created to free some streets of road traffic, creating a network of green axes and squares where pedestrians have priority [21].

A Superblock will cover approximately 400 m × 400 m (in some parts of the city the Superblock design may deviate). Within the Superblocks, pacified interior roads will provide a local road network that is accessible primarily to active transport (i.e., walking and cycling) and secondarily to residential traffic with a maximum speed of 20 km/h. The Superblocks will be framed by the basic road network that connects the city and accommodates through traffic at a maximum speed of 50 km/h (*Figure 2.3*). Besides accommodating cars and motorcycles, the basic road network will contain segregated cycling and pedestrian infrastructures and segregated bus lanes for rapid transit. For optimal access, bus stops will be placed every 400 m at the main intersections of the Superblocks (in non-grid-like superblocks this distance can vary) and buses will circulate at a high frequency, making public transport an attractive alternative. With the implementation of 503 Superblocks, private motorised traffic is expected to decrease considerably, and traffic flow on the basic road network is expected be less congested, because of avoided turns into the Superblocks [22].

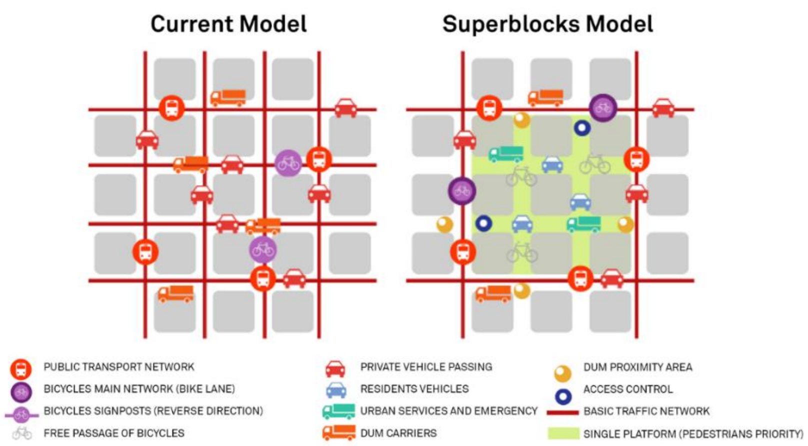


Figure 2.3 – The superblock model

3. Challenges

The cities that were mentioned in chapter 2. are very different from one another for various aspects. First of all, population varies: there are mid-populated cities such as Portland and Ottawa, highly populated ones such as Barcelona and Melbourne and real metropolises like Paris and Shanghai. Density is different too: for instance, Melbourne and Bogotá cover about the same surface, but the former has a density which is almost half of that of the latter. Also, morphology is different: Bogotá is set on the mountains at more than 2000 metres above sea level, while Melbourne and Barcelona are mainly flat. These differences are the reason why a similar concept is being developed under different names—15-minutes neighbourhood, 20-minutes neighbourhood, Vital Neighbourhoods, Superblocks—each responding to the distinguishing characteristics of the cities and the challenges they face. So, what are these challenges?

According to Eleonora Pieralice [2], walking is favoured in "non-vertical" cities, where the slopes do not create states of fatigue; small in size, where the radius of the distances does not exceed 2 kilometres; or where environmental or ecological islands, together with protected routes for people with reduced mobility, allow access to the activities of daily life (schools, public transport, public services, shops, etc.). Her studies highlight that the most virtuous European cities are those with a population between 300,000 and 500,000 inhabitants over 500 km^2 or less than 100 km^2 with walking average values greater than 30%. In the territorial extensions of less than 500 km^2, the smaller cities have on average higher values for all classes of demographic amplitude except for Athens, the only city with more than 1 million inhabitants (8%). Finally, among the cities with more than 1 million inhabitants, those between 500 and 900 km^2 in size express a greater disposition for pedestrian mobility (31%).
However, to implement a 15-minutes city, a deeper interpretation of walking rate should not stop at considering the mere population or the geographical extension of a city. It should also consider what modes are chosen for trips as an alternative to walking, based on the offer in the municipality. In fact, cities in general are not just about walking. As an example, Naples has a higher walking percentage than Copenhagen, but considering "soft mobility", understood as the sum of movements

on foot or by bicycle, we have that the majority of European cities use these modes for 20-40% of their transfers, while only in 8 cities the share rises to over 40% and among these Copenhagen is first with 56% (*Figure 3.1*) [23].

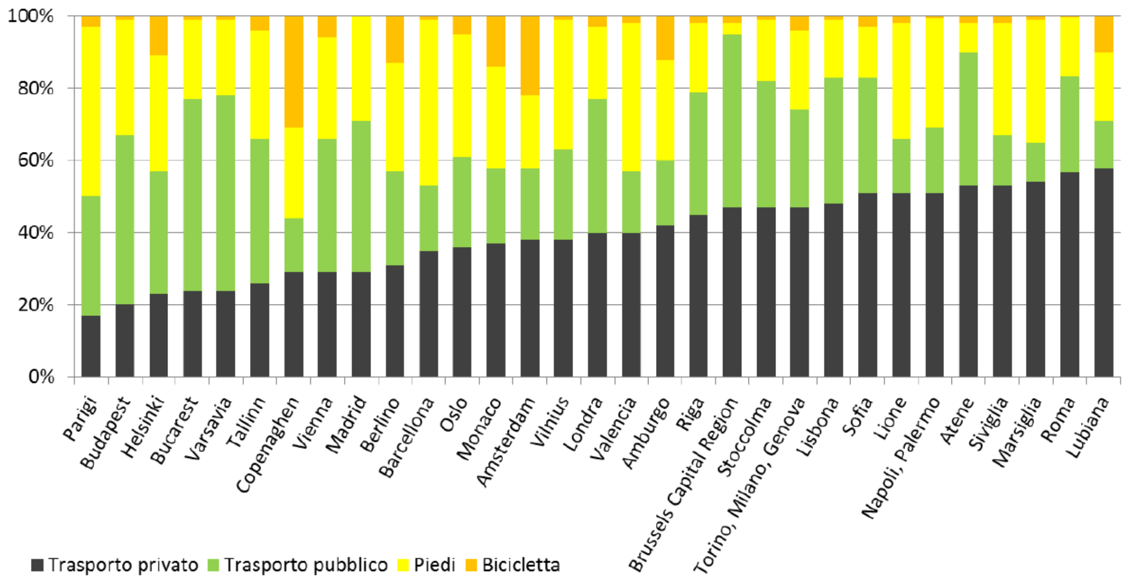


Figure 3.1 – Mode of travel in European cities over 250,000 inhabitants [23]

The real distribution of homes within the city, and the actual population density, are also to be considered, particularly for non-European cities. It may be perceived that big cities are more suitable for a 15-minutes project, because they are populated enough and have all the services at reach. But defining whether a city is big or not might be tricky. For example, Melbourne has a population of 4.900.000 residents on a surface of 4705 km^2, which means an average population density of 2873,9 res/km^2. Paris, instead, has a population of 2.175.601 residents on a surface of 105 km^2, which means an average population density of 21.000 res/km^2. Being density one of the four pillars of the 15-minutes project and being minimum suggested density approximately 5200 res/km^2, Paris is much more suitable to become a 15-minutes city than Melbourne. Paris appears even more suitable, when looking at the actual population distribution. Paris' population is very much concentrated (yellow) in the municipal area, while it becomes less dense (red) and slightly sprawled in the metropolitan area (*Figure 3.2*). Melbourne population, instead, has an almost constant concentration, as it is all the same colours, and very much sprawled, being the red dots even less dense than those of Paris' metropolitan area (*Figure 3.3*).

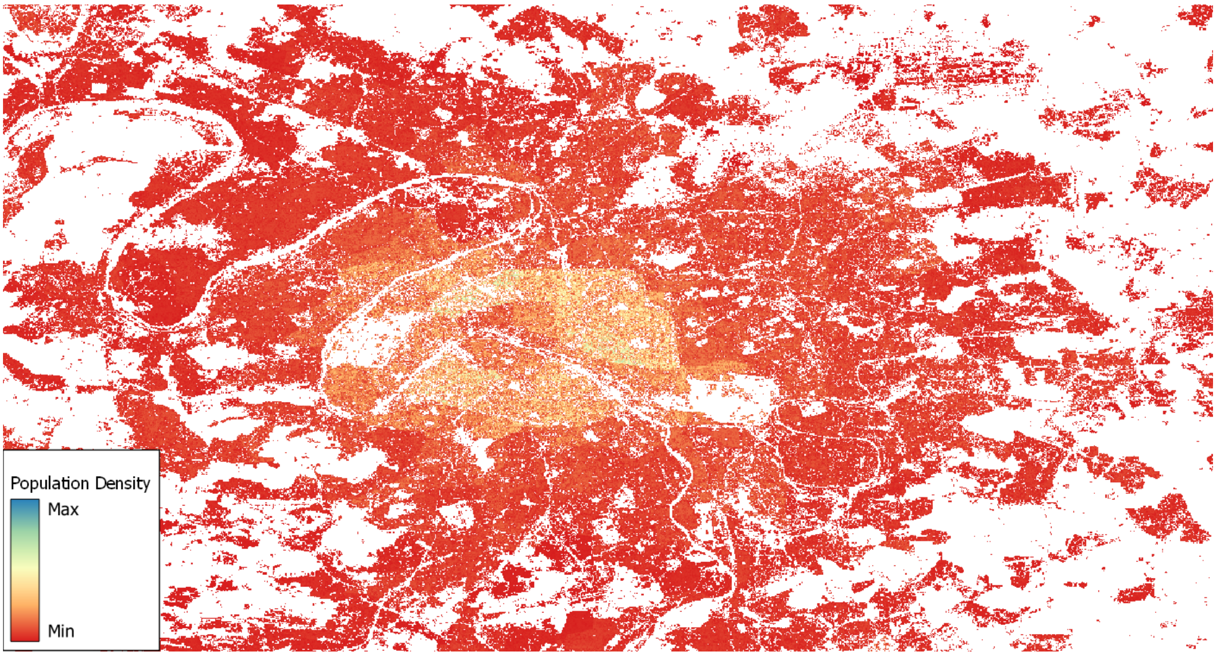


Figure 3.2 – Paris' population distribution

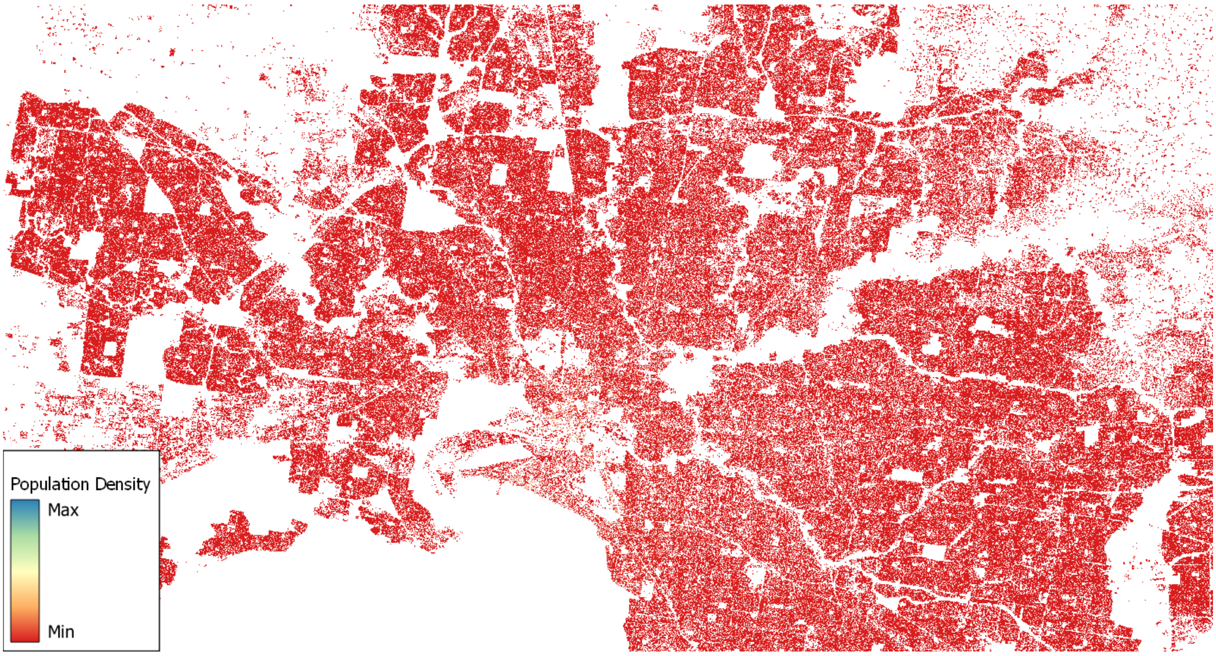


Figure 3.3 – Melbourne's population distribution

Another important pillar of the 15-minutes project is proximity. So, even though Melbourne's population density and distribution is not proper to make it a 15-minutes city, the services concentration and distribution might be. Intuitively, though, as shown in *Figure 3.5*, services' distribution and density reflect that of population and comparison with Paris is dramatic (*Figure 3.4*).

Such a difference should not be a surprise. In fact, Melbourne's urban development pattern was shaped by car-oriented policies, unlike many European historical centres. As such, it consists of a low-density zonal type of development with separation of basic urban functions such as housing, working, entertainment, shopping etc. For this reason, Melbourne is implementing 20-minutes neighbourhoods, instead of 15-minutes neighbourhoods, supporting the idea with research showing that 20-minutes is the maximum time people are willing to walk to meet their daily needs locally and that this 20-minutes journey represents an 800m walk from home to a destination and back again [17].

Most urban areas built prior to the overwhelming proliferation of cars have the structure of a 15-minutes city, so restoring the goal may be relatively easy, depending on how much damage was done due to urban renewal. For more recent cities and suburban areas, the task will be more difficult, as cars are not subject to spatial discipline, and a 20-minutes project such as that of Melbourne may be implemented, rather than a 15-minutes one, while "soft mobility" may be reconsidered, giving more credit to electric bikes and scooter, or small electric vehicles, rather than just human-powered transportation, given the bigger radius of the neighbourhoods [7].

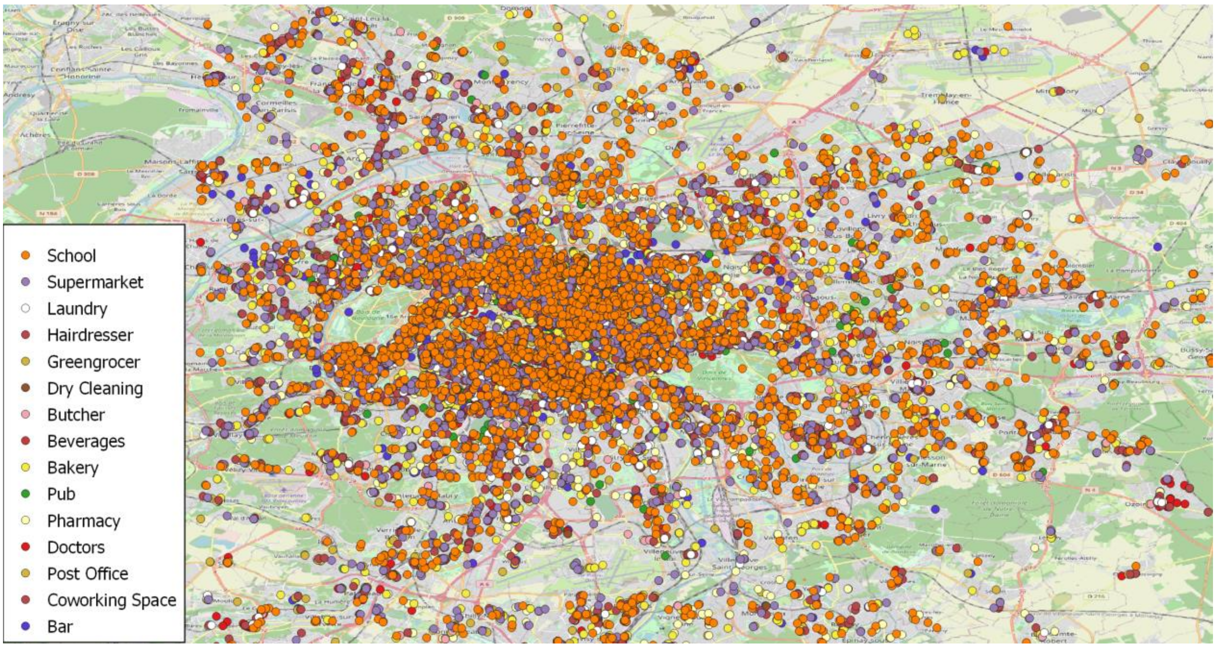


Figure 3.4 – Paris' main services

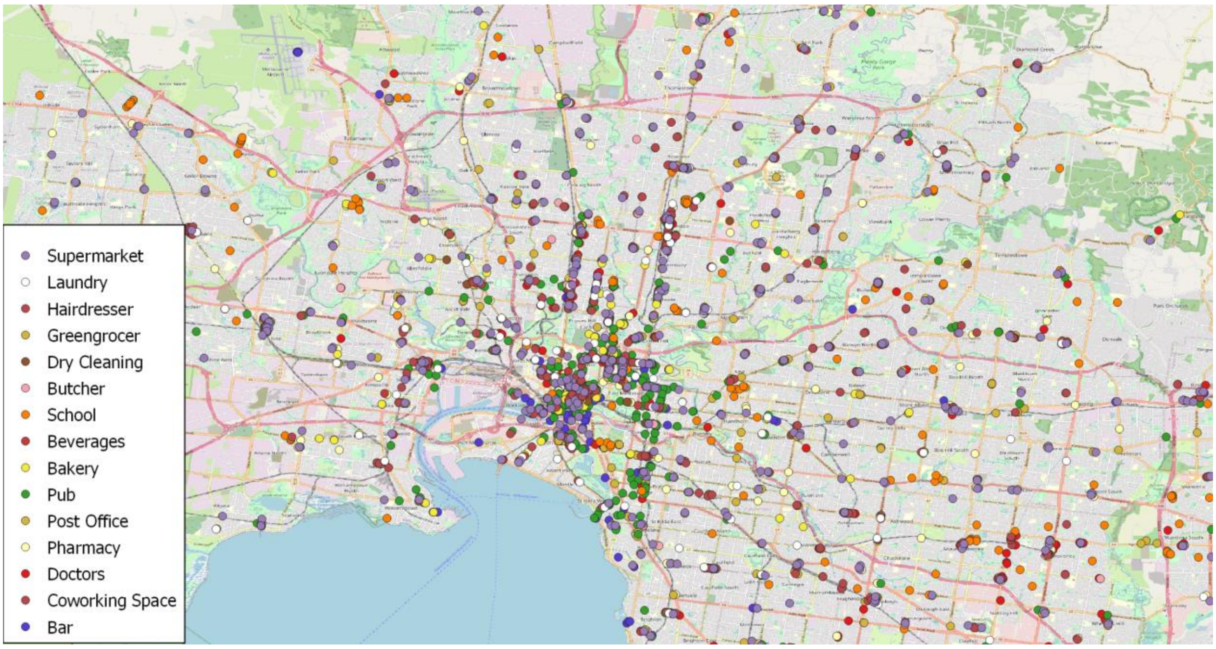


Figure 3.5 – Melbourne's main services

Finally, geomorphology is another very influencing factor when planning a 15-minutes city. For example, due to its geographical and physical conditions, in Bogotá there will be two 'neighbourhood sizes' that will depend on whether you live in the plains or if you live in the hills. In the case of the plains, a District is what you can do within 5 kilometres around, while, on the hillside, a District is what you can do at 2.5 kilometres around (*Figure 3.6*) [20].

In the case of uphill neighbourhood, as well as in that of 20 minutes neighbourhood, different "soft mobility" solutions shall be implemented to make it easier for residents to complete their trips, particularly less agile people.

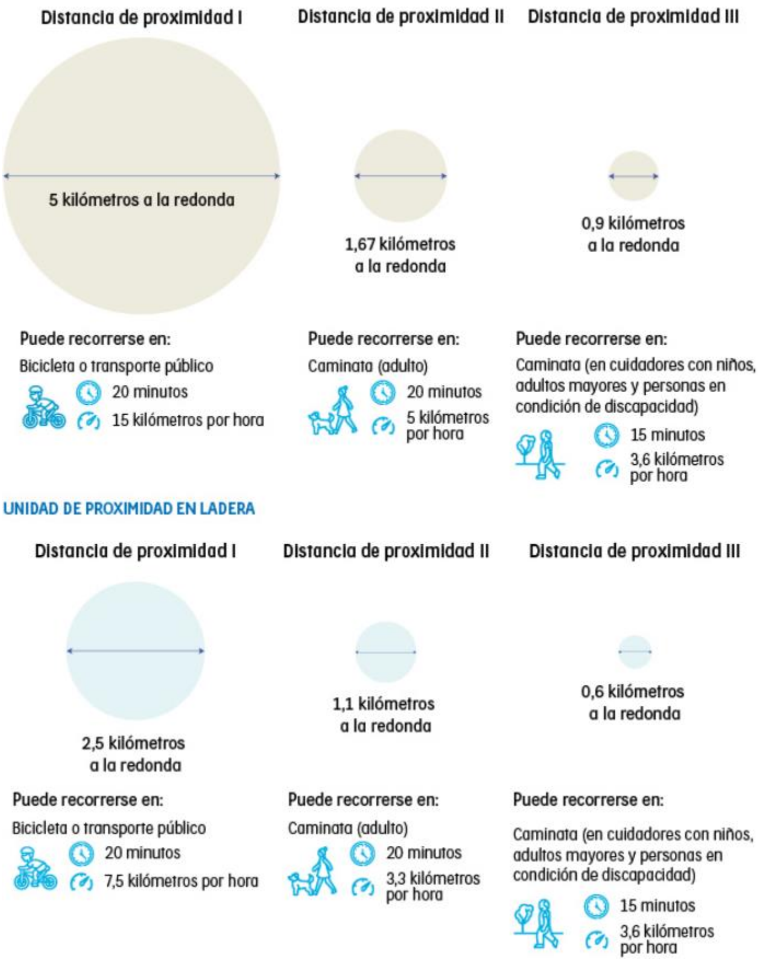


Figure 3.6 – The measure of proximity in Bogotá [20]

4. 15-Minutes City Mobility

The 15-minutes city project aims at eliminating all the unnecessary and unwanted trips, by bringing services closer to people. However, it does not aspire to confining people to their own neighbourhood. On the contrary, providing easy connections across the city is another core 15-minutes city principle. Most cities' streets, though, are designed for private vehicles first. For these reasons, transit paradigms that focus on people and bring the sharing concept to a higher level are needed in order to eliminate the need for car ownership. In the past, mobility paradigms were common practice. A mobility paradigm emphasizes the quick movement of vehicles, whereas an accessibility paradigm focuses on the ability of people to reach their destinations. Accessibility increases when the mixture and density of land use increases, bringing our destinations closer to where we begin. Our mode of travel may be slower, but it takes us less time to get where we are going [24].

Thus, a new transit scheme where mobility and accessibility paradigm are balanced shall be found. Taking inspiration from the cities that were presented and considering the challenges they face, a set of fields to act upon were selected and analysed to realise a new mobility scheme that fits in a 15-minutes city, where higher accessibility should be granted. These fields are namely: Transit Oriented Development, Traditional Infrastructure renovation, Shared Use Mobility, Neighbourhood Logistic and Smart Infrastructure.

4.1 Transit Oriented Development

Transit-oriented development (TOD) promotes denser, mixed-used development around public transport services, enabling a large-scale shift away from reliance on private vehicles. Realising TOD is a long-term undertaking, so it is important that the vision is seen to be owned more widely by the city and its residents, thus requiring widespread cross-party support and long-term investment in transit and urban development [25].

In a TOD vision, the gravity centre of a neighbourhood should be placed in correspondence of a station or public transport stop (*Figure 4.1*), because all basic services should be ideally placed in a barycentric position and cross city mobility is certainly one of those, as mentioned. Also, stations are usually provided with main services, so, placing a station as a gravity centre helps organising a neighbourhood where services are at a 15-minutes distance for everybody in the neighbourhood, instead of requiring some residents to cross the neighbourhood, taking more than 15 minutes to reach their destination. Obviously, stations are not everywhere, thus, less important stops should also be considered, such as suburban railway stations and metro interchange stations, but also those of LRT and BRT lines, because they are usually already surrounded with amenities and can attract new ones. As an example, the NAC of Melbourne is exactly a street at the centre of the neighbourhood, usually hosting a tram line, where amenities are concentrated.

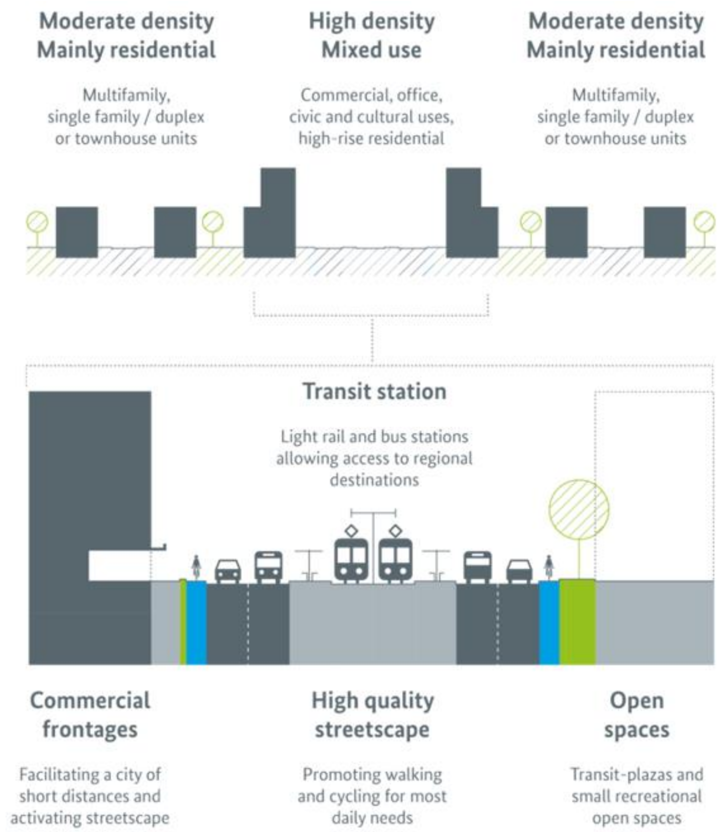


Figure 4.1 – Transit Oriented Development

TOD promotes social equity not only through inclusive access and mobility but also through inclusionary housing and its equitable distribution over the different areas of the city. A mix of housing options makes it more feasible for workers of all income levels to live near their jobs and helps prevent lower-income residents dependent on lower-cost public transit from being systematically displaced to poorly served outlying areas. Inbound and outbound commuting trips are more likely to be balanced during peak hours and throughout the day, resulting in more efficient transit systems and operations. Upgrading substandard informal housing in situ and the protection of residents and communities from involuntary displacement caused by redevelopment are promoted too [26].

This goal can be achieved by using residential infill as a way of improving levels of services and amenities, while providing affordable housing in accordance with cities' policies. In fact, urban density is needed to both accommodate growth within the inherently limited areas that can be served by quality transit and to provide the ridership that supports and justifies the development of high-quality transit infrastructure. Also, implementing residential infill is an opportunity to guarantee a balanced mix of complementary uses and activities within a local area (i.e., a mix of residences, workplaces, and local retail commerce), especially when large in scale, so that many daily trips remain short and walkable. Diverse uses peak at different times and keep local streets animated and safe. They encourage walking and cycling activity, support extended hours of transit service, and foster a vibrant and complete human environment where people want to live. People of all ages, genders, income levels, and demographic characteristics can safely interact in public places.

Depending on the scale of the infill needed for a neighbourhood it can require shorter or longer time for completion, but it is a project to be developed in the medium-term.

Small Scale Infill is the shortest time demanding form of infill because it includes small size houses [27]:

- Secondary Suite: A self-contained dwelling within a single detached house.
- Garage Suite: A self-contained accessory dwelling above or attached to a rear detached garage, on a single detached lot.
- Garden Suite: A self-contained accessory dwelling at the rear of a lot, separate from the primary house onsite.
- Small Lot: A single detached house on a narrow lot.
- Duplex: One building with two dwellings placed one on top of the other.

- Semi Detached: One building with two dwellings attached at the side.
- Fourplex: One building with 4 dwellings, arranged 2 deep up-and-down, or back-to-back. Row Housing (up to 5 units): 3 to 5 dwellings attached at the side.

Small scale infill can be placed both in the interior and exterior of neighbourhoods, depending on how much space is available. According to the TOD new development should focus on neighbourhood edges, block ends, and across from neighbourhood parks and schools. However, if density needs to be increased and land on the interior of the neighbourhood does not allow for large or medium scale infill, small scale infill is a viable option.

Medium Scale Infill certainly requires longer time for each building, with respect to small scale infill, but it may be quicker if the population density raise rate is considered. In fact, with one of the following buildings it is possible to achieve a population increase that requires 4 or more houses with a small-scale infill [28].

- Row Housing (6 or more units): Six or more dwellings attached at the side.
- Stacked Row Housing: A building with multiple units stacked 2 deep either vertically or horizontally.
- Low Rise Apartment: A building up to 4 storeys with many dwelling units stacked in a vertical and horizontal configuration.

Medium scale infill should be placed close to shopping centre sites to raise the level of proximity and adjacent to transit corridors, accordingly to TOD, but also on comprehensively planned large sites on the edge of neighbourhoods.

Finally, large scale infill includes [29]:

- Mid Rise Apartment: A building of 5 to 8 storeys with dwelling units stacked horizontally and vertically, sharing a ground level entrance. feasible on sites of 1 hectare or larger
- High Rise Apartment: A building of 9 storeys or more with dwelling units stacked vertically and horizontally, sharing a ground level entrance. feasible on sites of 3 hectares on the edges of mature neighbourhoods, and sites of 5 hectares within them.

Large scale infill areas should be adjacent to main transportation, such as LRT, BRT or metro, which means that major transport infrastructure should be built too, if not already existing. Large scale infill should also be developed together with a shopping area that should be included in the building, the purpose of which is to satisfy proximity requirements for new incoming residents.

This is an example of mix-use for buildings, which refers to the presence of a variety of functions – such as residential, retail, office, institutional and/or light industrial. Mix-use (*Figure 4.2*) allows for a compact development that means higher-density development making greater use of the same land area and is particularly when there is little amount of land at disposal for development. The mix-use approach can be applied not only when planning a large-scale infill, but also with smaller buildings based on the availability of land and the need of services of the neighbourhood: If only a particular amenity is missing in the neighbourhood, it may be placed within a low-rise apartment building.

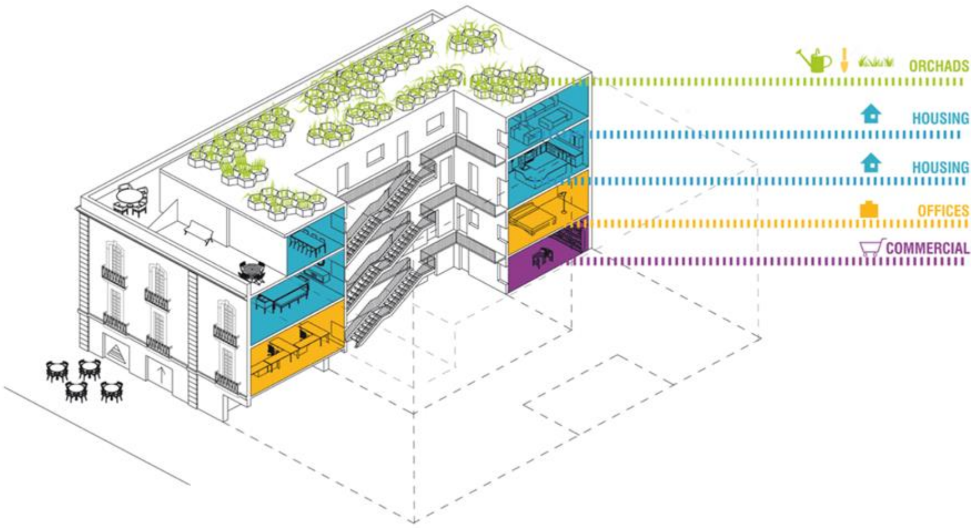


Figure 4.2 – Mix-use

Not only new buildings can be designed for mix-use, but also existing buildings can be turned into mixed-use buildings to host different purposes than they were originally designed for: adaptive reuse by private developers could be promoted for municipally owned properties, so that cities can optimise their assets' use, as well as adaptive reuse of vacant or underused buildings or areas will allow more productive use while preserving their character.

Mix-use does not take place in space only, but in time too, just like curb differentiation. For instance, municipally owned premises can be used for multiple purposes at different times of the day and week. For instance, school yards can be used as public parks, as it is planned in Paris, while libraries can host music or other cultural events out of hours. By the same token, private spaces can be put to much greater use. With ad hoc regulations restaurants may be able to open as co-working spaces during the day out of mealtime, nightclubs could open as daytime cafés, or shops and galleries as bars in the evening.

TOD cannot be applied everywhere across a transit network, as densities of jobs and residents vary widely. It usually targets areas that already have transit access.
Cities should commission analysis to determine which areas are good candidates for TOD, the level of density those areas can absorb, and the appropriate local development mix to strike the right balance between jobs, housing and other amenities. In the medium-long term, as density increases, investment in transit must keep up with increased demand. If not, new residents will drive instead of using public transport, impacting on parking, increasing local traffic congestion, and eliminating the emissions reduction potential of TOD.

4.2 Traditional Infrastructure

In order to achieve a 15-minutes city mobility that enhances walking and cycling, intervention on infrastructure must be undertaken, so to bring an improvement in the typical use of the street, but also a change in its cultural perception. Although the street remains the domain of mobility functions, it must also respond, especially within the residential space, to other functions, such as social interaction, meeting, commerce and, in areas of greater tranquility, it should also be able to accommodate children's play.

4.2.1 Traffic Moderation

The most basic feature of urban walkability and inclusivity is the existence of a complete, continuous, and safe walkway network including safe crossings that link origins and destinations together and to the local public transit station. The network must be accessible to everyone, including elderly and handicapped people, and well protected from motor vehicles. A variety of configurations and designs of paths and streets are appropriate to the safety and completeness objective. Protected walkways separate from roadways are needed when vehicular speeds exceed 15 km/h.

Walking can be easily discouraged by detours and is particularly sensitive to network density. A tight network of paths and streets that offers multiple routes to many destinations, frequent street corners, narrower rights of way, and slow vehicular speed make walking and cycling trips varied and enjoyable and invigorate street activity and local commerce. An urban fabric that is more permeable to pedestrians and cyclists than to cars also encourages the use of nonmotorized and transit modes with all the associated benefits [26].

Traffic moderation can provide that urban fabric required for higher walkability and cyclability levels, enhancing soft mobility as a way of moving inside the neighbourhood. Traffic moderation arises in response to road accidents. In urban areas, 80-90% of pedestrians and cyclists involved in accidents are injured, compared to 5-10% of motorists. A very high figure which, in addition to compromising the livability of cities, causes a social cost for the community, mainly caused by the excess speed of motor vehicles, which is the most determining factor in the severity of the accident [12].

By reducing speed, it is easier to avoid accidents involving weak road users (children, the elderly, cyclists), it is easier to communicate between motorist and pedestrian, to perceive each other's intentions, avoiding dangerous behavior, and motorists are more willing to stop and give way at a pedestrian crossing.

The change in driving style, dictated by traffic moderation, has shown beneficial effects both on traffic and the environment, in terms of reducing noise and pollution (with less braking and acceleration, fuel consumption is estimated to have decreased by 12%).

To obtain traffic moderation much can be done from the infrastructure point of view. The first step is to identify an area called Moderate Traffic Zone (MTZ) where only residents' vehicles and carriages for residents' services and emergencies can access the neighbourhood. Transit traffic, surface public transport network and main bicycle network will be constrained to the edge of the neighbourhood, similarly to the Barcelona's superblock model. An MTZ is in fact a circumscribed area, generally delimited by main roads, in which the residential function usually prevails. It is an area of the city equipped with the main services of the neighbourhood and interested by a circulation mainly of local radius. Within an MTZ the road is mainly conceived

as a space of relationship between a plurality of functions and users: pedestrians of different ages and abilities, cyclists moving at different speeds and in different ways, vehicles of different sizes.
Thus, the vehicles' speed is often limited to 30 km/h, making it a so-called zone 30. Zone 30 is a low-impact requalification that redesigns the area concerned, making it safer for the weaker categories of road users, particularly for pedestrians [30]. Experiences have widely shown the effectiveness of their realisation for a better traffic management and urban requalification. If there were Zones 30 in all neighborhoods, the duration of the motorist's average door-to-door journey would increase by only 3% at most. In Hamburg, the losses caused by crossing Zones 30 were measured: total displacement was only slightly higher. The time lost with speed limitations was regained with a smoother, more regular, less confrontational circulation [12].
In the case of residential roads, the maximum speed limit allowed may be established to 15 km/h for a greater containment of vehicular traffic. This measure is especially necessary for roads with the presence of city services such as schools, streets with high presence of commercial activities and streets with occupation of public land in the roadway [31].
In an MTZ, streets' cross section is all on the same level, which means there is no distinction between footpath and road and pedestrians have the priority. Eventually, some furniture can be used (*Figure 4.3*), but these furnishings must maintain their functionality over time, respecting the different areas of design. They must also ensure accessibility to all users, with particular attention to the most fragile categories [31].

Figure 4.3 – Traffic moderation features [32]

By being on the same level, pedestrians, as well as cyclists, will feel free to move anywhere, instead of feeling constrained to the curb, while drivers will perceive that entering an MTZ with a car is an exception and more attention and caution are required, reducing probability and severity of accidents. MTZ is a brilliant solution, since it exploits psychological impact on people, particularly drivers, creating an environment that is more suitable for social activities than motored vehicles circulation, but it is likely to be as useful, even with autonomous vehicles. In fact, the layout of many MTZs is designed in order to drive vehicles out of the zone, after they have entered it, and these paths could be easily followed by AVs. Also, AVs are more likely to respect speed limits. By respecting the speed limit and being equipped with technological sensors, AVs will allow to completely eliminate all physical barriers that were eventually installed in an MTZ, providing an even greater sense of freedom for pedestrians and cyclists and contributing to the creation of an even more social environment.

4.2.2 Road Diet

Outside the MTZ, the streets' cross section is different, allowing transit traffic of any mode to cross the neighbourhood and reach other parts of the city. Pedestrians and vehicles would be on different levels as it already happens today, with pedestrians on a higher level to be protected by vehicles. Most of the section is dedicated to vehicles themselves, meaning that this environment is not very suitable for pedestrians. Cyclists, instead, can be either put on the same level as pedestrians or on the same level as cars, and would require a dedicated bike lane for higher safety and better service. Likewise, public transport would require dedicated lanes to be more effective and attractive.

A solution to balancing the needs of all road users is the "road diet". The original thinking held that wider roads meant better traffic flows, especially at rush-hour, but new lanes attracted new traffic, leaving much wasted road space outside the peak periods. The concept of road diets, also called road reductions or road conversions, emerged as a response to the common practice of expanding two-lane urban arterials into four lanes once vehicular traffic hit a certain point—roughly 6,000 cars a day—which, at a deeper analysis, resulted in an increase in traffic volumes, but also in delays, speeding, crashes, and injury rates.

A typical road diet is the conversion of a four-lane road (two lanes in each direction) with no bike lanes into a five-lane road, with one auto lane in each direction, a centre turns median and two bike lanes (*Figure 4.4*).
Removing two automobile travel lanes seems to reduce automobile throughput. However, studies of road diets often show that the improved flow achieved with left turning vehicles using the centre median maintains or improves upon previous throughput numbers and reduces dramatically the number of conflict points, compelling a raised level of road's safety.
Also, implementing a road diet does not cost much. When timed with regular road maintenance and re-paving, road diet policies require little more than the paint needed to re-stripe lanes. Obviously, some major urban roads cannot slim down overnight without creating huge traffic problems. However, road diets have proved to be successful, for instance, in New York City of all places [33].

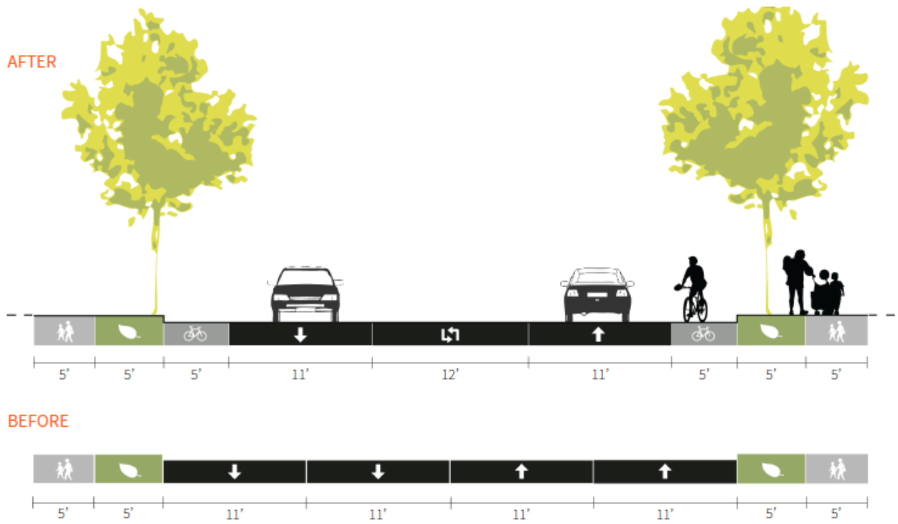


Figure 4.4 – Road diet [24]

Benefits of road diet involve cyclists and pedestrians too. Bicycle and pedestrian traffic tend to soar at these sites, as the recaptured road space gives way to bike lanes or street parking that provides a sidewalk buffer from moving traffic or crossing islands, and as vehicle speeds decline. A good example is represented by Honolulu, Hawaii, where the two-mile stretch of King Street, a principal corridor which had four lanes for one-way vehicle traffic, curb-side parking on both sides and no bicycle lanes, has been modified by converting one of the lanes into a two-way cycle track.

The main outcome was an 88 percent increase in average daily ridership from 384 to 745 cyclists and a decrease in the number of cyclists riding on the sidewalk. In fact, an average of 67 percent of cyclists rode on the sidewalk prior to construction, while only 4 percent did so after the conversion to a two-way cycle track [24].

4.2.3 Velopolitain

A safe cycling network connecting buildings and destinations by the shortest routes through developments and station catchment areas is a basic feature of TOD and traffic moderation, together with road diet, are a chance for its realisation. In fact, the first step for a widespread of cycling network consists in improving the existing infrastructure: when converting road lanes, new bike lanes can be created, and when this is not possible on major roads, MTZ can be exploited to identify cycle paths. This will give more people better access to jobs, services and opportunities, and encourage the use of pedestrian and cycling facilities. Freight delivery could also take advantage from this change.

Various types of cycle-safe configurations can be part of the network, depending on the size of the street and the context within the community (*Figure 4.5*).

Sharrows are symbols painted in the lane indicating that drivers and cyclists share the travel lane. This solution shall be applied when no space is available for realising a proper bike lane and where traffic volumes and speed limit are low. In fact, separated cycle paths are required when the vehicular speed is to exceed 30 km/h. Shared roadway markings are recommended when the allowed vehicular speed is between 15 and 30 km/h, while shared streets and plazas with allowed vehicular (including cycling) speeds under 15 km/h can remain unmarked.

Bike lanes typically range in size from 1,2 m to 2,4 m, and are lanes specifically dedicated to cyclists, though they may occasionally share space with cars for right turns at intersections. They usually exist on busier streets and demarcate bicycle space from motorized vehicle space with a line of paint.

A design that is meant to last longer in time is that of *Cycle tracks,* which are like bike lanes but are physically separated from the motorised traffic. The barrier further protects cyclists from cars and dooring (collisions between cyclists and the open doors of parked cars). Cycle tracks may be one way or two ways.

Buffered bike lanes are a hybrid design that widens the strip of paint between a bike lane and motorized vehicle lanes. This extra buffer, often 0,6-1 m, provides extra

space and comfort to a wider range of people on bikes. Like bike lanes, buffered lanes and cycle tracks are generally located on busier streets.
In the case of cycle logistic, instead, it is recommendable that streets offer a minimum of 2.25 m cycle lanes and, if cycle lanes are physically impossible, it is advisable to use a 30km/h speed limit on mixed use roads [24].

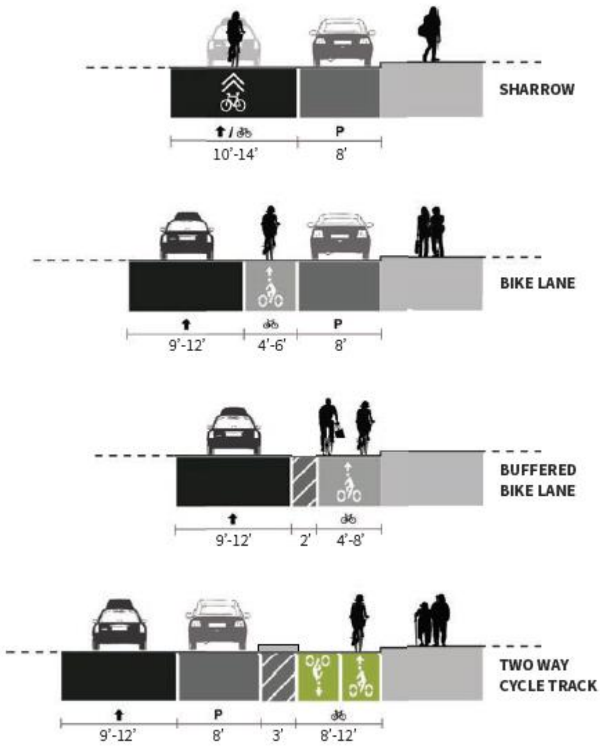


Figure 4.5 – Bike Lane building options [24]

The second step consists in thinking existing and new infrastructure in a wider context, such as lines connecting nodes, just like metro lines. This concept can be applied to bike lanes network too, as it is proven by the successful example of Pesaro, with the so called "Bicipolitana" (velopolitain). The velopolitain takes inspiration by an overground metro, where the rails are the cycle paths, and the carriages are the bicycles. The used scheme is that of metros around the world: coloured lines connect the different areas of the city, allowing a rapid, flexible, efficient movement without polluting emissions. This is an actual infrastructure of the urban and peri-urban mobility in all respects that reaches peaks of 60.000 passengers/day, a volume of users higher than that of the Brescia metro. The success of such concept is proved also by the fact that it is being exported not just to other Italian cities, such as Florence and Bologna, but also abroad, such as in Paris [2].

The same concept can be perceived with walking routes. A map of the city can suggest the routes between the main points of interest, indicating the walking and cycling distances and the minutes of travel, with a graphic that recalls the schemes of the metropolitan networks to facilitate readability. These maps are already common in city centres and show the points of cultural, historical and naturalistic interest, presented as "stops" on a pedestrian network, connected to various pedestrian "lines" identified with different colours, but could and should be used for other neighbourhoods or groups of neighbourhoods [2].

4.3 Shared Use Mobility

Changing how passengers use the transit system by moving trips away from peak hours or onto shared modes can bring to demand optimisation. If people move away from driving themselves to using rail, bus, or shared vehicles, existing infrastructure will be able to carry more passengers without increasing congestion or even reducing it.

In the last decade, new mobility services grew and developed around the concept of sharing. Shared mobility—the shared use of a vehicle, bicycle, or other low-speed travel mode—is an innovative transportation strategy that enables users to have short-term access to a mode of transportation. It encompasses the submarkets of carsharing, bike sharing, ridesharing, public transit services, on-demand ride services, scooter sharing, and alternative transit services, such as shuttles and micro transit. Shared mobility can also include commercial delivery vehicles providing flexible goods movement, known as courier network.

Shared mobility can also be leveraged by the public sector to address service gaps: the synergistic relationship between shared mobility systems and smartphone applications presents new opportunities to enhance understanding of shared mobility and to incorporate this insight into local transportation planning and operations activities. The individual mobility apps of service providers and mobility aggregators (apps that provide routing, booking, and payment functions) collect an array of data points that are useful to public agencies for both static planning and analysis and real-time network management and response.

Following are the definitions of some of the most common shared systems, with related impacts, and an explanation of how they are intended to be combined with communication technology.

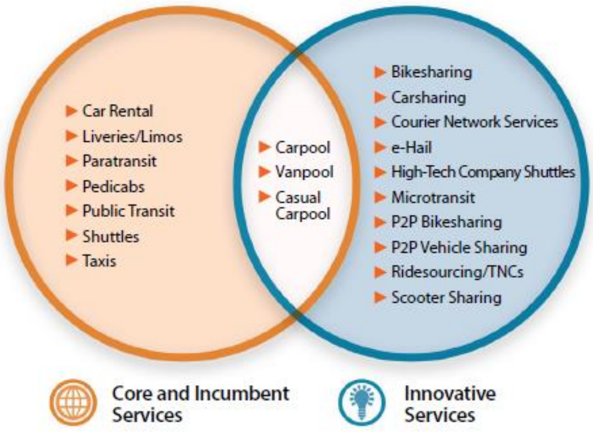


Figure 4.6 – Shared mobility categories [34]

4.3.1 Ride Sharing

Classic ride sharing is simply what was previously called carpooling: two or more travellers sharing common, pre-planned trips made by private automobile. In recent years, thanks to GPS and mobile technologies, ridesharing has evolved into a real-time or dynamic ridesharing that can match drivers with riders in real time without planning in advance [13]. This ride-matching process is conducted through mobile apps that connect drivers with passengers traveling similar routes, in real time, at predesignated pickup locations. Up to 2014, carpooling was the second most common travel mode to work in the United States behind driving alone and brought major benefits. A 2011 study of casual carpooling in the Bay Area estimated a total reduction up to 3 million litres of gasoline per year, the majority of this savings attributable to ridesharing's congestion reduction impact on the rest of traffic [34].

4.3.2 Car Sharing

In its most basic form, car sharing, as well as bike sharing, is a vehicle rental by the hour. Providers include commercial entities as well as private individuals who rent out their own vehicles through peer-to-peer car sharing programs. These services give consumers all the benefits of car ownership without its attendance costs, including purchase cost, insurance, maintenance, and parking. Nowadays, they are all supported by mobile apps [13].

It may be argued that carsharing service is not properly shared, since a driver can use the car by himself, however, the use of the same car is not exclusive to one driver only but can be accessed by anyone who is subscribed to the service, without the need for owning the car. The effects of car sharing, instead, are very less questionable. According to European studies, a carsharing vehicle reduces the need for 4 to 10 privately owned vehicles on average. Roundtrip and one-way carsharing also has a notable impact on modal shift. Studies have examined the impact of roundtrip and one-way carsharing on public transit and non-motorized travel. While they found a slight overall decline in public transit use, carsharing members exhibited an increase in use of alternative modes, such as walking and bike sharing, the latter in favour of private bicycle use.

Overall, car sharing reduced the private automobile use, thus leading to a reduction in the need of private automobile ownership, which may result in lower Vehicle-Kilometres-Travelled (VKT), reduced traffic congestion and parking demand, and an increase of other transport modes (such as biking and walking, as mentioned). Unsurprisingly, reduced vehicle ownership rates and VKT lead to lower greenhouse gas emissions levels. In Europe, car sharing is estimated to reduce the average user's carbon dioxide emissions by 40 to 50 percent, while in North American cities, it is estimated to reduce greenhouse gas emissions by 34 to 41 percent per household [34].

4.3.3 E-Hailing

E-Hailing, also known as ride sourcing, allows passengers to "hail" or "source" rides from a pool of drivers that use their personal vehicles via online platforms (mobile apps) developed by transportation network companies (e.g., Mytaxi, Uber) [13].

Despite E-Hailing being popular, its effects on vehicle trips, vehicle occupancy, VKT, greenhouse gas emissions, and other transportation modes have not been extensively studied and are not well known [34].

4.3.4 Bike Sharing

Cycling is a sustainable mode of transport, with proven benefits for individuals and society (e.g., health and fitness, green mobility, etc.), but it is still underutilized and supported compared to other modes. While it is still considered as an offline activity, there are several works that consider the potential of smart "velomobility" and recommend the use of IoT and ICT for including bicycles in urban transportation planning. With the use of cycling apps in smartphones, people can collect and share cycling data with other members of the app community as well as with the local authorities, that can use them for improving urban planning and highlighting routes of interest. Luckily, bike sharing moves in this direction. Customers access bicycles on an as-needed basis for one-way (point-to-point) or roundtrip travel. Station-based bike sharing kiosks are typically unattended and concentrated in urban settings, and offer one-way service (i.e., bicycles can be returned to any kiosk). Free-floating bike sharing offers users the ability to check out a bicycle and return it to any location within a predefined geographic region. The majority of bike sharing operators cover the costs of bicycle maintenance, storage, and parking.

Bike sharing can be integral in bridging first-and-last-mile gaps in the transportation network and encourage multimodal trips. Studies indicate that bike sharing can also enhance mobility, reduce congestion, and fuel use, lower emissions, and increase environmental awareness [34].

4.3.5 Mobility As A Service

SUM could be viewed as a door-opener for a more radical solution known as mobility-as-a-service (MAAS). Conventionally, transportation service providers tended to operate separately, and it could be difficult for a user to move across different modes (services). Each developed their own information systems to manage their operations and related activities, and these were not shared with other stakeholders. MAAS challenges this standard model with a new way of thinking at how the delivery and consumption of transport is managed: it replaces privately owned transport with personalised mobility packages that give access to multiple travel modes on an as-needed basis by exploiting the riches of modern information and communication technologies.

Today, digital mobility solutions make use of a Journey Planner, i.e., a search engine aimed to find optimal routes and ways of moving between one location and another. The process mainly involves decisions on the mode of transportation and potential routes to get to the destination. The choice of the mode of transport and routes could consider several factors. The most important factors are journey time, journey cost, number of interchanges, type of transport means; but other factors can be contemplated such as sustainability issues.

Today, Trip Planner, Travel Planner, and Route Planner are often used as a synonymous of Journey Planner, but they can be slightly distinguished:

- Route planners are typically thought of as using only one mode of private transportation (such as driving, walking, or cycling)
- Journey planners usually make use of at least one public transport mode which operates according to published schedules and usually provides connection information, distance, and travel cost
- Trip Planner and Travel Planner are often used as trip organizer, i.e. for tourist or visiting travellers, thus including transport, but also hotels and so on

Regardless of the distinction, the core component of a planner is the (shortest) path search algorithm. In the case of road planning, for instance, one can compute driving directions in milliseconds or less even at continental scale. The techniques for solving the vehicle routing problem includes basic approaches. Journey planning on public transport systems, even though conceptually similar, is a significantly harder problem due to its inherent time-dependent and multicriteria nature. The multimodal route planning problem, which seeks journeys combining schedule-based transportation (buses, trains) with unrestricted modes (walking, driving), is even harder, relying on approximate solutions even for metropolitan inputs. Solving such a general problem efficiently seems beyond the reach of current algorithms. The ultimate goal would be a worldwide multimodal journey planner that takes into account real-time traffic and transit information, historic patterns, schedule constraints, and monetary costs [13, 35].

Some applications of MAAS already exist in the world: Nugo has been developed in Italy by "Ferrovie dello Stato" but has been shut down at the time of this writing; Whim operates in Finland, while Ubigo operates in Sweden. Siemens, instead, is developing a standard app with a modular software, so that cities and public transport operators can successively integrate means of transport and functions for trip planning, booking, ticketing and payment. However, these examples are still an exception. Public transport and SUM providers as well the providers of digital interfaces and electronic applications are currently lacking the desire to cooperate with each other and share the available data. Also, the legislation in many countries does not act as a supporter of innovation and change when it comes to mobility and, so far, national, and local governments are not actively giving an emphasis on financially supporting MAAS pioneers.

4.4 Neighbourhood Logistic

In recent years, the face of urban commercial delivery has vastly changed. Parcel-delivery vehicles are double-parking and blocking lanes, e-grocers such as Walmart and Kroger, and food-delivery services such as DoorDash, Uber Eats and Postmates are increasing their online revenue by offering home deliveries in the downtown core via vans, bikes and scooters in increasingly shorter time windows. As a result, demand for last-mile delivery is soaring and is expected to grow by 78% globally by 2030.

A new era of online presence has begun, and consumers are fully embracing online sales. Globally, 82% of all consumers have shopped online within a three-month period. A total of 2.1 billion people is expected to buy goods online by 2021. The need for speed is significantly contributing to the overall increase in demand for last-mile deliveries. Deferred delivery – with a typical delivery time of one to three days – is, and will continue to be, the largest delivery segment. Same-day and instant delivery, however, are the fastest-growing segments in the last-mile environment, growing by 36% and 17% annually.

In the supply chain, the "last mile" is considered to be the most expensive, inefficient and pollution generating segment. This is due to the high incidence of failed deliveries due to "not at home" recipients, which results in extra costs, distance travelled and emissions. Consumer deliveries increase the incidence of "empty running": multi-drop loads almost by necessity result in an empty leg as they return to the depot. Finally, difficulty in executing a profitable, efficient routing plan due to low density is another cause for inefficiency of last mile delivery. For home deliveries in some regions, the level of consumer density may be poor, leading to increased transit time and additional costs [36].

Thus, a consolidation of the very last mile is more desirable than a consolidation of the second-to-last mile for logistics players, as the level of disruption would be manageable. The management of the last mile changes according to the business model, which in turn will directly influence the supply chain. The delivery method, as well as all the activities that precede or follow the delivery, must be adapted to the logic of Business to Business (B2B) and Business to Customer (B2C) [37]:

- Production chain (B2B): the last mile plays a crucial role as the supply of raw materials that are used to advance the production processes of the factories is carried out.
- Distribution chain (B2B): in this case, the products needed to supply the shelves of the stores are delivered in the last mile.
- Retail distribution chain (B2C): this is perhaps the case that presents more complexity as we are talking about delivery directly to the customer as a consequence of a purchase made online

If the new planning of an existing quarter (urban redevelopment) is carried out, logistics should also be integrated from the beginning. Logistics too can take advantage of a 15-minutes neighbourhood, by implementing cycle logistic, which can use the same bike lanes at disposal of residents. Cycle logistic is gaining more and more consent as a clean and quiet alternative to traditional ones for shorter trips in dense urban areas. Definite attention is required for a good and right future development so to be put in place to support a transition away from road freight trips by diesel vehicles, while ensuring freight demand is met.

Various types of trips can be undertaken by cargo bikes, from personal use to logistics and freight, and they are designed to respond to different needs that are included in the 15-minutes city layout, whether it is delivering a parcel to a client or supplying a shop. When it comes to parcel delivery, cargo bikes are particularly suitable for small, light consignments, which are currently on the increase, especially for deliveries to private customers of goods and services such as food and health care. Cargo bikes can efficiently make deliveries within a 2-3 km radius of a logistics facility, while electric assisted cargo bikes (e-cargo bikes) and trikes can extend the radius to 7-8km.

Within a city, different areas are suited for cycle logistics. Basic characteristics for a high suitability are:

- Inner city area, preferably with a strong residential component (core city, partly not city)
- High or highest stop density in delivery
- Poor conditions for conventional vehicles (e.g., areas for pedestrians, access restrictions, etc)
- Increased traffic problems (e.g., high proportion of second-row parking)

The introduction of cargo bikes is also linked to the objective of improving traffic flow by reducing the disruptive effect of second row stops. When stopping in the second row, vans are strongly dependent on the width of the road, while cargo bikes allow for better overtaking in the lane on wide roads and have the potential of stopping on sidewalks or in cargo bike stopping zones without influencing traffic flow (*Figure 4.7*), contributing to emissions and congestion reduction (*Figure 4.8*) [38].
A Cross River Partnership study for the Central London Sub-Regional Partnership estimates that for every light goods vehicle replaced in central London (assuming an average 80km per day), 6 tonnes of CO_2 and at least 14.1kg of NO_x and 21g of PM_{10} could be saved every year. Another study by the University of Toronto shows that a cargo bike replacing a van could save up to 1.9 tonnes of CO_2 per year [3].

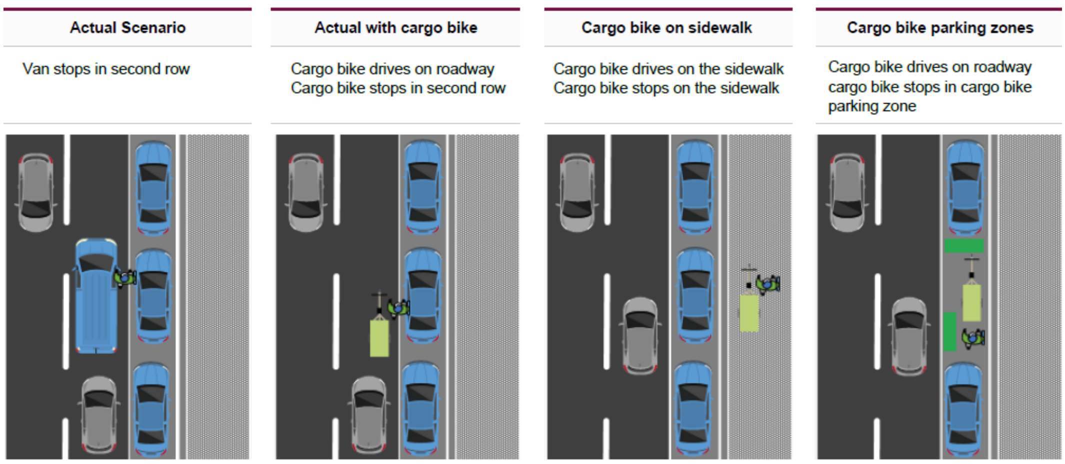


Figure 4.7 – Variation of CEP delivery with cargo bike [38]

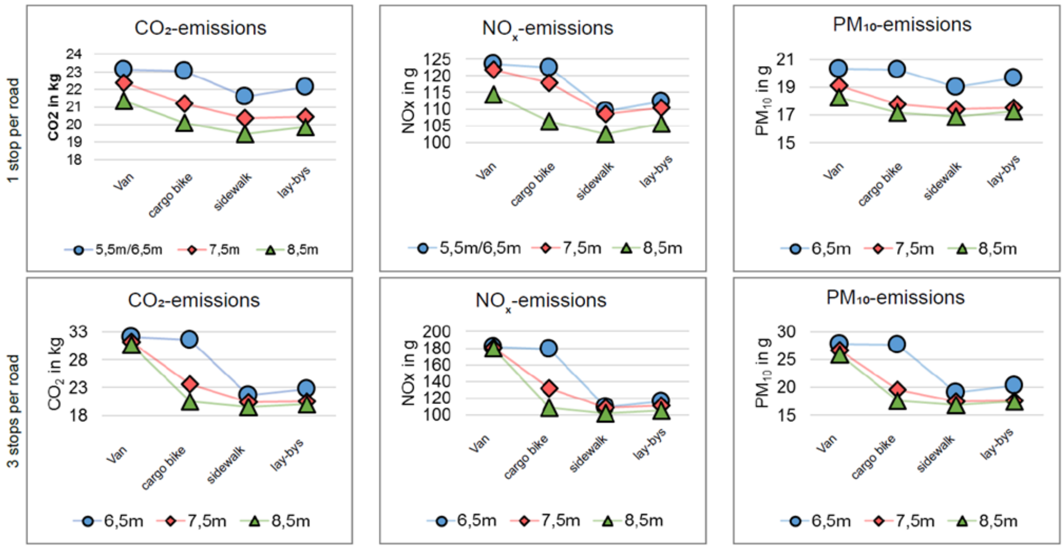


Figure 4.8 - Air pollutant emissions from delivery by vans and cargo bikes [38]

Nonetheless cities need to be aware of the needs of last-mile logistics operations. Proper infrastructure is needed, and bike lanes are only one element of it. Local logistic hubs can allow freight to be dropped off in consolidated loads in less time.

However, inner-city space is expensive for operators, most of whom have low profit margins. This makes it difficult for local hubs to be set up centrally to serve zero-emission last-mile solutions, although cities might assist by identifying underused spaces within the urban or neighbourhood core, such as underground parking and loading bays or disused buildings and ensuring access to designated parking and charging infrastructure for e-cargo bikes [3].

In such a scenario, cycle logistic hubs become very useful and respondents to the needs of last-mile delivery. A cycle logistic hub is a centre typically located in a dense urban area that houses one or multiple courier services. In these hubs, parcels are sorted and redirected on cargo bikes throughout the city. As opposed to conventional delivery structures, cycle logistics hubs offer a model that alleviates traffic congestion by effectively replacing motorized vehicles. Deliveries suitable for cycle logistics hubs are often small and time-critical shipments, a delivery type that is quickly growing in dense residential neighbourhoods.

Supply of these hubs could take place at night or during off-peak hours. Goods transport accounts for almost 20 percent of congestion. By allowing night deliveries, for example, cities can take stop-and-go commercial vehicles off the streets during

the day. The concept has been piloted in cities, reducing travel times for all users by as much as five minutes.
Electrification intervention could produce great interactions with night deliveries, as noise emissions of EVs are minimal. Overall, such a scenario could reduce CO_2 emissions by 35%, unit costs by 15% and congestion by 25%.

Taking a look further in the future, technology is a significant enabler for ever-shortening delivery times, allowing for more efficient supply-chain processes and the launch of alternative delivery methods such as drones and droids. Increased autonomous penetration together with connectivity solutions as well as IoT and big data players will help optimizing routes and reach a new level of delivery thanks to new means for transporting parcels such as drones or Autonomous Vans, which could possibly make cycle logistic hubs and cargo bikes obsolete.

4.5 Smart Infrastructure

If traditional infrastructure enhances walking and cycling and SUM optimises demand, smart infrastructure, namely Electrification and Automation, can optimise supply, helping cities to reach a higher level of sustainability. Cities can enhance supply the traditional way, by building more roads and related infrastructures, but they can also do so by using their existing assets more intensively. Mobility electrification will bring to a better exploitation of the electricity infrastructure, to the elimination of local pollution and will benefit congestion, since fuel supply vehicles will not be needed anymore, and cars will not have to reach a gas station for recharge. Automation, instead, will bring to a better use of the road infrastructure, allowing vehicles to safely drive closer together and enhancing shared services, with great benefits for congestion.

4.5.1 Electrification

One of the most important challenges in mobility, to which the 15-minutes project aims to contribute, is to improve transportation sustainability, which refers to finding ways to decrease environmental harm and improve public health that do not otherwise affect the supply or demand for transit. Electrification is not just one of the tools used to face the challenge, but the most widespread, recognised and technologically advanced.

The future of vehicles is in fact forecast to be electrified. According to Politecnico di Milano, there will be 1,5 million electric vehicles in Italy by 2025. Globally, governmental and societal pressures could bring around 40% of light vehicles production toward electrified vehicles by 2030, with that percentage increasing to 95%+ by 2050. For instance, on December 17th, 2018, representatives of the European Commission, the European Parliament, and the European Council agreed on a compromise for the European Union (EU) regulation setting binding carbon dioxide (CO_2) emission targets for new passenger cars and light-commercial vehicles for 2025 and 2030. The agreed-upon targets aim to reduce the average CO_2 emissions from new cars by 15% in 2025 and by 37.5% in 2030, both relative to a 2021 baseline. For light-commercial vehicles, a 15% target for 2025 and a 31% target for 2030 were agreed upon. Concerning heavy duty vehicles, from 2025 onward, manufacturers will have to meet a 15% emission reduction for the fleet-wide average CO_2 emissions of their new lorries registered in a given calendar year and a 30% reduction from 2030 on [38, 39, 40].

Achievement of the 2025 targets can be reached with the application of existing or shortly coming technologies such as electric, plug-in hybrid, and gasoline-electric hybrid cars that are becoming mainstream. Both mild hybrids and plug-in hybrid models will see growth over the coming years, as both consumer demand and emissions targets are sought to be met. Some vehicle segments (especially larger models) could see gasoline mild hybrids becoming the default base-model option, as diesel is gradually displaced from the market. Plug-in models offer consumers an excellent blend of the flexibility and range of a combustion-engine model alongside sufficient EV range for many daily driving tasks. They are likely to remain a popular choice for many consumers for as long as recharging a battery electric vehicle will take longer and bigger efforts than to fill a combustion-engine vehicle with gasoline, although their main drawback is cost, since they require two drivetrains. As battery technologies improve, allowing lower-cost and longer-range BEVs, PHEV consumers who have regular and easy access to recharging infrastructure are expected to start moving across to BEV models [42].

For the achievement of 2030 targets a higher degree of electrification is needed (*Figure 4.9*), comprising technological and a major infrastructural improvement. One of the biggest advantages of electric vehicles in the short-term is that they can be easily integrated into the current energy system, using the existing infrastructure, but, at growing stock, additional facilities such as charging points and power line reinforcements will be needed.

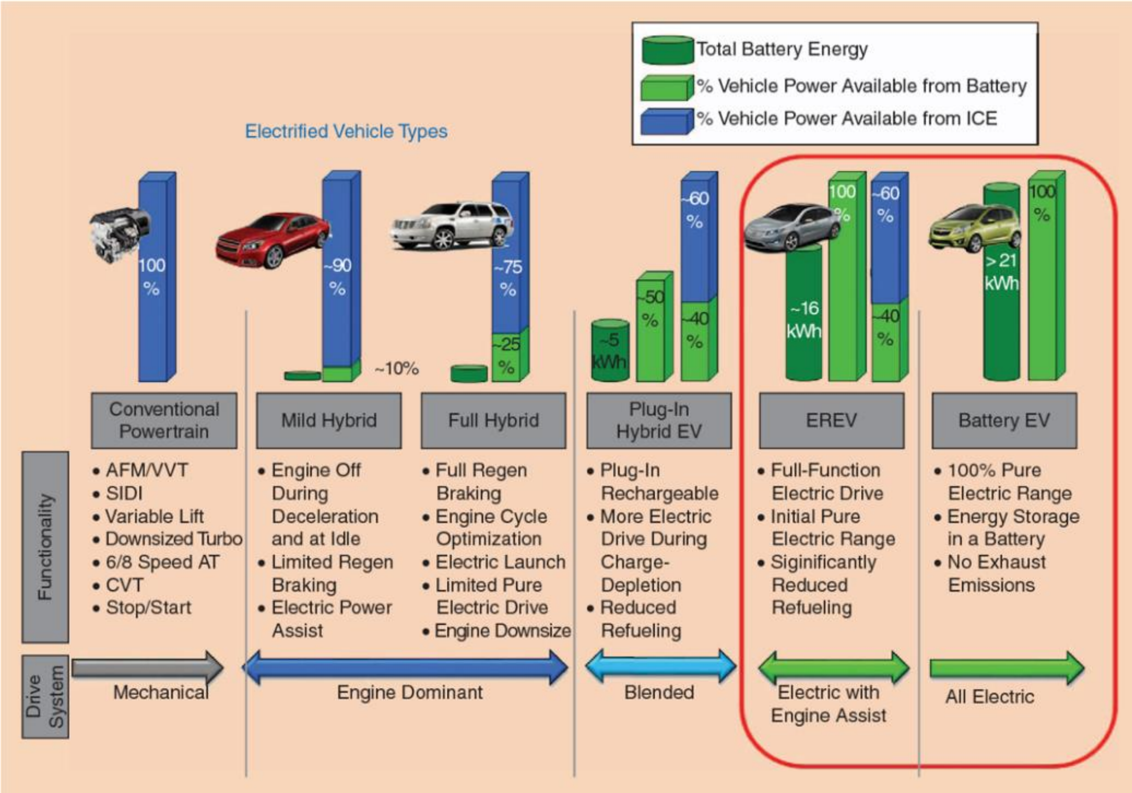


Figure 4.9 – Hybridisation degrees

Regarding charging technology, the International Electro Technical Commission defines 4 modes of conductive charging: (1) slow charging from a regular electrical socket; (2) slow charging from a regular socket but which equipped with some EV specific protection arrangement; (3): slow or fast charging using a specific EV multi-pin socket with control and protection functions; (4): fast charging using some special charger technology (CHAdeMO).

EV chargers can also be distinguished between unidirectional (V1G) or bidirectional (V2G) chargers. Unidirectional charger allows to activate a charging process or to switch off an ongoing charging only, while bidirectional charger allows to activate a charging process or to switch off an ongoing charging and to provide energy back to the grid. Bidirectional chargers can make an important contribution to the stability and efficiency of the electricity system, allowing for a concept called Vehicle-to-Grid, which is the integration of electric vehicles into the electrical power grid to form a

virtual power storage station. This concept is key if we consider that another way to decrease environmental harm of transit is to progressively move from electricity sources that emit carbon dioxide to sources that do not. In fact, in a grid with a high proportion of renewable energy sources but fluctuating energy production, the load can be stabilised by the storage, feeding and charging of electricity from electric vehicles. For instance, it is possible to use surplus power from renewable energy systems to substitute peak- loads, instead of providing electricity that is normally produced by non-renewable power plants.
Concerning the 15-minutes project, charging facilities are a necessary service to be placed in the neighbourhood to allow green mobility across the city, since not all movements will be human powered. Charging columns should be placed in particular in correspondence of parking lots, particularly for shared cars. In fact, enhancement of electrification of shared fleets and public vehicles, which are used more intensively, would encourage a shift toward sustainable mobility. Amsterdam, for example, has made special citywide parking permits available for electric-car-sharing fleets. Charging facilities should also be placed at docks for e-bike sharing, as it is already happening in many cities around the world, but also at staging areas for drop on/off for people and goods.

4.5.2 Automation

AVs can bring to a better, more efficient, and effective use of existing roads, although some improvements are required, following the 5 stages of automation (*Figure 4.10*) [43]:

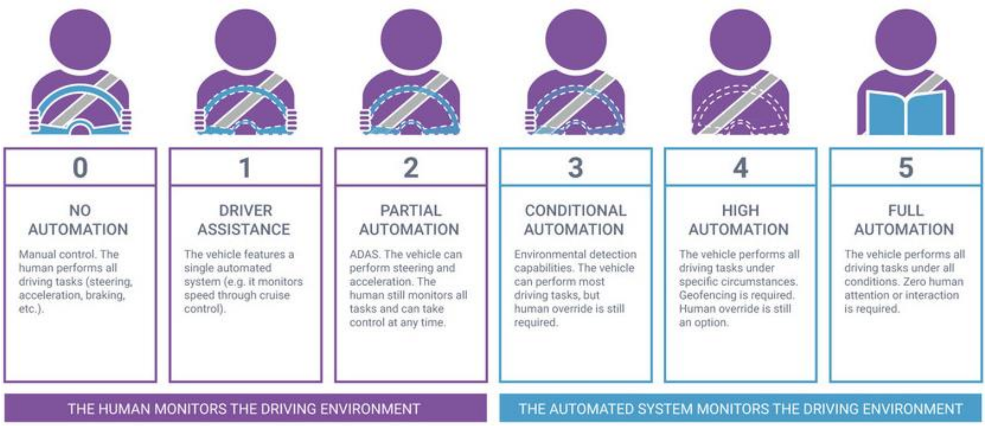


Figure 4.10 – Levels of driving automation

- **Level 0: No Automation.** The driver is completely responsible for controlling the vehicle, performing tasks like steering, braking, accelerating, or braking. Level 0 vehicles can have safety features such as backup cameras, blind spot warnings and collision warnings. Even automatic emergency braking, which applies aggressive braking in the event of an imminent collision, is classified as Level 0 because it does not act over a sustained period.
- **Level 1**: **Driver Assistance.** At this level, the automated systems start to take control of the vehicle in specific situations, but do not fully take over. An example of Level 1 automation is adaptive cruise control, which controls acceleration and braking, typically in highway driving. Depending on the functionality, drivers are able to take their feet off the pedals.
- **Level 2: Partial Automation.** At this level, the vehicle can perform more complex functions that pair steering (lateral control) with acceleration and braking (longitudinal control), thanks to a greater awareness of its surroundings.
- **Level 3: Conditional Automation.** At Level 3, drivers can disengage from the act of driving, but only in specific situations. Conditions could be limited to certain vehicle speeds, road types and weather conditions. But because drivers can apply their focus to some other task, this is generally considered the initial entry point into autonomous driving. Nevertheless, the driver is expected to take over when the system requests it. For example, features such as traffic jam pilot mean that drivers can sit back and relax while the system handles it all — acceleration, steering and braking. In stop-and-go traffic, the vehicle sends an alert to the driver to regain control when the vehicle gets through the traffic jam and vehicle speed increases. The vehicle must also monitor the driver's state to ensure that the driver resumes control and be able to come to a safe stop if the driver does not.
- **Level 4: High Automation.** At this level, the vehicle's autonomous driving system is fully capable of monitoring the driving environment and

handling all driving functions for routine routes and conditions defined within its operational design domain (ODD). The vehicle may alert the driver that it is reaching its operational limits if there is, say, an environmental condition that requires a human in control, such as heavy snow. If the driver does not respond, it will secure the vehicle automatically.

- **Level 5: Full Automation.** Level 5-capable vehicles are fully autonomous. No driver is required behind the wheel at all. In fact, Level 5 vehicles might not even have a steering wheel or gas/brake pedals. Level 5 vehicles could have "smart cabins" so that passengers can issue voice commands to choose a destination or set cabin conditions such as temperature or choice of media.

"Many current vehicles have Level 2 and 3 technologies such as cruise control, hazard warning and automated parallel parking. Sensors become the eyes and ears of the driver and embedded computing platforms become the brain and nervous system, and the effort remains on making this technology reliable, fault-tolerant, and stable at any condition. The Automatic Emergency Braking (AEB) of Tesla Model S, for instance, uses a radar/camera fusion module, which has been designed to prevent accidents by early predicting front-to-rear collisions. The Advanced Driver Assistance System (ADAS) automates the steering, braking, and throttle and comprises a Traffic-Aware Cruise Control (TACC) system and an autosteer. If the lane is clean the TACC keeps the driver defined speed, whereas in case of a leading vehicle, the TACC controls the throttle pedal to keep a safe distance from it. The autosteer system uses information from the forward camera, the radar and ultrasonic sensors, detects lane markings, other vehicles, and objects and provides automated lane-centring steering control" [5]. Sensor fusion is a key component of Level 5 autonomous vehicles, which, under optimistic conditions, might be reached by 2030, although experts acknowledge that Level 5 automation will require many more years for development and testing, especially if the technology proves to be unreliable and dangerous, causing high-profile crashes.

Not only are vehicles forecast to be autonomous in the future but also connected, in order to achieve cooperative driving. Cooperative driving means gathering information and sharing it with other drivers, adapting to the surrounding traffic and environment conditions, interacting with other traffic participants in a solution-oriented way, and obeying traffic rules and regulations.

Cooperative Vehicles must be connected to other vehicles and to service centres as well as to infrastructure information systems. Therefore, communication is the most crucial component of Cooperative Driving. Connected Vehicles have a big advantage compared with isolated vehicles. Connected vehicles have non-sensible information from far ahead and from the driver's intentions and communicate them enabling negotiation and coordination of actions.

The Connected Vehicle serves as a Remote Sensor and Remote Actuator, though remote information is not a substitute for on-board sensors and can be used to complement other sensors either for calibration or for redundancy.

The Connected Vehicle as a remote sensor makes vehicle generated data about driver's intentions, vehicle status and motion and about the environment available for other vehicles and service centres. Safety relevant information should be communicated as fast as possible to other vehicles. Traffic and weather-related information will be collected as "Floating Car Data" in service centres and serve as content for the service business.

Based on the available information, the connected vehicle works as a remote actuator where recommendations are carried out by the driver, when he is in the loop or by the vehicle controller. This enables warning and information systems and improves advanced assistance systems [44].

Main communication technology available for the purpose is wireless technology. Wi-Fi and cellular are the two most popular wireless technologies that make IoT networks possible. Although Wi-Fi has been the dominant choice for IoT for years, cellular has recently grown in popularity and is now a highly viable alternative, because these devices use cellular technology connected to the Internet, using the same networks as smartphones and other mobile devices. Wi-Fi does have one disadvantage: the more devices trying to access the network, the more the Wi-Fi signal will degrade. This means that Wi-Fi performs noticeably worse in high-population areas as devices compete for bandwidth. Cellular networks typically do not face this issue, thanks to the technology's underlying protocols and hardware. Also, Wi-Fi has a larger range than cellular, but it is also more easily obstructed by obstacles. As a local area network (LAN), Wi-Fi can provide strong coverage in a limited area close to an access point. Once the device leaves that area, however, connectivity will decline rapidly. In other words, Wi-Fi is not the best choice if the device will be highly mobile, such as a vehicle, or deployed in a remote location. Both Wi-Fi and cellular can provide accurate location information by measuring your distance from the nearest router or cell tower, respectively. In some instances, cellular networks may be able to pin down your location when you are out of range of Wi-Fi. In addition, the impending 5G upgrade is expected to offer further improvements to cellular bandwidth [45].

The second key element of Cooperative Driving is the Located Vehicle. The Connected Vehicle needs to know its position relative to infrastructure and relative to other vehicles. When vehicles have precise lane information and location of other vehicles and obstacles and can thus execute manoeuvres on a very high level of confidence.

Global Navigation Satellite System (GNSS) and Cooperative Vehicle Localisation (CVL) are used for positioning. In a GNSS satellites transmit signals to equipment on the ground. GNSS receivers passively receive satellite signals; they do not transmit. They calculate their positioning by a process known as triangulation. To achieve this, GNSS receivers require an unobstructed view, normally of at least three satellites. The system, therefore, only works outdoors and will not work in tunnels, and often does not perform well within forested areas or near tall buildings (commonly called the urban canyon effect, as the buildings mask direct line of sight to the satellites).

CVL, instead, uses floating car data for positioning. In fact, whenever a vehicle is not able to access any GNSS measurement, the accurate absolute position of the neighbour vehicles can be received via vehicle-to-vehicle communication. Assisted with distance sensors and local inertial sensors, the local absolute position can be determined.

Thus, by implementing the dedicated technology and infrastructure, AVs could help integrating a TOD in those areas where requirements are not met, and lead to a more efficient and sustainable last-mile network in many regions worldwide [46].

Two highly possible products of automation which will take a significant number of privately-owned vehicles off the road that may be seen are unmanned buses and shared driverless taxis. Cheaper taxi services can provide convenient mobility for non-drivers, either door-to-door or as a feeder to bus stops and train stations. Such a service should be particularly effective in suburban and rural areas where conventional transit is inefficient, but also in a 15-minutes neighbourhood. In fact, the aim of a 15-minutes city should be to eliminate unnecessary and unwanted trips, so autonomous vehicles could be placed in such a neighbourhood for short range trips, particularly for those with disabilities, limited mobility capabilities (injured, baby trolleys, ...) or for people carrying weights, or for last mile trips in the place of walking and using a bike or a scooter. However, until most households shift from owning vehicles to relying on shared mobility services, and until a greater share of households live in compact and multi-modal neighbourhoods, autonomous taxis will affect only a small portion of total travel and provide modest community benefits [26].

5. Roadmap

As more people take advantage of new services and public transport, city planners can use urban design not only to accommodate these modes of transfer but also to make transit systems more efficient and to put land and infrastructure-investment capital to better use.
If chapter 4. explained where to act, chapter 5. aims at explaining how to act, by finding a standard set of guidelines to be followed and adapted to different realities to implement a new transportation system in a 15-minutes city.
The steps focus on enhancing walking and cycling and increasing the efficiency of collective transportation against private alternatives, by overcoming the spatial bias for which most road space is dedicated to cars and connecting all collective transport both in space and time, so to increase land and population coverage and reduce waiting times and total travel time.
These steps were identified by combining literature review, strategies of cities that are already implementing the 15-minutes project and a case study that is used to approve the guidelines as if they were a model, by applying the previously analysed fields and the 15-minutes model in the city of Monza with QGIS.

5.1 Short Term

According to TOD, the Gravity Centre should be positioned in correspondence of a main station or an LPT stop. So, it is advisable to use main regional transit stations as a gravity centre because population and services are often concentrated around these stations, although this is not always the case. So, whenever placing a new gravity centre, population density and the presence of basic services in the neighbourhood should be evaluated following the schemes shown in *Figure 5.1* and *Figure 5.2*.

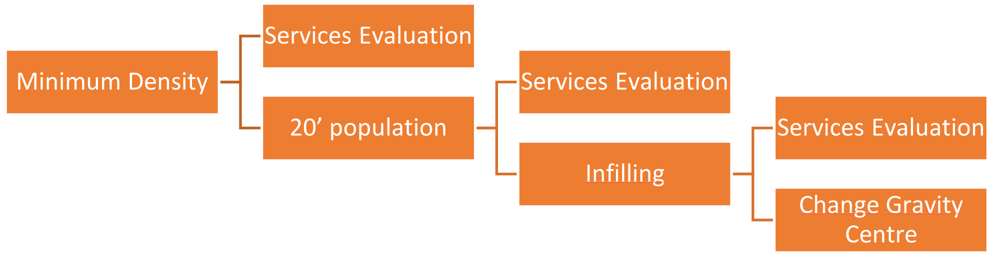


Figure 5.1 – Population density evaluation

Population density in the shed should be at least 5.200 residents/km^2, as it was explained in chapter 1. . If average density is not satisfied, an amplification to a 20-minutes neighbourhood, as it happens in Melbourne, shall be considered, where population should not be less than 23.000 residents. If population constraint is not satisfied once more, infilling projects should be considered to raise the number of residents in a longer term. Finally, if infilling projects do not allow to reach the minimum population required, another displacement for the gravity centre shall be found. Whenever one of the constraints is satisfied, instead, services presence should be evaluated.

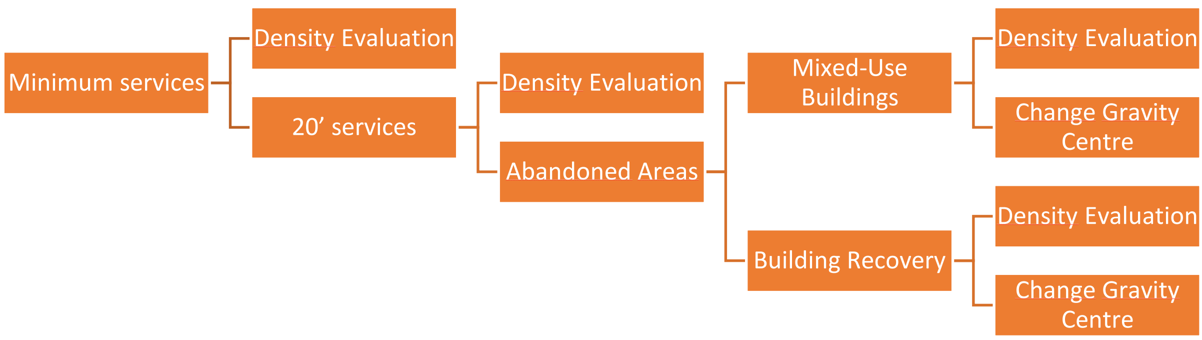


Figure 5.2 – Services density evaluation

All minimum services should be available in the neighbourhood and the logic to their evaluation could be very similar to that of population evaluation. If some services are missing in the shed, the amplification to a 20-minutes neighbourhood should be applied. If services are still lacking, abandoned areas can be recovered, if available, otherwise mixed-use buildings shall be implemented.

If the recovery of abandoned buildings or the redesign of buildings for mix-use do not allow to have all the necessary services within the neighbourhood, then the gravity centre shall be replaced. Whenever the services' constraint is satisfied, the population constraint must be evaluated.

Both the population and services requirements must be satisfied for the gravity centre to be approved. In the example of Monza, a 20-minutes isochrone was needed around the station to satisfy both the constraints (*Figure 5.3*).

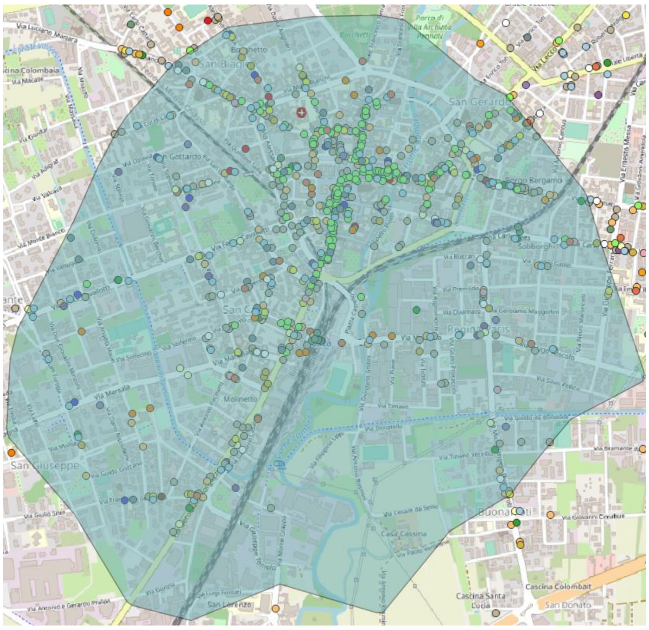


Figure 5.3 – Services in 20 minutes from Monza's station

Obviously, a few neighbourhoods centred on regional transit stations are not enough to cover the whole territory of a city, so new gravity centres must be found, and eventually positioned correspondingly to metro stations. The case of Monza is peculiar, because there is no metro line, but a new one will be built in the next decade, together with a new regional transit station, so these stops could be used to plan neighbourhoods in advance with respect to infrastructure completion. However, metro stations are too close to one another to place a gravity centre on each one of them, as for most metros in the world, so a different solution must be found.

In order to have accessible public transport, main bus stops too were considered as gravity centres, leading to the result shown in *Figure 5.4*.

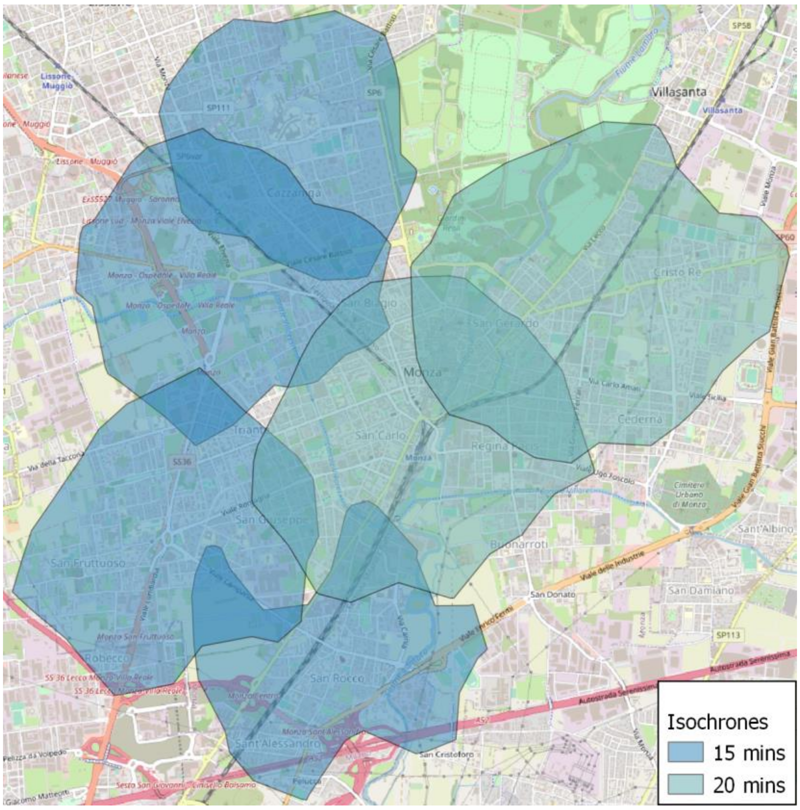


Figure 5.4 – Short-term neighbourhoods' configuration in Monza

When dealing with reality, the displacement of gravity centres may not be ideal. In fact, not all cities around the world have well planned metros or LRT and BRT services or even have these services at all, although population density would justify them. Also, services distribution is often not ideal either. In some places they may be concentrated in shopping centres located far away from most residences, thus requiring the use of cars to be reached.

It is important, though, that in the short-term most of the city territory is assigned to at least one neighbourhood. If neighbourhoods' territories overlap, it shall not be a problem. In fact, it is better for a portion of territory to be assigned to two neighbourhoods and have a higher level of accessibility to services, than to be assigned to no neighbourhood and have a lower level of accessibility to services.

Whenever it is not possible to have a station or an LPT stop as a gravity centre, in the short-term, the gravity centre might be placed in correspondence of some other point of attraction, such as a shopping centre, a school centre or an institutional centre that might be surrounded by several services. Anyway, access to main transportation lines shall be granted, as it is considered one of the necessary services.

Once the neighbourhoods have been identified, it is possible to proceed to traffic moderation. The first step to be taken in the short-term is to divide each neighbourhood in permanent Limited Traffic Zones (LTZ). They are areas in which access is limited to vehicles owned by residents, emergency vehicles, vehicles with special permissions, and where speed is limited to 30 km/h, so to discourage transit of the zone, enhance other activities and other forms of mobility inside zone and increase overall safety.
The LTZ can be delimited by special gates for the recognition of vehicles authorized to enter. These gates can be made up of bars that can be opened with special passes or with electronic permits or by cameras placed at the entrance; in the latter case, the cameras placed at each entrance to the limited traffic areas record the number on the plates of entering vehicles and transmit any transgressions by unauthorized vehicles at the entrance to the competent command of the local police.

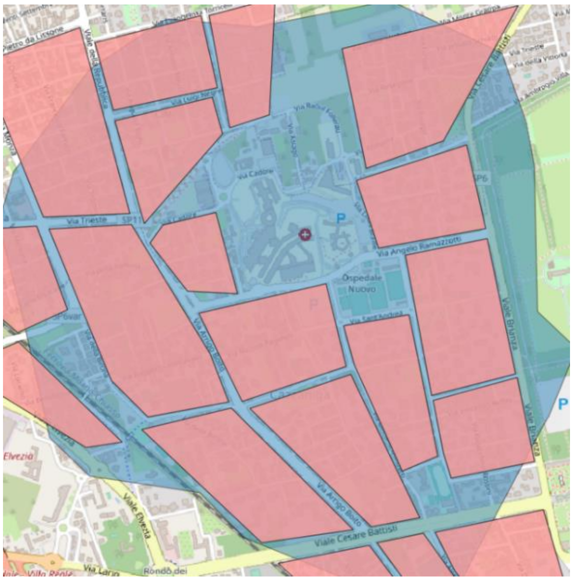


Figure 5.5 – LTZs identification in Neighbourhood

Such a division can be achieved according to streets typology, using main streets as a perimeter (*Figure 5.5*). In fact, urban streets can be distinguished in urban flowing roads, urban neighbourhood streets and urban local streets. The task might be easy when dealing with residential areas: the streets in the LTZ must respond mainly to a residential function, not a transit one, and main streets can be distinguished with little effort. In central business districts, instead, the task might be harder, but it may be resolved, by looking at the traffic volumes to understand what streets are the most important. However, it is advised that LTZs dimensions resemble those of a 5-minutes shed whenever possible, which means people take 5 minutes from centre to edge at an average walking speed. In fact, realising walkable islands is certainly positive for pedestrians, but at the same time smaller blocks improve walkability [10]. Since LTZs are meant to become a whole block in the future, an equilibrium could be found in the 5-minutes size.

Once the LTZs have been identified, another important limitation shall be undertaken. Parking on the curb inside the LTZ should be eliminated to discourage car-ownership, and particularly multiple car-ownership. In many cities realities residents own garages they can keep using to park their car. In those realities where garages are not available, parking on the curb may not be eliminated completely, but limited to the essential (e.g., one car park for each apartment).

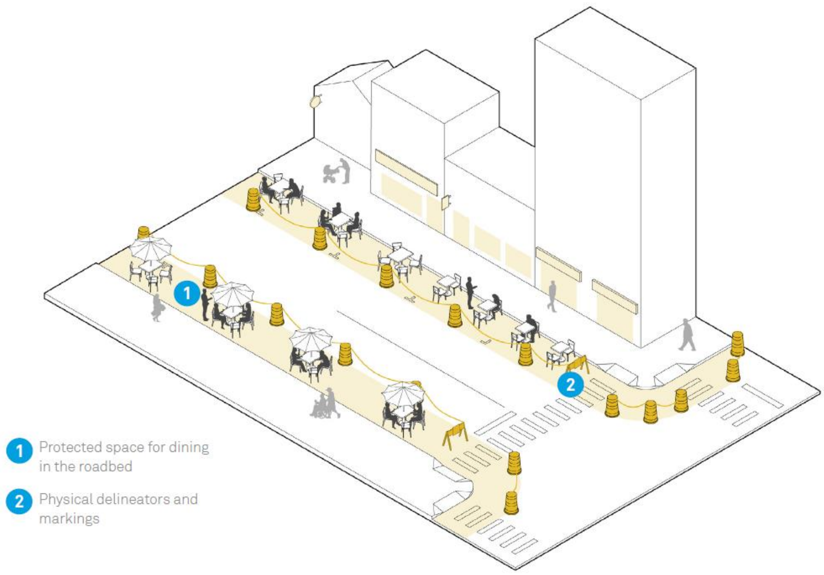


Figure 5.6 – Curb differentiation [47]

Not only will eliminating parking lots discourage the use of cars, but it will pave the way to new opportunities for the use of curb side (*Figure 5.6*). Examples of this are already a reality during the recovery from the pandemic: many restaurants were

recognised street space in the place of parking spots, in order to compensate the reduced number of tables on the inside, due to distancing restrictions. The curb may not be used for dining only, but also to identify pickup sites for taxis or neighbourhood shuttles, which will be implemented as a part of the new transportation scheme, and drop off zones for delivery. These staging areas could be fitted with charging facilities for electric vehicles, to allow recharging during the await, since they are considered as a basic need in the mobility field, as previously disputed. In fact, a delivery that is not suitable for cargo bikes could be served by an electric van that can be recharged during unloading operations, as well as a taxi could take the chance for a fast charge while luggage is loaded.
The curb may also be used in the short-term to realise bike lanes or as sidewalk extension to raise the level of walkability inside the LTZ. During the pandemic, many pop-up bike lanes appeared in many cities in the world, to encourage bike mobility as an alternative to public transport, due to distancing restrictions. This solution is very suitable for a short-term implementation, since they are very easy to be put in place, and particularly for LTZs, because speed limit for cars is set to 30 km/h, thus a miscellaneous use should be avoided.
Differentiation of the curb may not take place just in space, but in time too. For example, during lunch time, the curb could provide parking space for food trucks and, at night, a site for freight delivery. Altogether, differentiation of the curb can help providing new services and, thus, more proximity.

The use of cars may be discouraged, but it should be compensated by the use of other modes. In fact, the realisation of LTZs may encourage walking and cycling inside the zone, since smaller traffic volumes, lower speed limits and eventual extended sidewalks or bike lanes increase the level of walkability and cyclability.
However, different modes than car must be encouraged for longer haul trips than those taken inside the LTZ. In the short-term it could be possible to apply a form of road diet on the streets outside of the LTZs, by turning car lanes into LPT reserved lanes and bike lanes. As already discussed, rearrangement of lanes can be quick and cheap, if re-paving takes place, since only stripes painting is required. This particularly applies to bike lanes because less space is needed compared to bus lanes. Since these streets are dedicated to transit traffic, speed limit is above 30 km/h, so separated cycle tracks should be put in place.

In some cases, particularly in European cities, the available space for this kind of redesign may not be enough. A circulation rearrangement could then be considered, realising one-way streets hosting a car lane and bus lane or a bike lane, in place of a street hosting two car lanes, one for each direction. This model is very common in grid-planned cities such as New York or Barcelona (*Figure 5.7*), where it will be applied even more so with superblock implementation, and allows to eliminate left-turn conflict points, guaranteeing a safer and smoother traffic circulation.

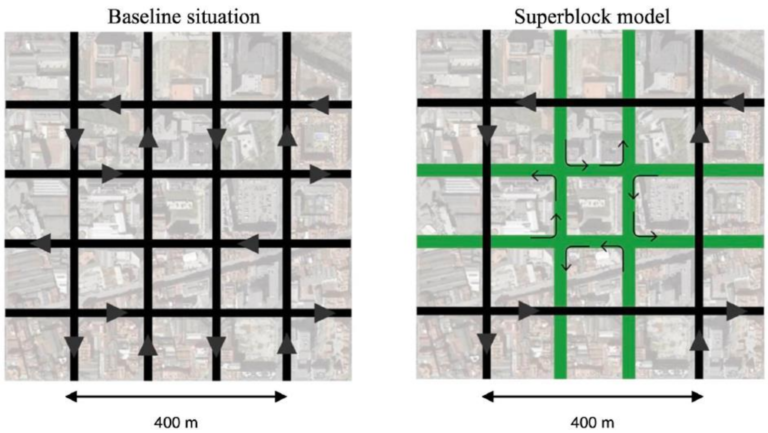


Figure 5.7 – Superblock traffic circulation [22]

Also, in Barcelona's planning, bus stops are placed at each corner of a superblock. Likewise, LTZs could be ideally provided with bus stops on their perimeter. Such a solution is not always practicable, because not all cities are grid-planned and are able to provide a bus line for each street, as Monza itself proved, so it may be considered to place a car sharing staging area where it is not possible to have an LPT stop.

Cycling, instead, could become an even more viable alternative to cars for short and medium haul city trips, if bike sharing service was developed. To make this service competitive, bike sharing docks would have to be very accessible and in great number. Bike sharing could also serve as a last mile mean of transportation increasing LPT and car sharing accessibility. Thus, bike sharing docks would have to be placed at each bus stop and car sharing dock to make these options more accessible and attractive. Bike sharing docks should also be places inside the LTZs in a way that maximises overall bike sharing accessibility, by using dedicated algorithms such as "betweenness" algorithm (*Figure 5.8*).

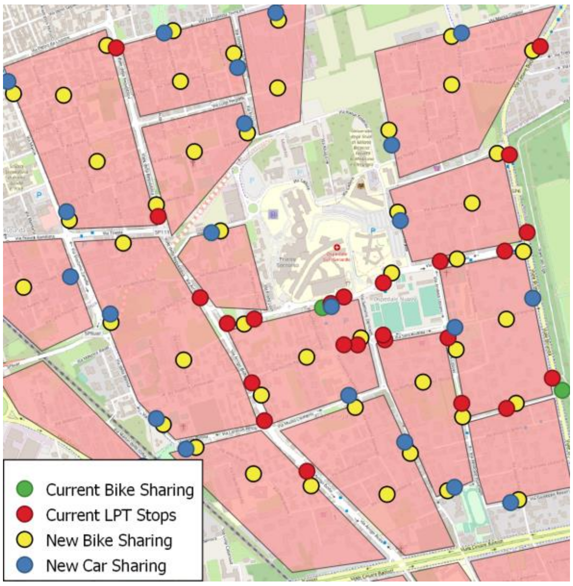


Figure 5.8 – Sharing docks and LPT stops

Obviously, since not everybody has the same capabilities and not all cities are plane, depending on the distances and the geomorphology, other means than bikes, such as e-scooters and e-bikes, can be shared.
Finally, shuttles for short distances might be implemented on specific routes connecting to specific services such as supermarkets or hospitals, particularly for those with motoric disabilities or seniors who cannot carry heavy weights, but also schools, for children, as it happens already in many countries in the world.

Regarding the implementation of a neighbourhood logistic, cycle logistic hubs can be installed in the short-term, allowing both residents and shops to be supplied with cargo bikes, and placed at the edge of the LTZs so to be easily accessed and supplied by vans (*Figure 5.9*). As discussed, vans should be electric to abate both air and noise pollution, allowing night deliveries. So, the hubs should be fitted with charging facilities for the vans to allow recharge while downloading freight. Cycle logistic hub types vary, and each type should be considered when searching for an area and determining a hub's needs. Hub types can be divided into two rough categories: semi-stationary hubs, and stationary hubs. Semi-stationary hubs include swap bodies and trailers and can be used for pilot projects. Stationary hubs can be further divided into container hubs, property hubs and parking compartments. The latter case might become more common in the longer term, when car ownership and usage will have decreased and underground (or overground) parking will need to be repurposed.

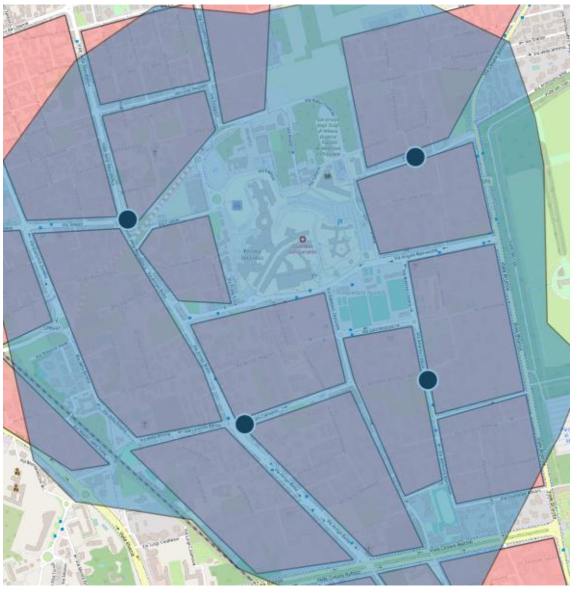


Figure 5.9 – Cycle logistic hubs in neighbourhood

One key determining factor when choosing a hub type is understanding how many CEP (courier, express, parcel) services the hub will house. So, depending on the number of CEP services and the type of hub, between two and five cargo bikes are used at each individual location. Stationary solutions should be preferred, especially for long-term use, although there are possibilities to carefully integrate semi-stationary solutions into the cityscape, if no suitable areas are available.

Regardless of the type of hub, immediate proximity to the delivery area is crucial, which means no more than 1.2 km away from transhipment hub or that the delivery radius around a transhipment hub does not exceed 500 m. The shorter the distance between the hub and the focus area of the stops, the more efficient and economical a cargo bike concept is. If larger urban areas (> approx. 1km^2) are to be planned, several transhipment hubs are advisable. Considering an average walking speed of 4 km/h on a flat territory, the radius of a 15-minutes neighbourhood is exactly 1 km, which corresponds to a circular area of 3,14 km^2. From a distance point of view, this means that 4 hubs should be ideally placed in a 15-minutes neighbourhood, and around 10 hubs in a 20-minutes neighbourhood.

Neighbourhood logistics could be completed with parcel lockers or boxes to be placed at each block of flats or house, just like mailboxes, where riders can drop parcels, eliminating failed deliveries due to "not at home" recipients. This intervention could also include a multi-brand approach, in which consumers can pick up and return parcels from different players. Consumers would have more control over when they pick up their shopping, rather than having to wait for deliveries or risk parcels being left in the wrong place, while retailers would have a more seamless, easy delivery.

In a short period of time that could be quantified in five years or less, much improvement can be achieved in a town with strategic interventions that are recalled in *Table 5.1*. These interventions do not require big investments, invasive constructions or futuristic technology, but mainly repurposing of existing revenues and a change in the perception of existing revenues. Despite the little effort, a big difference can be made, not only in improving air quality, decreasing chaos due to traffic and increase overall liveability, but also in changing people's mentality, opening it to a new approach to transit that includes more walking and cycling, and a more sustainable use of mechanically powered vehicles.

Table 5.1 – Short-Term Roadmap

TRANSIT ORIENTED DEVELOPMENT	**TRADITIONAL INFRASTRUCTURE**	**SHARED USE MOBILITY**	**NEIGHBOURHOOD LOGISTIC**	**SMART INFRASTRUCTURE**
Neighbourhood Gravity Centre	Limited Traffic Zones LTZs Curb Side Differentiation Car Lanes into Bus & Bike Lanes	Bike Sharing Car Sharing Neighbourhood Shuttle	Cycle Logistic Hubs Parcel Lockers & Boxes	Charging Columns

5.2 Medium Term

When identifying the neighbourhoods, it is possible that some population and services requirements are not respected.
If population density is not high enough for a 15-minutes density or overall population is not enough for a 20-minutes neighbourhood, infilling projects should be considered for the development of the neighbourhood and could be completed in the medium-term.

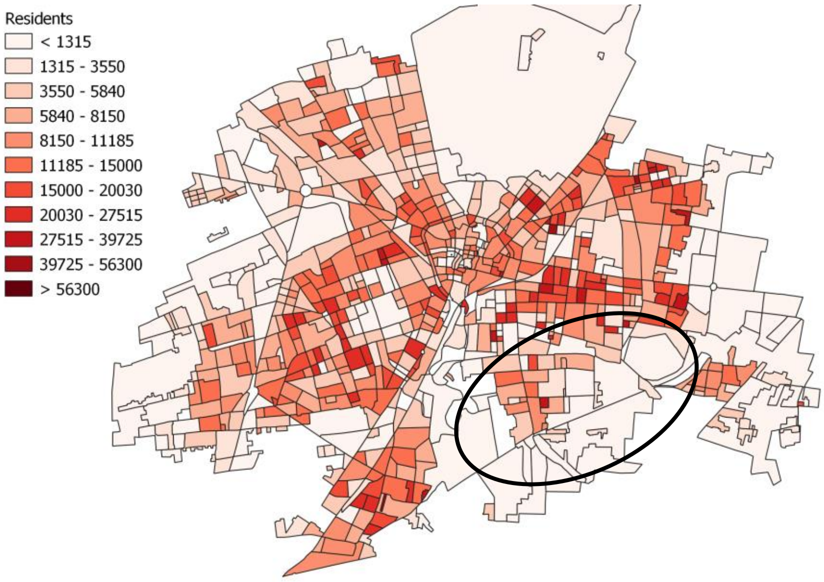


Figure 5.10 – Monza's census zones densities

Such a development is particularly suitable for land that is being repurposed, as it often happens with former industrial areas, or for newly developing areas. As an example, in the former arrangement of the neighbourhoods of Monza, a part of the city, highlighted in *Figure 5.10*, has been excluded, because average population density was not high enough and some services were lacking. However, the figure shows how parts of the same area are quite populated, while others are almost not populated at all. In the same area a large amount of land is abandoned and waiting to be repurposed, namely an old prison, an old slaughterhouse and other former industrial sites. This is the case in which a large-scale infill could benefit the area in the medium-term and the city as a whole, bringing to a new 15-minutes neighbourhood's arrangement that should guarantee that most of the city territory is covered, population have a minimum accessibility level to basic services and private vehicle movement is avoided as much as possible (*Figure 5.11*).

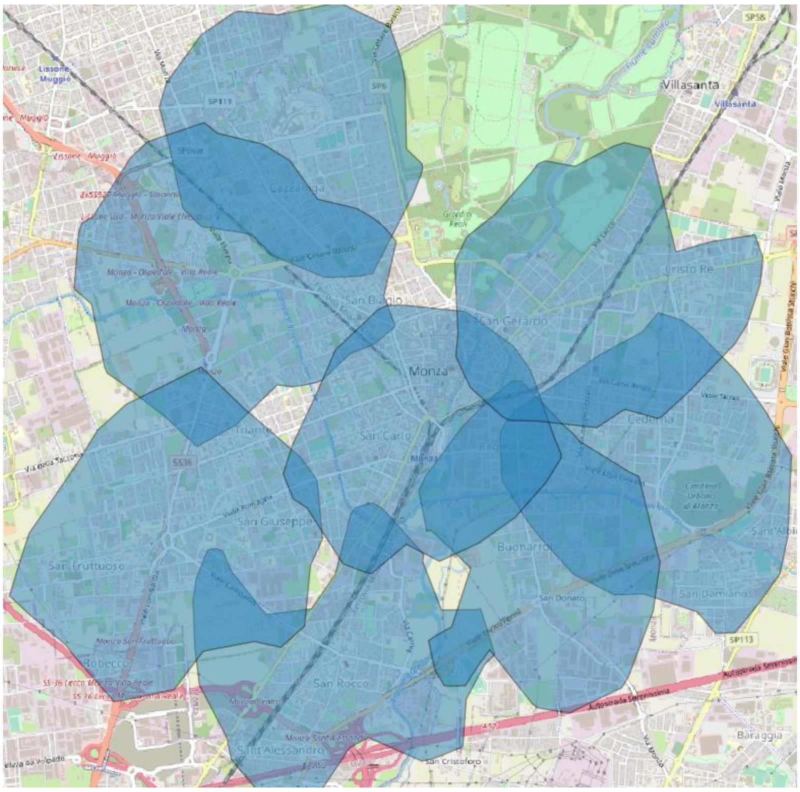


Figure 5.11 – Medium-term neighbourhoods' configuration in Monza

Once a new configuration is achieved, new LTZs can be implemented in the new neighbourhoods. Meanwhile, in those neighbourhoods where LTZs had already been implemented a further development toward traffic moderation can be achieved in the medium-term. In fact, to achieve a proper traffic moderation, repaving and changes in the appearance of the infrastructure are needed.

Repaving means replacing asphalt with stone or recovery blocks and bring road level to sidewalk level. This means there will be a hump at the entrance of the MTZ which will force vehicles to slow down. In fact, the speed limit will change from 30 km/h to 15 km/h [31]. This measure is especially necessary for the streets with the presence of city services such as schools, with high presence of commercial activities, with occupations of public land on the roadway or where there is interaction among a plurality of users. The latter is certainly the case of an MTZ, where shared use by pedestrians, cyclists and vehicles is encouraged.

While repaving it is possible to widen the sidewalks, which are usually tight, separating them from the road with furniture elements that guarantee a good level of protection for pedestrians when a vehicle is passing, but allowing them to easily occupy the street when there is no vehicle at the same time.

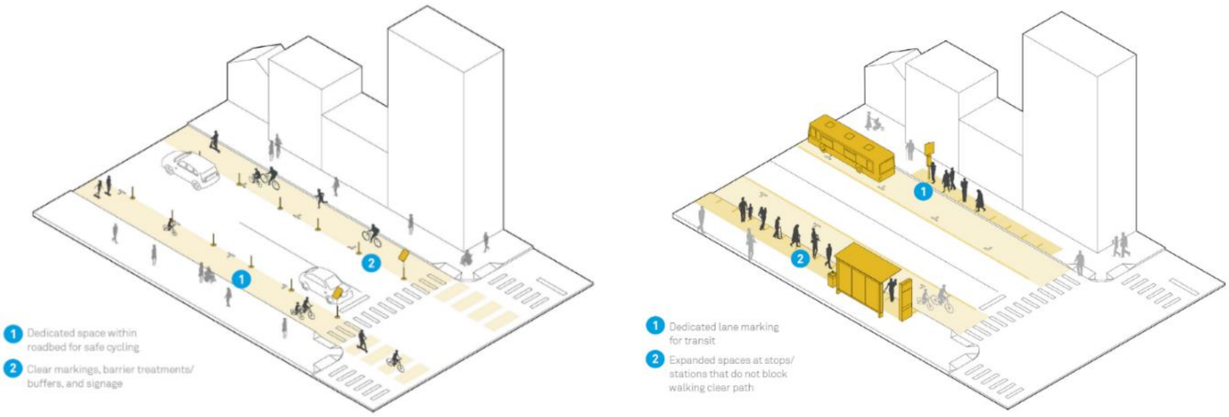
(a) *(b)*

Figure 5.12 – Via Carlo Alberto in Monza now (b) and then (a)

These implementations are typical of historical city centres (*Figure 5.12*) but should be brought in the other neighbourhoods of the city too. The installation of such infrastructure is usually combined with a vehicular circulation, mostly made of one-way streets, that force vehicles to exit the zone on the same side they entered it, thus preventing them from crossing it. This circulation is certainly ideal, but it cannot be always duplicated. In fact, as it happens with Monza, some have a streets' arrangement that resembles a cross and does not allow to create loops (*Figure 5.13*). Thus, to prevent vehicles from crossing the zone, the special gates that were installed for LTZs for the recognition of authorized vehicles must be kept in place.

Figure 5.13 – MTZ's real streets

Regarding streets outside the MTZs, many were expected to be still car dependent in the short-term, so car lanes were turned into LPT reserved lanes and bike lanes,to people take the habit of walking short distances to reach destination or using last-mile mobility to complete their trips, term. If the goal has been well achieved, public administrations could consider discouraging car ownership in the medium-term, by eliminating curb parking in favour of bicycles and buses (trolleybuses, trams, …) to make public transport and bicycles even more competitive for city trips (*Figure 5.14*).



(a) *(b)*

Figure 5.14 – Curb parking conversion [47]

Planning of car lanes and curb parking conversion into bike lanes would obviously be made in advance. Such a planning could include the realisation of a velopolitain, with well distinguished routes for bikes that connect nodes inside the city, that would be likely to be achieved in the medium-term, when a sufficiently extended network of bike lanes has been built, following to the above-mentioned conversions.

A velopolitain network will certainly increase the level of cyclability in the city, since it will be easier for users to orientate and find the way to their destinations and is a very viable alternative for city trips to collective transport for those cities that are flat, not very well served by public transport and are aiming at reducing the overall number of cars on the streets.

Such could be the case of Monza where the new metro line that will connect it to Milan will only serve the western side of the city and where some areas are not directly connected with bus lines. The current bike lanes network includes mainly two cycleway tracks (highlighted in black) and a route that could be considered as the first line of velopolitain, which connects the north-west area to the eastern area of town, running along a canal. Two more lines could be added with little building and much converting, integrating the existing bike lanes. The green line could connect the southern part of town with the north-eastern part, allowing a more direct connection than that of the existing bus line, which takes more than an hour to connect the same areas. The blue line, instead, would allow to connect the north-eastern area, where some important schools and institutions are placed, to the north-western area, where the hospital is located. This line could be very useful, since there is no bus line linking these areas and, in the future, it will allow to connect the north-eastern area not only to the hospital, but also to the metro line (*Figure 5.15*).

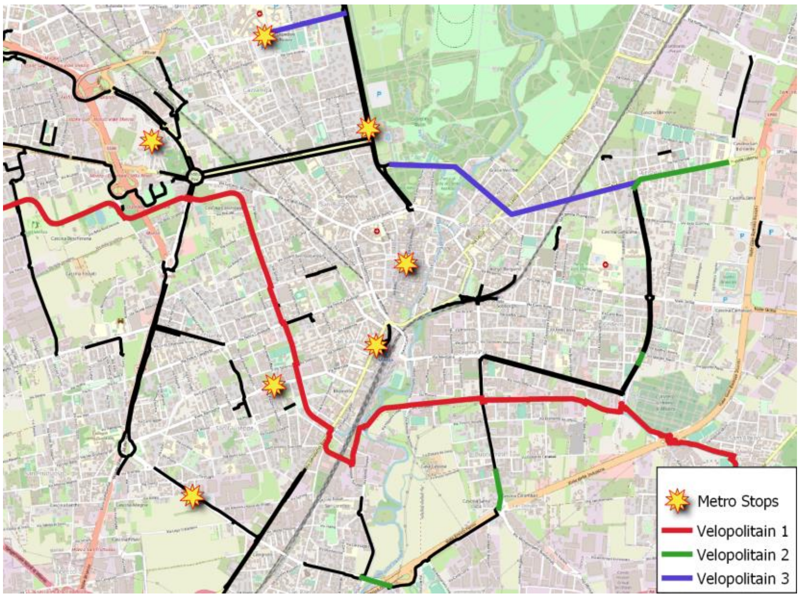


Figure 5.15 – Possible velopolitain configuration in Monza

The use of solutions such as public transport and car sharing for city cross trips and bike sharing for cross neighbourhood and last-mile trips needs to be enhanced by the application of the MAAS concept, which would make the use of these solutions even easier for customers, particularly for what concerns the payment and the interchange, but also for what concerns navigation.

Today transportation service providers tend to operate separately. Currently in Monza the bike sharing service has its own app and so do e-scooters. Two different companies provide bus service, although ticketing has been recently integrated with that of rail service, which is provided by yet another company. Tickets can be purchased on the railway service provider app, which also informs customers of train schedule, but it does not inform them about buses' schedules nor routes. A multimodal route planning app that allows to purchase tickets combining schedule-based transportation (buses, trains) with bike and e-scooter sharing and providing navigation is not supported yet by current algorithms, but significant steps are being taken in this direction and their evidence will be seen in the medium-term thanks to technological advancement. Meanwhile, companies must jointly agree on the methods of payment and the subdivision of the revenues.

In this process car sharing may not still be involved in this step since many companies providing such service operate at a national and not regional level. However, if the same companies providing bus and train services implemented car sharing services, this should be included in the app.

The end-user would then be required to join the platform to access available services. Not only would the subscription facilitate the use of the services, but it will also enable service personalisation, which ensures requirements and expectations are met more effectively and efficiently by considering the uniqueness of each customer.

Customisation, instead, enables end-users to modify the offered service option according to their preferences. This can increase MAAS' attractiveness and customers' satisfaction and loyalty. Obviously, all of this would not be possible without a combination of different technologies such as e-ticketing and e-payment system; electronic devices (e.g., computers and smartphones); a reliable mobile internet network (WiFi, 5G); GNSS; and integrated infrastructure of technologies (i.e. IoT). Such combination of technologies will require time, especially to become very reliable, which is yet another reason to expect MAAS to become a reality in the medium-term, although some attempts have already been made.

These same technologies are also fundamental to enable the connectivity that will guarantee a safer and better mobility. Forecasts state that although Level 2 vehicles will account for most vehicles on the road, the market share of Level 3-4 vehicles could no longer be ignored in the medium-term.

The recent progress on the hardware has been very significant. The cost of LIDAR, for example, has dropped by a factor of ten over the last five years. Similarly, the amount of computational capacity that the GPUs (Graphic Processing units) can provide has gone up dramatically.

Nonetheless, two challenges remain. The first one is object detection and categorization, which is the ability of a car, for example, to recognize a pedestrian and whether the pedestrian is pushing a stroller, carrying an umbrella or a plant, or when a pedestrian doesn't look like a pedestrian, etc. The second challenge is decision making. When there is human driving, there are a lot of subtle signals that drivers send to each other—right of way, etc.—that AVs cannot understand.

In a mix-level operation existing road infrastructure will have to be maintained to ensure the safe operation of more conventional vehicles, while digital communication facilities will have to be built for vehicles with partial automation functions [48].

An example of communication facilities that could be installed to guarantee mix-level operations are smart traffic lights. Smart traffic lights are a vehicle traffic control system that combines traditional traffic lights with an array of sensors and artificial intelligence to intelligently route vehicles and pedestrian traffic. The signals communicate with each other and adapt to changing traffic conditions to reduce the amount of time cars spend idling. The signals can also be set up to sense the approach of buses or trams and change the signals in their favour, thus improving the speed and efficiency of sustainable transport modes.

Using fibre optic video receivers like those already employed in dynamic control systems, the new technology monitors vehicle numbers and makes changes in real time to avoid congestion wherever possible. Smart traffic lights have already been successfully installed in San Jose and Houston, where commuting time was reduced by 15 minutes.

Level 3 and 4 vehicles will be able to integrate smart traffic lights with communication protocols which allow AVs to communicate with the infrastructure and with one another so they can drive closer and more safely together on the same roads. Such tools are currently being implemented, namely Signal Phase And Timing (SPAT) and Map topology (MAP) periodic messages for signalized intersections. Particularly, SPAT allows a vehicle to have dynamic information, status of traffic controller, prediction of duration and phases at a traffic light intersection. MAP, instead, allows a vehicle to have static information, topological definition of lanes within an intersection, topological definition of lanes for a road segment and types of lanes (allowed manoeuvres).

Regarding protocols for communication among vehicles, instead, there are Cooperative Awareness Messages (CAM) for periodic awareness information and Decentralized Environmental Notification Messages (DENM) for situation-based information triggered by an event (e.g., an accident or if an emergency vehicle is in action) [49].
Assurance that roads have clear signage and are in good repair, but also adoption of communication tools and protocols will allow to achieve exchange of status data (position, speed, events, …), enabling vehicles to disseminate their status information and allowing other vehicles to become aware of their presence and of eventual hazards detected on the road, and exchange of sensors data (objects, field-of-view, …), allowing road users to provide additional information gained through on-board sensors. Drivers will be able to cooperate because they will know everything going on around them, even things they cannot sense themselves, and can condition themselves to react more quickly and in a better way.

The implementation of such technologies and communication protocols will also favour logistics and particularly robot delivery. Technology is already existing. A simulation of delivery with robots was undertaken in Hamburg 2016, while the Japanese government has introduced the use of delivery robots on roads in 2021. The evaluation of the experiments showed that the use of parcel robots for time window delivery does not affect the driven distance and total CO_2 consumption in a significant way, although from a customer's point of view, the selection of individual time windows with notification of the exact time of delivery improves the service level and is very convenient. Also, no further infrastructure than that for cycle logistic is needed, since they could be deployed by the same hubs and use the sidewalks for circulation, although there are concerns about the use of sidewalks themsleves, since it would mean that robots will drive with walking speed (~ 4 km/h).
However, there are technological and political challenges that refrain from the adoption of delivery robots. From the technological point of view, the issue mainly regards the limited driving range, which stands between 6 and 10 km with a single charge. From the political point of view, according to media reports, although policy issues such as the standardization of vehicles and operating rules to prevent harms like additional congestion resulting from the low speed of the vehicles need to be worked out.

Finally, private companies and the authorities must jointly agree on the rules for safe and efficient operations on paths shared by pedestrians. To do so, they need to build more detailed mapping databases and legislation to unify rules for unmanned operations. For this reason, robot delivery is not foreseen to be achieved very soon [45, 48].

Major construction and technological interventions can be started and completed in the medium-term (*Table 5.2*), which could be numbered in ten to fifteen years. Construction interventions include building new houses or facilities, but also street repaving aimed at its repurposing. Street repaving itself may not require such a long time, but the number of streets to be repaved would. Instead, technological interventions include actual infrastructure at support of Level 3-4 vehicles, but also new algorithms for MAAS, and protocols for which also political involvement is necessary. These interventions combined together aim at bringing the short-term achievements at a higher level, so bringing more people to walk and cycle more, by completing new 15-minutes neighbourhood and enhancing walkability and cyclability of existing ones. Medium-term interventions also aim at tackling car ownership with MAAS, car park conversion and velopolitain realisation, by providing easier access to better collective transport.

Table 5.2 – Medium-Term Roadmap

TRANSIT ORIENTED DEVELOPMENT	**TRADITIONAL INFRASTRUCTURE**	**SHARED USE MOBILITY**	**NEIGHBOURHOOD LOGISTIC**	**SMART INFRASTRUCTURE**
Infilling Mixed-Use Buildings Reuse of vacant buildings and areas	Moderate Traffic Zones Car Park into Bus & Bike Lanes Velopolitain	Mobility As A Service	Robot Delivery	Cooperative Driving

5.3 Long Term

In the long-term, it is foreseen there will be a technological adaptation of what has been developed and implemented in the short and medium-term.

By 2045 as much as half of new vehicle sales and 40% of vehicle travel could be autonomous, according to Todd Litman [51]. These vehicles will be able to exchange intention data, enabling cooperative driving phase among vehicles, which will share their intentions and synchronize their drive for higher traffic efficiency, better fuel economy, and collision avoidance. They will also be able to exchange coordination data, enabling the synchronized driving phase, in which vehicles are autonomously driven through almost all situations (levels 4 and 5) and can synchronize driving trajectories, achieving optimal driving patterns.

Studies expect CAVs to increase both traffic throughput and transport. The effective capacity of existing roadways is expected to increase because CAVs will have the ability to follow more closely, smooth out traffic flows, coordinate traffic flows through intersections, and minimize accidents that can cause non-recurring congestion. CAVs may also accommodate geometric modifications to add lanes.

On the other hand, AVs are very likely to increase the propensity to travel, because of future cost reduction, on-demand door-to-door convenience, and more reliable travel time from smoother traffic flow and fewer incidents. For the same reasons, CAVs adoption will also influence a mode shift toward cars and car ownership, contrasting with the purpose of the 15-minutes project, although a shift from private car ownership toward the use of Shared AVs (SAVs) will result in fewer vehicles moving more people [52]. Thus, spreading a culture of sharing vehicles before the advent of CAVs is fundamental.

At this point, however, it is important to consider that technologies often create externalities that spur new regulations. Unconstrained autonomy could look like the early days of bike sharing or e-hailing when change came faster than the policies needed to guide them did.

Martinez & Crist conducted a study for the city of Lisbon regarding SAVs, exploring two different self-driving vehicle concepts, for which they have coined the terms "TaxiBot" and "AutoVot". TaxiBots are self-driving cars that can be shared simultaneously by several passengers (Ride Sharing), while AutoVots pick-up and drop-off single passengers sequentially (Car Sharing). Together, they are assumed to substitute all car and bus trips.

Results show that cars reduction effect of shared self-driving fleets is very important. Significantly fewer cars than today would be travelling at peak hours, while service levels are largely maintained compared to the base case. With no private car use, Ride Sharing system in combination with high-capacity public transport would use 65% fewer vehicles, while a Car Sharing system in combination with high-capacity public transport would remove 43% of the cars used today. Instead, a Ride Sharing system without high-capacity public transport would use 57% fewer vehicles, while a Car Sharing system without high-capacity public transport would still remove 24% of vehicles, compared to base case.

However, overall vehicle-kilometres travelled would increase in comparison to today. With high-capacity public transport, the increase for the Ride Sharing system is relatively low: 6% more over the day and 9% more during peak-hour; while for the Car Sharing the increase is significant: 44% more over the day and 55% more during peak hour. Without high-capacity public transport, the increase becomes significant also for the Ride Sharing system: 22% more over the day and 25% more during peak-hour; while for the Car Sharing the increase becomes dramatic: 89% more over the day and 103% more during peak hour [53].

If a scenario with Ride Sharing system combined with high-capacity public transport would remain manageable, any other scenario would not. This study proves that high-capacity public transport should not be fully replaced, but eventually adapted, and should take advantage of the technological innovation.

While autonomous metros already exist, unmanned buses are currently being tested and could substitute human driven buses in the long-term. Since labour represents the majority of transit operating costs, autonomous technologies could significantly reduce the costs of providing transit services. With a given budget, transit agencies could provide more frequent service using smaller vehicles, and in some situations, have flexible routes that deliver passengers closer to their destinations (paratransit). For instance, smart shuttles are being successfully experimented in the Uvrier district in Sion and in the Oslo’s harbour. They may not run on a pre-determined route, but they will chauffeur customers on demand from one stop to another, among a set of stops. This extensive coverage would mean all residents of the neighbourhood have a

stop in the direct vicinity of their home and simplified access to major transportation network.
Meanwhile, through effective regulation and incentives, planning and programming, cities will encourage a proper use of SAVs also thanks to the implementation of these other modes of transportation: for example, cities will probably not allow SAVs' pricing to come close to or even undercut public-transport cost. Cities will also control the size and composition of the AVs' fleet to improve performance on all the five indicators that characterise a transit system: availability, efficiency, affordability, convenience, and sustainability.
The achievement of this result does not depend on technology development only, but also on the development of laws and regulations on responsibilities to be jointly agreed upon by public and private parties.
In order to ensure that CAVs reduce physical harm to people, the EU suggests that "manufacturers and deployers, together with policymakers and researchers must collaboratively define the metrics and benchmarks that will be used as evidence for the net positive effect of CAVs on road safety. Researchers should be supported to develop new methods to do this in a scientifically sound manner. In the short-term, manufacturers and deployers should be clear about the benchmarks to which they are comparing their CAV safety metrics. In the long-term, policymakers will need to define a standard set of benchmarks against which the safety metrics of CAVs will be compared. CAV safety performance should not be assessed as a single snapshot but continuously monitored and improved. Policymakers should encourage the accessibility of data about collisions and near-collisions for independent crash investigation agencies and for researchers. Thus, policymakers should detail what sorts of data could and should be deemed high value in the CAV context, and therefore be kept free and open, and they should do this in dialogue with manufacturers and deployers of CAVs, as well as third party data stakeholders. Also, policymakers need to identify specific obligations for state, public and private actors to provide certain types of data as open data, in the interests of transparency, fair competition, financial and industrial development, and competitiveness" [54].
Finally, if autonomous vehicles prove to be reliable at 100%, policymakers could forbid human driving itself.

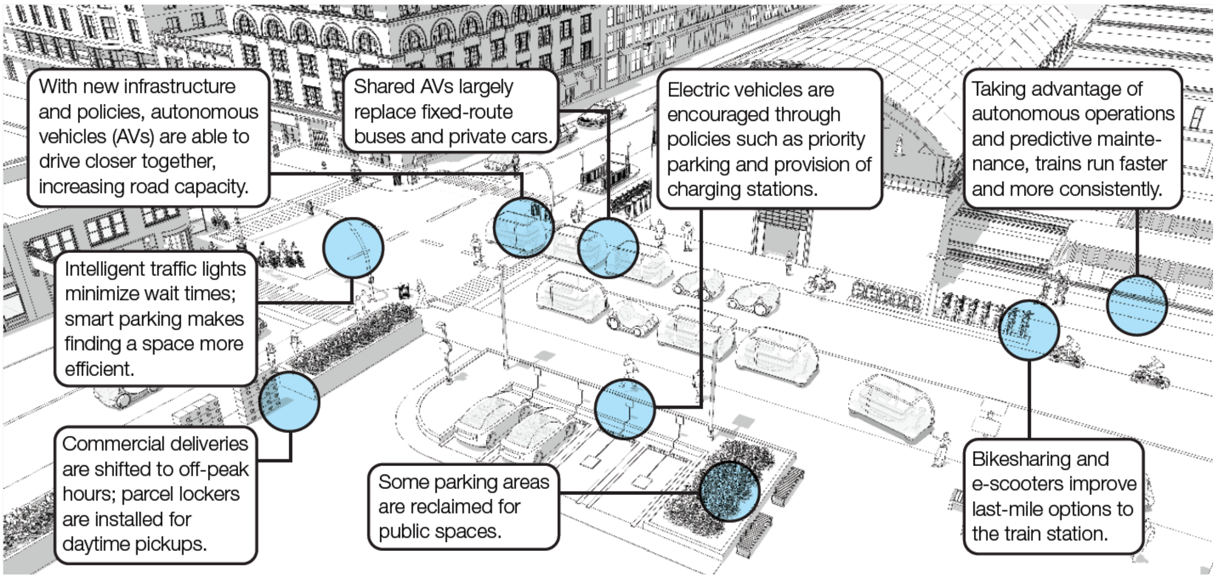


Figure 5.16 – Seamless mobility [55]

The implementation of a transportation scheme as it has been described, combined with the technological advancement that is foreseen in the future, can result in a higher-level MAAS that will be completely seamless (*Figure 5.16*). In a Seamless Integrated Mobility System, the boundaries among private, shared, and public transport would be blurred, and travellers would have a variety of clean, cheap, and flexible ways to get from where they are to where they need to go.
According to Mckinsey&Co., this system "could accommodate up to 30 percent more passenger-kilometres (availability) while still reducing average time per trip by 10 percent (efficiency). It could cost 25 to 35 percent less per trip (affordability), increase the number of point-to-point trips by 50 percent (convenience), and, considering AVs to be electric, reduce greenhouse gases emissions by up to 85 percent (sustainability)" [55].

As automation technology breaks through, robots and drones could replace riders, while autonomous vans could replace cycle logistic hubs. In fact, autonomous vans could transport delivery robots in a very barycentric point, for example in those staging areas that had been identified in the short-term for unsuitable to cargo bikes deliveries, where robots themselves can be deployed for the very last-mile delivery. This way, autonomous vans would serve as a mobile hub which will eliminate the need for a permanent one and will very likely reduce the energy required by robots, since the distance they will have to travel will be shorter, allowing them to complete a higher number of deliveries with the same battery capacity. Autonomous vans could also notify consumers for picking up the parcel themselves if they prefer, making the service more flexible.

Not just robots may be deployed for delivery, but also drones (*Figure 5.17*). Players in this sector will create a specific value proposition for certain customer segments, while complementing existing delivery modes. Cargo drones could make deliveries at high floors, for example, without requiring the client to reach ground floor, or might result more suitable than robots in case of steep routes or routes with stairs [56].

Figure 5.17 – Future automated logistic

Today, it is the logistics industry, and not the Urban Air Mobility sector, that leads the way in already-operational UAV (Unmanned Aerial Vehicle) use cases. This is largely thanks to the growing number of national authorities that have issued permits allowing companies to trial commercial cargo drones, led by pioneers such as Australia, Singapore, Iceland and Switzerland. Cargo drones are being experimented in Italy too. Leonardo company, in collaboration with the City of Turin and D-Flight (Enav group), started a series of tests, authorized by Enac, for the transport with an electrically powered drone weighing 130 kg of a 25 kg load. This project aims at making cities more functional, sustainable and ecological through the use of new unmanned technologies in logistics, to be used also in emergency situations such as the Covid-19 pandemic.

The primary social benefit of drones in logistic is in fact forecast to be in healthcare. According to Will Hetzler [57], cofounder of Zipline International, "drone delivery

has the potential to affordably provide everyone with near-instant access to vital medical supplies, regardless of whether they live in a city or a rural community. Such delivery will reduce the logistical burden of managing chronic health conditions, enable more home-based acute care, and avert hospitalisations and trips to the emergency room or pharmacy", which would respond very well to the goal of the 15-minutes city concept of eliminating unnecessary and unwanted trips.
Due to technical and regulatory constraints, today, drones are best suited to small-package delivery and most easily deliver to single-occupancy, detached structures. As technology continues to improve over the coming decade, the proportion of urban addresses that are serviceable by drones are foreseen to increase.
Meanwhile, companies such as Amazon and Uber Technologies have engaged stakeholders in a dialogue about infrastructure and definition of how drone air space potential will be used in the future. On the government side, it seems that interest in infrastructure is also growing, with some public agencies investing in the development of air-mobility infrastructure for drone use cases.
In fact, the problem right now is that most mature unmanned-aerial-systems (UAS) applications — and the only ones where drones are widely used in either the corporate or the consumer sector — involve short-range surveillance and associated photographs or videos. During these flights, drone operators can identify obstacles and redirect the flight path as needed, since the vehicles always remain within their visual line of sight. All drones that travel further distances require unmanned traffic management (UTM), a system of radar, beacons, flight-management services, communication systems, and servers that coordinate, organize, and manage all UAS traffic in the airspace. Cargo drones will also need to be part of an over-arching system, if urban UAV delivery is to become a commercial reality. This will involve developing a framework for the system, by determining the conditions in which it will exist, as well as implementing the system itself. In terms of necessary conditions, comprehensive regulations for drone operation and interaction with the environment are the number one priority. For all the named reasons, despite the mean of transportation itself already exists, its application in urban parcel delivery is not likely to be widespread any time soon [56].

In the long-term, 20 or more years from the time of this writing, it will be possible to see the effects of the technological progress in the field of mobility, accompanied by ad hoc political regulations. Full automation is expected to make its way, positively

impacting safety both of car users and weak street users, and so benefitting the 15-minutes project with an even higher level of walkability and cyclability. Logistics will also improve thanks to automation, particularly with UAVs.
Finally, the interventions that are foreseen to happen in the long-term would be to complete the task that was started in medium-term of eliminating car-ownership, with great benefits for land use, by bringing sharing concept and availability to a higher level with a fully seamless MAAS (*Table 5.3*).

Table 5.3 – Long-Term Roadmap

TRANSIT ORIENTED DEVELOPMENT	**TRADITIONAL INFRASTRUCTURE**	**SHARED USE MOBILITY**	**NEIGHBOURHOOD LOGISTIC**	**SMART INFRASTRUCTURE**
–	–	Autonomous Shuttles Shared CAVs Fully Seamless MAAS	Autonomous Vans Cargo Drones	Fully Autonomous Driving

6. Conclusions

The 15-minutes programme is the standard that has been taken as a model in different places in the world for an urban planning that aims at making the cities' establishment more liveable, resilient, and self-reliant both in the short and long terms.

Regarding transportation in particular, the 15-minutes model proposes an accessibility paradigm that focuses on the ability of people to reach their destination, rather than a mobility paradigm, focusing on the movement of vehicles, so that, even though the mode of travel is slower, it will take less time to get where we are going.

Cities such as Paris, Melbourne, Bogotá and Barcelona show there are different ways to apply the model that vary according to the context. Cities developed by with specific land destination, such as business districts, university campuses or health precincts, raising the mobility demand. Modern cities that grew after cars proliferation are very sprawled and distances force people to move by car. In other cases, the geomorphology, combined with insufficient proximity of services or insufficient transport alternative, refrains people from walking or use.

Changing or improving previous development certainly requires a cultural change, which is proposed by the 15-minutes model and has been incentivised by the pandemic, but also an infrastructural and technological support and, above all, time.

In this scenario, the work aimed at finding guidelines to implement a transportation scheme that combined an accessibility paradigm, as required by the 15-minutes model, and a mobility paradigm, which guaranteed cross-city trips while reducing pollution and congestion.

Transit Oriented Development, Shared Use Mobility, Traditional Infrastructure renovation, Neighbourhood Logistic and Smart Infrastructure Development were identified as the fields of action for the realisation of the new scheme, which was developed using the case study of Monza in order to validate a set of steps to be followed for new case studies and eventually adapted according to their characteristics.

These steps are grouped according to the area they belong to in a Roadmap (*Table 6.1*) that summarises their temporal and logic sequence.

Table 6.1 – Full Roadmap

	SHORT TERM	**MEDIUM TERM**	**LONG TERM**
TRANSIT ORIENTED DEVELOPMENT	Neighbourhood Gravity Centre	Infilling Mixed-Use Buildings Reuse of vacant buildings and areas	–
TRADITIONAL INFRASTRUCTURE	Limited Traffic Zones LTZs Curb Side Differentiation Car Lanes into Bus & Bike Lanes	Moderate Traffic Zones Car Park into Bus & Bike Lanes Velopolitain	–
SHARED USE MOBILITY	Bike Sharing Car Sharing Neighbourhood Shuttle	Mobility As A Service	Autonomous Shuttles Shared CAVs Fully Seamless MAAS
NEIGHBOURHOOD LOGISTIC	Cycle Logistic Hubs Parcel Lockers & Boxes	Robot Delivery	Autonomous Vans Cargo Drones
SMART INFRASTRUCTURE	Charging Columns	Cooperative Driving	Fully Autonomous Driving

The identification of neighbourhoods' gravity centres will always be the very first step to take, because it is the core of a 15-minutes neighbourhood around which to implement the new scheme. In the short-term, the aim is to make people get used to the idea of walking, by instituting Limited Traffic Zones with no curb parking, and sharing, by providing a good sharing service, which would also encourage a shift toward a green mobility, if it was electrified.

In the medium-term, the first aim is to reduce overall movements and shorten their distance, by really implementing 15-minutes neighbourhood. In fact, it may happen that 15-minutes concept requirements are not immediately met. Then, in the medium-term the neighbourhoods can be developed with infilling, for population

densification, or with the repurposing of existing buildings for mix-use and the recovery of abandoned ones if services are lacking. The second aim is to raise the level of walkability, which is necessary for the 15-minutes model implementation, by turning the limited traffic zones into proper moderate traffic zones, where walking function prevails, and by making roads safer with technological development allowing for cooperative driving. The third aim is to improve public transportation and cycling attractiveness, by making it more competitive with infrastructural interventions such as lanes and curb parking conversion into reserved lanes for higher frequency and punctuality of the former and higher safety and agility of the latter. Public transport and sharing services could be combined altogether with MAAS, making collective transport more convenient overall than private car use.
Finally, in the long-term the aim is to completely abandon car ownership, by providing a completely seamless mobility system with regulated shared autonomous vehicles and complementary public transport that could make use of autonomous shuttles. The will for car ownership could also be decreased by the possibility of forbidding human driving, if full automation proves to be safe at 100%.
The new mobility scheme includes also freight mobility, which can be thought as the photographic negative of people mobility, because if people do not want to move for certain services and amenities, these will have to go to people. Logistics too can take advantage already in the short-term of a 15-minutes neighborhood development, if requirements are met, by implementing cycle logistic, and even more so in the medium-term, with bike lanes network expansion. Cycle logistic needs little infrastructure development that can be quickly achieved and is represented by cycle logistic hubs and lockers to avoid "not at home" recipients. When legislation will be ready, the streets could also accommodate delivery robots, completing the cycle logistic service. In the future, though, robots themselves, combined with autonomous vans and cargo drones could make cycle logistic as it has been presented obsolete.
These steps are the result of a case study application, literature review and analysis of the projects undergoing in different cities of the world. They are meant to be an ideal standard that does not really depend on the context they are applied to. However, future work could focus on their application in particular cases of study, such as uphill cities, in order to specify the steps themselves and find a new standard for that particular context, or study one particular step in details in order to quantify the action in terms of time, money and material resources.

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List of Acronyms

Acronym	Description
ADAS	Advanced Driver Assistance System
AEB	Automatic Emergency Braking
AV	Autonomous Vehicle
CAM	Cooperative Awareness Message
CAV	Connected Autonomous Vehicle
CVL	Cooperative Vehicle Localisation
DENM	Decentralised Environmental Notification Message
EV	Electric Vehicle
GNSS	Global Navigation Satellite System
LPT	Local Public Transport
LTZ	Limited Traffic Zone
MAAS	Mobility As A Service
MAP	Map Topology
MTZ	Moderate Traffic Zone
SAV	Shared Autonomous Vehicle
SPAT	Signal Phase And Timing
SUM	Shared Use Mobility

Acronym	**Description**
TACC	Traffic Aware Cruise Control
TOD	Transit Oriented Development
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UTM	Unmanned Traffic Management
VKT	Vehicle Kilometres Travelled