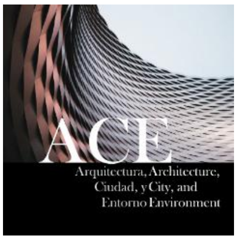

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Identification of Potential Technical Conflicts and Opportunities Arising from the Insertion of Collaborative Transport Robots (CTRs) in the Near Urban Environment: A Preliminary Field Study

Identificación de posibles conflictos y oportunidades técnicas derivadas de la inserción de robots de transporte colaborativo (RTCs) en el entorno urbano próximo: un estudio de campo preliminar

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Abstract

Keywords:
conflicts; opportunities; Collaborative Transport Robot (CTR); near urban environment

The Collaborative Transport Robot (CTR) is the result of the maturation of electric transport technologies combined with artificial intelligence, applied to a vital task in the near urban environment: the retail transport of goods in collaboration with its citizens. These devices are already appearing in some cities in the service of the new economy of digital commerce. It is necessary to consider the possible technical implications, suspecting both conflicts and opportunities, that their insertion in the near urban environment may trigger. This contribution is part of a project carried out in collaboration with a robotics engineering research institute concerned with the functional challenges posed by the introduction of CTRs in the daily mobility of this urban environment. To this end, observations have been made in various towns in the metropolitan area of Barcelona, taking advantage of the pilot field tests with CTRs; the considerations issued have been based on a qualitative methodology and have been ordered according to the twelve main vectors of this technology. The images collected during the observations show that many of the challenges detected will manifest themselves in the future according to determining aspects such as the service management profile of the CTRs, the speed of their implementation, the diligence of the authorities in their regulation or the capacity of these devices to acquire the necessary information in real time for their circulation in the near urban environment.

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Resumen

Palabras clave:
conflictos; oportunidades; Robot de Transporte Colaborativo (RTC); entorno urbano de proximidad

El Robot de Transporte Colaborativo (RTC) es el resultado de la maduración de las tecnologías de transporte eléctrico combinadas con la inteligencia artificial, aplicadas a una tarea vital en el entorno urbano de proximidad: el transporte de mercancías al detalle en colaboración con sus ciudadanos. Estos dispositivos ya están apareciendo en algunas ciudades al servicio de la nueva economía del comercio digital. Es necesario considerar las posibles implicaciones técnicas, sospesando tanto conflictos y oportunidades, que su inserción en el espacio urbano de proximidad pueda desencadenar. Esta contribución forma parte de un proyecto realizado en colaboración con un instituto de investigación en ingeniería robótica preocupado por los retos funcionales que plantearía la introducción de los RTC en la movilidad diaria de este entorno urbano. Para ello, se han realizado observaciones en diversas poblaciones del área metropolitana de Barcelona, aprovechando la realización de unas pruebas piloto de campo con RTCs; las consideraciones emitidas se han basado en una metodología cualitativa y se han ordenado de acuerdo con los doce vectores principales de esta tecnología. Las imágenes recogidas durante las observaciones muestran que muchos de los retos detectados se manifestaran en el futuro según aspectos determinantes como el perfil de gestión del servicio de los RTCs, la rapidez de su implantación, la diligencia de las autoridades en su regulación o la capacidad de estos dispositivos para adquirir la información necesaria en tiempo real para su circulación en el entorno urbano de proximidad.

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1. Introduction

Global urbanisation has been growing very rapidly in recent decades (Muhumed, 2022). This rapid urbanisation coupled with the fast growth of global trade in cities is likely to put further pressure on the urban distribution of goods and services: traffic congestion and the associated air pollution are some of the challenging problems. The last step of the urban goods distribution chain, which is known as the last mile, currently has many technical inefficiencies. At the same time, this mobility generates a high level of social interaction between citizens, which gives the near urban environment (NUE) its vitality and diversity.

Currently, Collaborative Transport Robots (CTRs), as autonomous, electric and collaborative devices, are considered one of the possible technological solutions to reduce friction (nuisance, mistrust, accidents, etc.) and dysfunctions (loss of time, energy consumption, unnecessary journeys, etc.) associated with last mile distribution (The International Transport Forum, 2011, 2017). The insertion of CTRs in the near urban environment urban space of proximity can also cause conflicts, like other perceptible changes (Aramburu Otazu, 2008), and at the same time offer substantial opportunities for improving micromobility activity. As with any technical urban change, their implementation will not be without conflict (Jaller et al., 2020).

Cimadomo (2017) considers it important to understand the effects that technological innovations can have on the immediate built environment around us. He also recognises the importance of the flows generated by technological companies in terms of their impact on the city and alerts urban planners to take these trends into account, assess potential threats, and take advantage of the opportunities that open up for better enjoyment and social inclusion in the urban context.

Cities are becoming highly attractive sites for experimentation with smart technologies, like CTR, which are potentially applicable across many areas of their economic and social life. These technologies overlap with existing urban networks and simultaneously expand their capabilities, reshaping both the built city and the everyday experiences of citizens (Macrorie et al., 2021). Goods logistic process automation is being introduced very fast but in an NUE plagued by as many opportunities as uncertainties, depending on each society, geography and type of good (Dekhne et al., 2019).

2. Theoretical framework

The incorporation of a new technical element into the NUE forces the rest of the existing technical elements that want to remain to reorder themselves to resolve new technical conflicts that have arisen and take advantage of opportunities that are detected. The advent of CTRs will be a new step forward in this constant technical reordering of the NUE, to integrate the complexity that a new technical element always entails. Similarly, almost nothing is new in the NUE and many technical elements that seem to us to be current come from previous elements that have disappeared but left a contribution.

This suggests that we should include in the theoretical framework an understanding of the relationship between technology and the production of the NUE, the impact of automation, the displacement of human labour or the appropriation of public infrastructure by private companies, which are attractive topics but require a different approach and an extension that goes beyond the physical limits of this article.

2.1. Urban logistic goods process

The impetus for the implementation of CTRs is based on a change in citizens' consumption habits associated with growing digitalisation and automation of logistic commercial processes within the framework of what is known as the smart city: its electric profile generates sympathy, but its autonomous profile raises questions.

CTRs potentially provide new dimensions that are appropriate for goods distribution and waste collection, which is perhaps the most inefficient end of the goods supply chain (Jallert et al., 2020): electrification of mobility, artificial intelligence and human-robot collaboration to improve the well-being of logisticians. Although the initial incentive for introducing CTRs will be convenience for urban clients who pay for the service, there are other potential and collateral technical conveniences (Shladover SE, 2022):

- Reduced energy use, and associated emissions per kilometre, with smoother and more efficient speed profiles, especially when they are coordinated with traffic light cycles.
- Reduced delays at signalised intersections by using real-time traffic light phasing status updates for the coordinated start-up of waiting vehicles.

- Increased traffic capacity per lane by safely allowing shorter distances between vehicles, thus making more efficient use of road space.
- Potentially reduced frequency and severity of accidents between vulnerable vehicles and pedestrians.
- Increased accessibility between activity centres and citizen users in low-density urban areas by making deliveries more economically viable due to reduced costs.
- Reduced traffic congestion associated with local parcel delivery by allowing these services to be provided by smaller vehicles that take up less road space.
- Possibility of reducing private car ownership, usage and parking requirements in the long-term, if automated transit and private transport services mature sufficiently to serve a larger fraction of urban trips.
- Exploitation of existing low congestion space and time intervals so that CTR services can take advantage of them to maximise infrastructure without substantially expanding or modifying it: "when the streets are empty, the houses are full".

Despite the potential benefits of CTRs, there are risks related to the identification of the competitive advantages, benefits and costs of such developments. Shladover (2022) also considers that CTR systems will still be heavily influenced by safety concerns for a few years and will therefore initially be implemented in limited traffic conditions and in coexistence with non-automated traffic. This hybrid transition will probably mean that the potential benefits will not be fully appreciated. In terms of quality of life, significant practical and policy barriers persist (Paddeu et al., 2020). This author also notes that urban environments are changing rapidly sociologically, with increased awareness of residents and the concern of urban authorities. This leads to changes in logistics-related policies and regulations, which makes logistics planning and management issues more uncertain. Jaller et al. (2020) highlight two difficulties related to the rapid insertion of CTR devices: the creation of a suitable urban environment and current legal uncertainty to promote their implementation. Some companies have chosen to develop CTR operations only in controlled environments (condominiums, corporate buildings, industrial establishments, universities).

The NUE is probably one of the most complex outdoor scenarios for CTRs. In it, CTRs interact not only with fixed and predictable physical obstacles, but also with mobile and unpredictable ones: lampposts, trees and kerbs on the one hand, and people, cars, pets, etc. on the other, which move simultaneously in a very limited and changing physical space.

During the collaborative interaction between clients and CTRs, which is always guided by a mutually beneficial relationship, technical opportunities and conflicts may occasionally occur with:

- clients, which must be resolved within the framework of the conditions of service,
- the other citizens in the neighbourhood, outside of the collaboration relationship, and
- the NUE, as the scenario where the collaboration takes place.

2.2. Individual interaction, client – CTRs

Before and during COVID, Yuen et al. (2022) and Koh et al. (2023) asked groups of 500 citizens who were selected as potential customers of CTRs about their predisposition towards CTR use as a last-mile delivery method. The responses showed a high consumer intention to use CTR services and revealed their perceived usefulness, susceptibility, severity, ease of use, subjective norms and behavioural control. It is therefore evident that there is a need to analyse in great detail any citizen perception of the introduction of a new service based on a technical innovation. According to Hossain (2023), since CTRs are a new phenomenon, customers still have mixed feelings and perceptions about their acceptability. The cost and reliability of the service are two key concerns expressed by the customers who were interviewed. Ease of use, intention to use and usefulness are thus perceived to be key drivers of their potential acceptance. However, the acceptance of CTRs also seems to depend on attitudinal and demographic factors. Indeed, residents are not a homogeneous group when it comes to accepting CTRs. For example, young people tend to be more predisposed towards them. This study also expresses the importance of making the purpose of CTRs clear, so that citizens have a broad understanding of them and can accept them. Pani et al. (2020) conducted a detailed analysis of consumers' preferences, trust, attitudes and willingness to pay for a service provided by CTR. The results reveal six diverse consumer segments: direct shoppers, e-shopper-loving shoppers, COVID-converted shoppers, omni-channel consumers, e-shopper-sceptics and indifferent consumers.

2.3. Collective interaction, rest of citizens – CTRs

Most citizens are not yet familiar with CTRs, and encounters with these robots on the street are mostly spontaneous, unplanned and unsolicited. In the public space, citizens adopt a more social behavioural role that differs from the private behavioural role adopted in the domestic space. However, they do maintain their basic behaviours (fear, suspicion, curiosity, etc.) in the face of something new that alters their stable and predictable environment. Shladover (2022) considers public attitudes towards CTRs are not yet formed, as very few citizens have had the opportunity to experience CTR operations in person and there is still too little tangible information available to offer realistic impressions to the rest of the population. Rosenthal-von del Pütten et al. (2020) confirm that research on human-robot interaction has predominantly focused on laboratory studies, to provide a fundamental understanding of how humans interact with robots, but only in controlled environments.

Shladover (2022) states that public opinions on the safety of urban vehicle automation vary widely in different places and among population groups, which makes it difficult to discern whether there is already a clear, well-established consensus. Current media reports on experiences with such vehicles tend to emphasise extreme situations and outlooks (including fatal accidents that unnerve pessimists or the more optimistic predictions stated by advocates). This further contributes to the volatility of public opinion. In general, the public does not yet have an accurate perception of the risks associated with the autonomous circulation of these devices. Hence, there is divergence between the real risks and those that are actually perceived. Industry advocacy groups tend to underestimate the actual risks, while citizen safety advocacy groups tend to exaggerate them.

To achieve social acceptance, it is not only essential to make CTRs perform their tasks effectively, but also to consider other forms of interaction with the citizenry. In fact, the robot is usually expected to comply with human social norms and habits: as is already the case with pets or private cars, each citizen-owner is socially expected to take care of the robot (Lupetti et al, 2019).

2.4. Environment interaction, near urban – CTRs

One of the unknowns regarding CTRs is whether they will really reduce current traffic congestion. The simultaneous and widespread use of these vehicles could potentially generate an increase in traffic congestion due to their low carrying capacity: for each current delivery van, more than one CTR is required. Therefore, it seems that some aspects of urban space and time partitioning need to be studied and regulated so that the replacement of current last mile delivery fleets by CTRs is ultimately beneficial in terms of congestion, time and cost (Lebeau, 2013). The results achieved with CTRs so far seem to show, in terms of effectiveness, that they should only be used in specific areas of the NUE, with maximum linear distances close to 2 km and not necessarily with a 1:1 replacement rate (Melo et al., 2014, 2017). It does not yet make sense to extrapolate the first results cited in this study to any situation because it is still difficult to determine the scalability of these technologies. More research is needed to determine the conditions under which CTRs should operate in the NUE, e.g. at what times, in what quantities and in which areas, as their widespread and indiscriminate use could lead to increased congestion and increased risk for users of the regular infrastructure (Jaller et al., 2020).

The transformation of NUE to accommodate CTRs will necessarily lead to challenges due to asynchrony between the fast development of CTRs and slow mobilisation of the urban environment planning, management and design processes.

2.5. Key knowledge gaps

It is clear that the recent literature has been led by three disciplines: collaborative robotics, goods logistics and consumer behaviour. This is probably because the private economic groups driving the application of CTRs in the NUE, where most consumers live, are obviously afraid that the considerable investments required to implement these technologies will be in vain due to a general rejection by citizens who are also pedestrians in these areas, legal obstacles established by urban managers or the measures applied by threatened urban agents who are already historically consolidated in the urban space. This view of new technologies as simply a direct solution to current technical urban problems is very limited and short-sighted.

The urban groups involved, whether neighbours, distributors, managers, traders, politicians or others, may see this novelty both as an opportunity to improve on the current difficulties and as a source of new conflicts arising from the insertion of a new technology unacquainted with the complexity of the NUE. Most conflicts will arise from mismatches between the nature of the current near city, the nature of its inhabitants and the nature of CTRs.

In this contribution, the authors propose a preliminary exploration, which only focuses on technical conflicts and opportunities in the NUE, based on the needs of CTRs to carry out their mission. This initial technical perspective does not exclude other future critical approaches that could enrich the analysis of the future emergence of CTRs.

3. Methodology

The methodology proposed to formulate the potential technical conflicts and opportunities at NUE that may arise due to the introduction of CTR devices, is qualitative, descriptive and based on previous studies by the authors. The process consists of contrasting the specific technological rules that apply to CTRs driving in the NUE, due to the requirements of their technology. These rules can be summarised as indicated in Table 1.

Table 1. Rules specific to CTRs

 1a	ORIENTATION: CTRs must be able to move around carrying a load of goods by orienting themselves within the urban environment to determine their position and that of their destination at any time.	 1b	ENERGY AUTONOMY: CTRs must be capable of refuelling when they run out of 1benergy.
 1c	ITINERARY: CTRs must be able to move a load along an assigned itinerary without distraction and without insurmountable obstacles.	 1d	WEIGHT, VOLUME AND FORMAT: CTRs must be able to move with a load of weight, volume and proportions commensurate with their mechanical capacity and power along an itinerary in accordance with urban gauges.
 1e	CONSIGNED SPEED: CTRs must be able to move while carrying a load at a speed in accordance with the conditions of each urban section.	 1f	RUN STABILITY: CTRs must be able to move with a load in urban areas without overturning, colliding or falling to a different level.
 1g	PREVISIBILITY: CTRs must be able to travel with a load and be able to anticipate (react to) unforeseen events on the route or itinerary.	 1h	SHELTER, PARKING, MAINTENANCE: CTRs, during inactivity (waiting, resting, loading), or at the indication of the teleoperator, must be able to find a suitable shelter and stop.
 1i	INTERCOMMUNICATION: CTRs must be able to move around and be able to communicate with the citizens they encounter.	 1j	PRESENCE: CTRs must be able to move while carrying a load and be able to project a decent presence (colour, volume, noise).
 1k	PICK-UP AND DELIVERY POINT: CTRs must be able to move transporting a load that they have picked up at an agreed point and must deliver it to another agreed point.	 1l	REMOTE ASSISTANCE: CTRs must be able to move while carrying a load and receive remote assistance from a teleoperator (control centre) in case of need (blockage, accident, doubt).

Source: own elaboration.

CTRs interpret the NUE as an alien scenario through which an authorised mobility track runs, linking a point of origin (loading goods) and a point of destination (unloading goods). In its transit along this track, CTRs will have access to pre-established places where they can "be" (recharge batteries, be repaired, wait for a new task, etc.). Along the authorised mobility track, a CTR must be attentive to recognise, in advance and with certainty, the obstacles present, the incidents that occur in the near environment and the externals alerts received. It must also check that the state of the assigned lane matches the forecast. If this is not the case, the changes are recorded and communicated to the CTR's guardians. CTRs move partly according to the confirmation information they exchange with the digital network and partly according to the information they exchange themselves. Each CTR rule, technical conflict and opportunity detected has been illustrated with annotated images taken on the street and is accompanied by a final summary table of the balance between conflicts and opportunities.

4. Development and results

The following is a preliminary map of technical conflicts and opportunities posed by the insertion of CTRs in the near urban environment. Based on their expertise, the observer discerns in advance the technical conflicts and opportunities that may arise from the appropriate insertion of CTRs, in accordance with the 12 rules set out above.

4.1. Orientation

The orientation experience of CTRs in an urban environment can be likened to the experience of a human tourist in a distant country who is visiting for the first time. They must achieve the following:

1. Find their way around and recognise where they are going.
2. Recognise uniformed agents in the space they pass through.
3. Consult with the person who has sent them, to resolve doubts or ask for assistance.
4. React to changes in comfort (light, sound, smell, temperature and wind) and environmental safety.
5. Travel within the authorised areas of passage.

The orientation that CTRs need will not be supported by current visual technologies but will most likely be supported by the new digital urban data transmission and reception networks. However, the physical city is highly complex and requires location accuracies which conventional networks do not always guarantee. Alternatively, and progressively, specific networks or stand-alone systems will have to be deployed to allow CTRs to compare the perceived reality with the predicted reality (Figure 1 & Figure 2).

Figures 1 & 2. Elements and issues on urban space

Figure 1. Visual signs that citizens need to find their way are accumulated by various actors, which makes it difficult to generate a map for CTRs to understand.

Figure 2. Existing street lighting poles placed in a very methodical and regular way, can also be an auxiliary support for this information infrastructure.

Source: Figures 1 & 2, author-generated and were captured during the fieldwork conducted on the case study.

The replacement of existing analogue guidance systems (signage and maps) with new digital systems is already very mature, so no major conflict is foreseen in this case. The unknown factor is the low accuracy of the urban mapping that is available in the last mile environment, which will require CTRs to be trained and probably cooperate. Table 2 shows the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 2. Conflicts and Opportunities: Analysis of CTRs orientation

Conflicts	Opportunities
• Difficulty in requesting assistance from a citizen in the street. • Loss of telematic contact with operator or navigation system or destination. • Inability to decide on alternatives at a junction. • Unplanned blockages along the route (roadworks). • The NUE is reconfigured in the day/night, weekday/weekend, summer/winter, war/peace. This can affect orientation.	• Share the same digital guidance systems as citizens. • Act as a road inspector in real time. • Share their vision with the teleoperator. • Their own location is permanent. • Ability to record the non-matching environment and send this information to the teleoperator.

Source: own elaboration.

4.2. Energy autonomy

The most common energy used by CTRs is probably electricity from batteries. These devices will have limited energy autonomy, depending on the battery capacity, the duration of the task, the set speed, the load carried, the gradient of the route, etc. One of the aspects associated with CTRs is their need to be supplied en route once their autonomy is exhausted. Energy is one of services that CTR needs to maintain continuity along the route or itinerary. Relevant scenarios for recharging are: routine (planned at the CTR's home), opportunity (recharging during break periods) and emergency (unplanned recharging). The current low-capacity charging network is inside buildings and the future high-capacity charging network is currently being deployed in the public space as a complement or substitute for the fluid fossil fuel network. CTR technology will have to opt for one of the two networks and for one of the two charging speeds. In any case, a new urban network of recharging points must be established so that CTRs can approach them, arrive and wait for a while as the battery is being charged. During charging, the CTRs will remain inactive and in a vulnerable situation, which will also require adequate protection and custody.

It is also likely that initially the network of recharging points will not be uniform or technologically standardised, so there will be an even greater number of initial adversities that will generate uncertainty, mistrust or rejection. It is therefore plausible to think that in a medium-term scenario, the deployment of a network of urban energy recharging points will follow an evolutionary process in phases or stages.

Figures 3-22. Elements and issues on urban space (continuation)

Figure 3. Shared electric bicycles are already recharged during passive parking periods.

Figure 4. Existing twenty-four-hour convenience stores located in private ground floor premises can be future points of energy recharging service provision.

Figure 5. urban fountain network is perhaps the oldest public water supply network and predates the availability of piped water in buildings.

Figure 6. Multi-service points in kiosks proliferate on the streets of today's city, offering a dense mesh of points where nomadic citizens can receive emergency services, such as energy recharging.

Figure 7. Urban electric car use is being deployed due to the public-private effort to create a network parallel to petrol stations, on a self-service basis.

Figure 8. The case of telephone booths shows that the obsolescence of service points in urban areas is very high due to technological evolution.

Figure 9. Urban solid waste containers are arranged in a regular, systematic way for filling and subsequent collection of resources.

Figure 10. Recharging points could be associated with other new service points that already have common compact volume-based structures.

Figure 11. The charging points could be set up in symbiosis with the public lighting network. Source: external

Figure 12. In return, recharging points could provide an urban barrier service.

Figure 13. In return, recharging points could provide an urban barrier service.

Figure 14. Recharging requires a temporary parking place. Recharging places may be welcomed, as they could help to drive out illegal parking.

Figure 15. Demand for electricity from CTRs will further strain the current electricity market. Ground floor charging stations could be combined with photovoltaic energy from the occasional surplus on the upper roofs of buildings.

Figure 16. Regular fleet CTR dispatch and reception locations, such as this supermarket, provide an opportunity to have recharging points either for their own use or for their customers.

Figure 17. The NUE already has stations in the urban public space with electricity services such as transformer stations.

Figure 18. The outdoor catering network (bars and restaurants) has the profile and flexibility to provide a charging service for their customers' individual CTRs.

Figure 19. Temporary regulated paid parking strips can also provide an opportunity for recharging.

Figure 20. Private recharging points could be set up at the perimeter of the access points to the interchange nodes between public and private transport modes.

Figure 21. The visual presence of charging points can also be an opportunity for advertising.

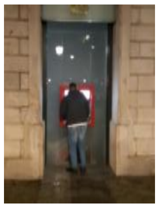

Figure 22. Areas for citizens' recharging are also present in windows in the façade of buildings. This proven model could be an opportunity that can be transposed to the recharging of CTRs.

Source: Figures 3-22, author-generated and were captured during the fieldwork conducted on the case study.

The NUE has a long tradition of providing service points in public spaces, such as underground service points (manholes), overground service points (control panels, waste disposal, signs) or overhead service points (lighting, wiring), and in collaborative interaction with buildings, on ground floors and in basements. Table 3 summarises the main conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 3. Conflicts and Opportunities: Analysis of CTR energy autonomy

Conflicts	Opportunities
• Recharging time and proximity to the recharging point is not accurately predictable. • Recharging is slow (needs parking places). Replacement is not yet feasible, due to the weight of the batteries. • Recharging technology still needs conductive cables. • A robot without power gets in the way, cannot defend itself and runs the risk of being vandalised. • Urban public space is scarce and cannot be used for parked vehicles. • Not being able to complete the service. • Competing for electricity with other public or private operators. • Danger of explosion, tampering, vandalism, humidity, etc.	• Ability to enter recharge routines in the software itself, in case of power failure. • The batteries are solid, stable and compact. • Share the charging service with other existing or retrofitted urban public charging networks. • Locate charging centres in locations with higher availability of renewable energy, e.g. unoccupied ground floors in buildings with rooftop solar panels. • Battery technology is evolving very rapidly. • Batteries are heavy and in the urban environment this weight can be used for retaining barriers, advertising ballast, planter bases, bench backs, light post bases, and boundaries of angled car parking spaces.

Source: own elaboration.

Urban energy supply is already undergoing a major revolution with the progressive substitution of fossil fuels by alternative energy sources. Cities are not currently energy self-sufficient, so this technological renewal will be accompanied by a foreseeable occasional energy shortage that will probably generate conflicts between urban fleets and CTRs.

4.3. *Itinerary*

Citizens value the formal diversity of the urban road they walk along, but at the same time they also value its predictability and accessibility without barriers. Citizens are curious and social, so they stop at any time on their journey to chat, rest, make inquiries or inspect the NUE they are passing through. Each CTR will trace its itinerary by travelling along routes selected on the basis of immediate efficiency criteria: reaching the target on time and returning home safe, with limited energy effort.

It would be ideal to have an exclusive, continuous and well-developed route for optimal movement. However, the only itinerary that currently exists that meets these characteristics is the road for vehicles. As CTRs approach the final destination of their itinerary, the route restrictions and the risk of service-disruption increases.

These incidents can be reduced either by restricting the simultaneity of traffic or by reducing the speed. This means that the NUE is committed to unifying shared routes and establishing agreements on timetables, preferences and signalling.

The current coexistence of the various urban agents for movement (buses, pedestrians, bicycles, pets, etc.) is strongly based on the mutual predictability of the trajectory of each of them. Almost all current vehicles move in a single direction on a single plane, which facilitates their coexistence.

In contrast, pedestrians are multi-directional. CTRs are potentially able to move along much more diverse trajectories (hyperbolic, polygonal, omnidirectional, etc.), which in part complicates their predictability for pedestrians and other vehicles.

The CTRs itinerary can be fully open or pre-closed, depending on the operator's criteria. Open routes are more suitable for domestic (private) customers and alternate simultaneously between road platforms, whereas closed routes are more suitable for regular (public) customers.

Figures 23-30. Elements and issues on urban space (continuation)

Figure 23. Any planned route may be temporarily interrupted by other parked vehicles or temporarily deposited goods. This is likely to be accompanied by ancillary movement by workers.

Figure 24. A barrier is a temporary type of street furniture. It is used in the NUE to temporarily restrict access to people and vehicles, but is not easily detectable by CTRs.

Figure 25. For centuries, architecture has been a refuge for pedestrians. The possibility of CTRs penetrating citizens' homes is a challenge that exceeds that of the last mile.

Figure 26. The design of mobility lanes is highly dynamic and continuous. If it does not provide opportunities for stopping, the lane can be blocked.

Figure 27. Obstacles often precede routes and need to be integrated into layouts.

Figure 28: The NUE is subject to incidents that require rapid interventions to restore service. This requires appropriate marking of spatial and temporal boundaries.

Figure 29. Any urban road platform has permeable sections with respect to buildings (refuges or safe parking areas) or other platforms (landing areas, platform changes, etc.).

Figure 30. Urban routes require intensive maintenance through periodic works that give rise to temporary "camps" that must be identified from a distance.

Source: Figures 23-30, author-generated and were captured during the fieldwork conducted on the case study.

Table 4 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 4. Conflicts and Opportunities: Analysis of CTR itinerary

Conflicts	Opportunities
• Transits between platforms (vehicle and pedestrian) are not always at the same level or with the same type of paving. • Discontinuous public greenery systems (flowerbeds, tree surrounds, planters, etc.) are not easy to detect, they grow and obscure the full view. • Currently, urban street design tends to create irregular obstacles and temporary setbacks to reduce the speed of internal combustion engine vehicles. These elements hinder the continuity of CTR traffic.	• The experience gained with satellite navigation systems can be easily incorporated into CTRs. • CTRs do not park in the public space like private vehicles, so after service they disappear. At the same time, they provide a variety of stimuli. • The pacification of the last mile of cities and the spread of single platforms is an opportunity for CTRs. • CTR routes can be reconfigured more easily than other vehicles to day/night, sun/rain or weekday/holiday changes. • CTRs can assist in urban micro-mapping of the many devices on the road that are discontinuously deployed by various actors (traffic lights, signs, trees, control panels, etc.). • Autonomous navigation can significantly reduce the visual "noise" produced by the current overabundance of signs and signals. • The new urban mapping should incorporate not only graphic attributes but also alphanumeric attributes such as rights, timetables, speed limits, etc.

Source: own elaboration.

Figures 31-40. Elements and issues on urban space (continuation)

Figure 31. The varied urban image reinforces the character of a diverse city, but at the same time can hinder the efficiency of the travel platform.

Figure 32. The CTR itinerary must be able to cope with a range of requirements. If there are many conflicts, invest in a separate specialised track.

Figure 33. When tracks or routes separated by fixed barriers coexist in parallel, coexistence on the same track is probably not possible.

Figure 34. Both static elements (street furniture, lampposts, etc.) and dynamic elements (separate lanes, keep-clear areas, bus stops) are found in the boundary areas between urban platforms.

Figure 35. The NUE is primarily a two-dimensional plane. Many volumes protrude from this plane. Most of the time these volumes are located on the pedestrian platform. CTRs will need to map these volumes to move properly.

Figure 36. Weather factors (rain and wind) are attenuated in the last mile scenario but can be a threat to CTRs that are poorly adapted to these circumstances.

Figure 37. Some urban specialised tracks are difficult to share, such as street lighting. This comprises a wired power supply network that is either buried or attached to buildings or poles, and static luminaries.

Figure 38. Routes through urban space tend to be minimalist, so their perceptual richness is often associated with boundary and signage elements. The visualisation of CTR tracks can be an opportunity to increase the perceptual richness of public space.

Figure 39. Once the service matures, CTRs will push for accessibility inside buildings as architectural barriers disappear and assisted navigation within buildings matures. This will also benefit people who encounter accessibility barriers inside buildings.

Figure 40. The use of CTRs will mean an increase in the productivity of mass roadside work but at the same time an opportunity to specialise the work of CTR supervisors in "last mile" adaptation work.

Source: Figures 31-40, author-generated and were captured during the fieldwork conducted on the case study.

4.4. Load (weight), volume (gauge) and format (proportions)

A CTR has greater power than a citizen, and this allows it to transport larger loads in collaboration with people, who may or may not accompany it. Transporting a load is a highly professional activity because of the necessary integrity, physical state, density, fractionation, toxicity and hazardousness of the goods. All these factors must be considered in order not to damage the goods. This physical transport includes accompanying transaction records related to the service—such as invoices, receipts, documentation, warranties, user manuals, and safety precautions—all of which must be managed both at the origin and destination of the route.

CTR vehicles are technically designed for load capacity, in accordance with their intended speed of travel. The load capacity must be in line with the load capacity of the travel track itself. An important decision, which is not for robot designers or city designers but for logisticians, is whether the same roving CTR distributes several parcels on the same route (shared CTR) or whether the distribution is unitary (one parcel per trip). The current distribution by means of vans with drivers corresponds to the first model. Its efficiency is good, but its gauge is almost always larger than the possible dimensions of the last mile, so the driver always uses an auxiliary forklift. The distribution of food at home corresponds to the second model and its bicycle gauge is better suited to the human scale of the last mile. The initial loading and final unloading of CTR (transfer) is likely to be carried out by humans, whether they are the transmitters or the receivers.

The existing city has historically been shaped by the clearances of large vehicles. This always makes it difficult for special (out-of-gauge) transport and provides opportunities for small-gauge vehicles that squeeze in between the standard-gauge vehicles. Since CTRs are intended for small loads, their clearance gauge will not be particularly problematic as long as it is visible to other non-autonomous vehicles. Successful uptake of a CTR service will rely heavily on waiting time or punctuality. The local city is highly unpredictable and does not guarantee compliance with these variables from the outset. The technology associated with CTRs will need to avoid waiting times, maintain cruising speed and avoid high speed. This means exploring the routes and time slots that are less crowded and less regulated, even if they are more minority and somewhat longer. CTRs can take advantage of the variable speed provided by the electric motor and the ability to accommodate safely and automatically the average speed of the cars that share their track. Table 5 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Figures 41-54. Elements and issues on urban space (continuation)

Figure 41. Not all cargoes to be transported by CTRs have the same cohesion and order characteristics. Bulk cargoes and packed cargoes are unlikely to share the same CTR.

Figure 42. The loads to be transported have their own attributes and strict transport conditions that modulate the maximum load per journey. Their fractionation and grouping are also modulated because even if they are part of the same consignment, they cannot be mixed.

Figure 43. Transport vehicles contrast visually with the rest of the elements of the urban scene and this gives them a recognisable image for the rest of the mobility agents, both public and private. The reduced dimensions of CTRs may initially cause confusion.

Figure 44. Large volumes constitute a safety risk because they reduce the field of vision of other urban agents and sometimes exceed the gauge of the tracks along which they run.

Figure 45. One of the most common conflicts in vehicle movements on public roads is exhaustion of the available gauge at junctions in the same or different directions.

Figure 46. CTRs could collaborate with each other and form convoys. The grouping of transport vehicles is always an added conflict when they run on the same platform.

Figure 47. Conflicts between vehicles with different gauges are most evident at crossings between platforms.

Figure 48. Conflicts often occur when vehicles for internal use in buildings complete itineraries in the urban space.

Figure 49. At loading and unloading times, the vehicle's clearance gauge is necessarily widened to carry out the preliminary work of loading and unloading in complete safety.

Figure 50. CTR applied to the assisted transport of people and their goods (sick people, babies, elderly, etc.) in the last mile environment is likely to be developed with the restriction of the current private combustion engine vehicle in residential areas to reduce noise and pollutant emissions.

Figure 51. CTRs can facilitate certain types of more delicate and insecure movements, such as vertical ones, in the NUE.

Figure 52. Goods are supplied in a variety of formats. These formats are related to price, dosage, regularity of consumption, etc. Urban bulk distribution used to be reserved for large vehicles.

Figure 53. Goods are moved or parked in different ways depending on whether they are involved in direct or reverse logistics (waste). Reverse logistics is gradually gaining importance for reasons of efficiency, and to promote reuse and recycling processes. Reverse logistics processes are not as refined so they require protected temporary storage areas (containers or enclosures).

Figure 54. The reduction of road traffic in central areas through dissuasive measures, together with parking restrictions for private vehicles, allows the extension of the pedestrian platform to accommodate loading and unloading bays without reducing traffic capacity on pavements.

Source: Figures 41-50, author-generated and were captured during the fieldwork conducted on the case study.

Table 5. Conflicts and Opportunities: Analysis of CTR load, volume and format

Conflicts	Opportunities
• Urban areas with narrow passageways or obstacles (e.g. balconies)	• Possibility of managing convoys to split up loads
• Temporary space for loading and unloading activities	• Access to private car parks
• Vandalism, theft	• Smaller vehicles can avoid cargo "cul de sacs"
• Exhausting the capacity of CTRs	• Possibility of accurately scheduling (and updating) timetables
	• Creation of continuous supply bridges (caravans)

Source: own elaboration.

4.5. *Setpoint speed*

The effectiveness of any transport system, including CTRs, depends to a large extent on achieving an average speed that makes it efficient, cost-effective and safe. Speed is defined as "average" because there will inevitably be periods of stopping or waiting along the route, either to divide the load, to obtain permits or to load and unload. The speed will always be reduced as it approaches the final delivery point, where the natural speed of citizens prevails. In today's city, average speed also decreases as congestion increases and most current transport systems cannot realise their full speed potential in all areas of the NUE because one is limited by the other. To overcome this handicap, historically, exclusive platforms, separate lanes, right-of-way preferences, raised platforms, restricted timetables, etc. have been implemented.

The speed at which a CTR travels must be convenient for the service that is provided and for the other vehicles with which it shares a platform. In any case, this speed must allow for the predictability of its trajectory for the rest of the vehicles in the urban environment. Heavier, slower, less urgent shipments are likely to coexist with lighter, faster, more urgent (express) shipments that will require priority passage. This will depend to a large extent on the type of cargo transported (value and expiry date), the contracted tariff (cost of the shipment, rental or purchase) and the customer's needs (in terms of weight and volume).

The efficiency of the CTR service will rely heavily on waiting time or punctuality. The NUE is highly unpredictable and does not guarantee compliance with this requirement. The technology associated with CTRs will need to avoid waiting times, maintain cruising speed and avoid high speed. This means exploring the routes and time slots that are less crowded and less regulated, even if they are more minority. The establishment of the setpoint speed of CTRs will be a source of considerable debate in existing cities. This speed is the basis of their commercial efficiency. At the same time, it is an indicator of social alarm among citizens who will demand strong limitation by the authorities. Figs. 55-56 are author-generated and were captured during the fieldwork conducted on the case study.

Figure 55. Professional CTR users can accompany the CTR on certain parts of the journey to facilitate its proper introduction.

Figure 56. Speed is a parameter that affects either the design of any urban vehicle or, in the same way, the design of the NUE.

Source: Figures 55 & 56, author-generated and were captured during the fieldwork conducted on the case study.

Table 6 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 6. Conflicts and Opportunities: Analysis of CTR setpoint speed

Conflicts	Opportunities
• If they drive with the same rules and on the same platforms, they will inherit the set speeds of most vehicles. • It does not seem appropriate to invade the pedestrian platform (as bicycles or motorbikes do on occasion) to get around congestion without taking measures. • The success of CTRs could lead to congestion again if no zone slots are established. • Pacification of the last mile is an opportunity for citizens to improve coexistence with pets and vegetation, which find it hard to interact with CTRs. • Existence of litter or abandoned waste (leaves, containers, etc.).	• Current urban layouts (lanes, corners, parking strips, keep-clear areas, etc.) are heavily influenced by the passenger car and its speed; therefore, they will be greatly affected when the speed is lower but constant (reduction of the danger of junctions). • Larger, higher speed and higher emission vehicles will be removed from the last mile. CTRs will be able to occupy this area that is set aside.

Source: own elaboration.

4.6. Walking safety

Any CTR system must avoid overturning or accidentally leaving its route. This may occur in case of cornering, braking, steep slopes, collisions, etc. When this occurs, it will be difficult for CTRs to recover their initial position or the load will be spilt without assistance. Walking instability may occur in cities that are in the process of consolidation but not in consolidated cities. In rural areas, CTRs could even be supported by quadricycle technology. One of the risks of any CTR vehicle in motion is rollover and collision while in motion. This is particularly likely at urban permeability points when a CTR transits from one area to another, crosses track transversely, changes platforms or starts or stops. A rollover is a conflict that has impacts on lives, property and time, the scope of which can extend over several kilometres.

Figures 57-61. Elements and issues on urban space (continuation)

Figure 57. Due to the limited width of many itineraries, operators increase the length or height of their haulage gauges to improve efficiency. However, if the roadbed is not well maintained, the risk of rollover increases.

Figure 58. Another important risk of conflict on road platforms is collision with vehicles in the same or different directions of travel. That is why one-way lanes that are well delimited around the perimeter are preferable.

Figure 59. One of the risks of any CTR vehicle in motion is rollover due to undetected changes in gradient.

Figure 60. CTRs can facilitate the mobility of groups that are outside the driver licensing system, such as minors, seniors or unlicensed adults.

Figure 61. Urban elements that pose a risk of overturning or collision should be adequately signposted in advance not only for CTRs, but also for the general public.

Source: Figures 57-61, author-generated and were captured during the fieldwork conducted on the case study.

Table 7 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 7. Conflicts and Opportunities: Analysis of CTR security

Conflicts	Opportunities
• As the delivery route progresses, the cargo box becomes emptier and the risk of accidental load shifting may increase. • When a CTR negotiates an unforeseen obstacle, it does so with an abrupt manoeuvre that can affect its stability.	• Scout CTRs can pass on information on stability, risks in the area (construction sites, spills, falls, etc.) to their colleagues. • In the last mile areas, the speeds are lower and the stability is higher. • Most of the current CTRs are 4-wheeled and not 1, 2 or 3-wheeled.

Source: own elaboration.

4.7. *Predictability*

The NUE bases its success on a delicate balance between the spontaneity that citizens crave and the predictability of the services that the citizen receives. CTRs will have fewer urban conflicts if they are predictable and recognisable in the service that they provide, but this will only be possible in the case of commercial fleets. The last mile urban routes of a CTR can be standard and determined by the guardian or operator (common route or itineraries, separated, specified or determined by slots), which makes them highly predictable. They can also be non-standard, because the service has been expanded in time (e.g. a Christmas campaign) or because the CTR is for entirely private use. They may be urgent: unforeseen events in an urban journey (rain, falling objects, scattered plant debris, etc.) affect citizens, but potentially have an even greater impact on CTRs, which have even more difficulties in terms of autonomy to make quick, viable or successful alternative decisions in the event of a sudden setback. The most novel aspect of the forthcoming introduction of CTRs in the urban environment will be autonomous driving without the presence of a driver. Although supervised by a remote operator, CTRs are potentially predictable and programmable and thus are likely to avoid congestion and improve the efficient use of shared infrastructure. If CTRs are networked, those encountering problems on the road can alert their CTR colleagues to take precautions.

Figures 62 & 33. Elements and issues on urban space (continuation)

Figure 62. Currently, much of the distribution of goods and waste collection is carried out at off-peak times to improve efficiency and reduce disruption.

Figure 63. The concentration of supply works at the same time saturates the spaces allocated to them. CTRs would make it possible to establish loading and unloading slots for the convenience of neighbours, distributors and customers.

Source: Figures 62 & 63, author-generated and were captured during the fieldwork conducted on the case study.

Table 8 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 8. Conflicts and Opportunities: Analysis of CTR predictability

Conflicts	Opportunities
• CTRs have difficulties in communicating their foreseeable intentions to other stakeholders (other CTRs, tourists, customers, road agents, etc.). • CTRs collaborating with unpredictable work. • Traffic, weather, power and energy disruptions alter predictability, as in the case of air traffic.	• Mainly implement CTRs in sectors that are highly routine and predictable. • CTRs are easy to programme to perform routine collaborative activities over time and along pre-established routes.

Source: own elaboration.

4.8. *Shelter, parking and maintenance*

Any vehicle, including a CTR, needs protected areas and premises in the NUE for shelter, parking or maintenance stops. Like any means of transport, the CTR may spend many hours in a parking situation (refuelling, repairs, energy recharging, etc.). Urban stopping, shelter and maintenance areas are technically complex because they require maximum flatness, free areas for manoeuvres, protection, delimitation of enclosures, etc. These aspects are scarce in the current urban environment. It will be difficult to locate these areas in an urban space that is already in great demand. The past experience of private vehicles parking on public roads can no longer be repeated. At the same time, an opportunity arises for many currently unoccupied private ground-floor commercial premises, which could be social meeting places for CTR customers and users to support their devices. Accidents involving vehicles interrupt traffic for a long time: a hard shoulder or adequate space must be available to move the disabled stationary vehicle out of the way.

Figures 64-73. Elements and issues on urban space (continuation)

Figure 64. Often an assisted CTR will not be able to access the assisted spaces under its own power. This can be a major source of conflict.

Figure 65. Improved outdoor climate conditions will encourage commercial outdoor uses. This will constitute a conflict with CTRs for the occupation of public space.

Figure 66. There should be a move away from the image of dark garages towards more open images such as location or repair shops where CTR customers socialise.

Figure 67. Specialised enclosures could take the form of parks located in the public space, becoming also sought-after meeting points.

Figure 68. In the same way that automobiles took advantage of carriage entrances in buildings, CTRs can take advantage of the same entrances where retrofitting is possible.

Figure 69. In view of the problems encountered by solid urban waste containers, second-generation solutions have already been put in place completely underground. They free up a lot of space that can be used for reverse logistics.

Figure 70. The implementation of urban solid waste collection systems also includes specialised isolated containers. Their redevelopment could be an opportunity for CTRs, as they could be used as an opportune mobile “green spot”.

Figure 71. There are waste collection processes, such as used furniture and household appliances, which follow specific paths. Their efficiency could be improved by incorporating CTRs.

Figure 72. In the first instance, shelter points could be camouflaged in the form of other existing service points, such as those that have been developed for cycling.

Figure 73. The revival of cycling as a personal vehicle has generated a private commercial network that supports all the needs. As CTR becomes an alternative personal vehicle, there will be a chance for the development of another network.

Source: Figures 64-73, author-generated and were captured during the fieldwork conducted on the case study.

Table 9 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 9. Conflicts and Opportunities: Analysis of CTR shelter, parking and maintenance

Conflicts	Opportunities
• Now, vehicles are not very resilient and have little capacity for autonomous reaction to unforeseen events and adversity. • Other unauthorised vehicles, private or public, may occupy these reserved spaces.	• The location of these open spaces either close to intermodal mobility spaces or close to facilities. • Ground floors of the buildings are gradually being freed from the retail trade and incorporated into the service sector. • CTRs can record everything concerning contingency and thus contribute to prevention.

Source: own elaboration.

Figures 5-73. Elements and issues on urban space (continuation)

Figure 74: Cars need an amount of surface parking that could not be satisfied by the existing NUE. Specific car parks were provided in the underground area. A reduction in the use of cars in the central urban area will free up space, and provide an opportunity for CTRs.

Figure 76: Improved outdoor climate conditions in cities will encourage commercial outdoor uses, especially on pedestrian platforms. This will lead to a conflict with CTRs for the occupation of public platforms.

Figure 76: Spaces for the rest of private vehicles and pedestrians already coexist informally. In the coming decades, there will be an opportunity for citizens and their own CTRs to temporarily rest in the same urban public realm.

Figure 77: The permeability between the road and pedestrian platform has been reduced and limited to regulated path crossings in order to improve predictability and thus safety. As a consequence, the border between the two platforms offers CTRs take advantage of this opportunity.

Source: Figures 57-61, author-generated and were captured during the fieldwork conducted on the case study.

4.9. *Intercommunication*

As CTRs move through a NUE that is increasingly closer to the recipient, they are more likely to intersect and interact with other urban agents. These agents could be other moving entities (people, mechanical means, pets, other robots, etc.) or fixed obstacles (facades, fences, kerbs, trees, lampposts, etc.). These crossings always generate conflicts because they are a source of misunderstandings, collisions, interruptions, etc. To avoid them, vehicles that are about to cross each other's paths must first communicate with each other by signalling or quick intercommunication, a visual or audible warning greeting, which is sometimes even frightening or late.

Figures 78 & 79. Elements and issues on urban space (continuation)

Figure 78. Current hand delivery systems of postal services have extensive experience of failed deliveries that generate dissatisfaction for the addressee and costs for the sender. Detailed reporting of the reasons for non-delivery is an opportunity for CTR intercommunication.

Figure 79. The implementation of the CTRs makes it necessary to establish a signage system of its own, but it is not possible to do so without the other visual signs that are already consolidated among citizens. Visual signs are currently accumulating dynamically and this generates signs that are difficult for CTRs to understand.

Source: Figures 78 & 79, author-generated and were captured during the fieldwork conducted on the case study.

There is very little experience of agile on-the-spot dialogue between citizens and CTRs. Citizens are already beginning to accept everyday communication with non-human devices such as mobile phones or smart assistants. This provides an opportunity for CTRs because there are already accepted patterns of non-human intercommunication, based on prior recognition. Conflicts will exist until an agile and universal code is established. The ability to ensure the quality of this information is essential to avoid errors and misunderstandings that would spoil the intended service. Table 10 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 10. Conflicts and Opportunities: Analysis of CTR intercommunication

Conflicts	Opportunities
• CTRs are not fluent in human or animal language. • There is still no code for humans to intercommunicate with CTRs. • Citizens often feel threatened by the fact that they do not feel heard or responded to in their language.	• Intercommunication was already imperfect in the urban environment before CTRs. • CTRs dominate other non-face-to-face means of written communication.

Source: own elaboration.

4.10. *Presence*

Any element, even a CTR, in the NUE is subject to decorum requirements in accordance with the whole in which it is inserted, its circumstances and attributes. All objects, whether fixed or mobile, and living beings that are present in the NUE are subject to social and cultural rules regarding their appearance. This makes them recognisable and part of the same whole. CTRs must also be adapted to this vocabulary in order to be recognised as an integral and non-invasive part. Whether they are dark, shiny, edgy or soft must be considered to avoid conflict over inappropriate appearance. Obviously, decorum is a local social agreement that evolves. When CTRs are private, leased or part of a fleet, the required decorum may be tilted towards more unique, corporate or camouflage values. The sensory aspect of CTR can be very relevant for its proper integration and acceptance by acting as non-verbal intercommunication. An "undesirable" appearance can alter other perceptions of nearby citizens such as anticipation of their mobility, belonging to the environment and recognition of familiarity. There is no expected friction in this respect because actually the development of vehicles is an area in which there is extensive experience and very good professionals. Friction will arise in the early stages when the foundations of this decorum are established and are markedly different from those of other urban vehicles.

Figures 80-85. Elements and issues on urban space (continuation)

Figure 80: Urban mobility devices spend a considerable amount of time on the street and constitute, together with facades, advertising and landscaping, an important urban presence.

Figure 81: Large volume vehicles are less efficient on the NUE, but at the same time they effectively communicate the image of the freight forwarder, the sender or the receiver.

Figure 82: Presence in the urban environment identifies and differentiates, to reduce misunderstandings. CTRs should take this opportunity to show where they belong, what type of trip they are completing or whether they are off duty.

Figure 83: The presumed disappearance of the driver's cab and the front internal combustion engine raises questions not only about the usable volume of CTRs, but also about the directionality or centre of gravity of the design.

Figure 84: The simplification of CTRs to become mobile warehouse boxes on wheels raises opportunities for reconfiguration by increasing the surface area of their presence.

Figure 85: Special events involving building work make it necessary to temporarily redefine the boundaries between adjoining urban platforms. Conventionally, this is carried out by signs, cones, fences etc. An opportunity for CTRs would be to temporarily become active signalling devices themselves.

Source: Figures 80-85, author-generated and were captured during the fieldwork conducted on the case study.

Table 11 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 11. Conflicts and Opportunities: Analysis of CTR presence

Conflicts	Opportunities
• There is no precedent for autonomous electric vehicles without passengers. • Conflicts in spaces shared with other vehicles and people, where there may be conflicts between forms of decorum.	• In traditional transport vehicles, the cab and engine were major attractions that are now virtually unnoticed, giving more prominence to the appearance of the transport box. • This provides an unprecedented opportunity to initially explore creativity.

Source: own elaboration.

4.11. *Pick-up and delivery points*

The service provided by CTRs requires a specific starting point (loading dock) and a specific destination point (unloading dock). The dock is not only a technical point that facilitates the physical transfer of the cargo but also an administrative point where all the authorisations involved (payment, acceptance, validity of the contract, etc.) are validated. It is therefore a potential point of conflict due to its complexity.

Collection and delivery points require high efficiency, specialisation, accessibility to public roads and the capacity to split, store or transfer shipments. If goods exchange in the NUE increase, it will be necessary to provide locations, spaces and configurations for micro-hubs, where goods transported by trucks or vans are transferred to CTR.

Figures 86-97. Elements and issues on urban space (continuation)

Figure 86: Where the façade of the delivery point coincides with the property boundary, delivery by CTR necessarily stops in front of this check point, occupying an already dense approach band during the transaction.

Figure 87: The traumatic experience of COVID served to develop systems for collection and delivery without human contact.

Figure 88: The depositing of large volumes of waste in transit is always a challenge because it requires adequate signage to warn of what may be behind it.

Figure 89: In the most professionalised unloading docks there are always strict protocols.

Figure 90: New customers and suppliers of CTRs do not yet have docks or links set up for shipping, which leads to many conflicts and inefficiencies.

Figure 91: Vehicles and their loads are frequently parked on the street, taking advantage of the proximity of poles, lampposts, boxes, etc.

Figure 92: Today's cybercafes can easily be converted into public hubs for the asynchronous delivery and collection of goods from consumers. The cybercafe service is already widely used by the most digitised migrant communities.

Figure 93: Some business premises need their own collection and delivery points. In this picture, a tobacco shop has its own box to deposit goods that are either sent or received, in an asynchronous regime.

Figure 94: Cargo cannot always be collected in enclosed spaces. The street itself is often the starting point of the shipment, as in the case of construction waste. This leads to the establishment of temporary collection hubs, especially on an occasional basis, as in the case of seasonal campaigns.

Figure 95: Small and medium-sized renovation works on buildings require the temporary occupation of NUE for the collection of materials and the removal of waste available for the duration of the works. This provides an opportunity for the temporary establishment of a delivery and collection service by CTRs.

Figure 96: The current reconversion of local commerce entails the temporary closure of ground floor premises. Some of them could be useful as micro-hubs to break up goods on route to or from the consumer.

Figure 97: In the case of MSW reverse logistics, there are already precedents for green points in the form of containers parked on public roads.

Source: Figures 86-97, author-generated and were captured during the fieldwork conducted on the case study.

Table 12 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 12. Conflicts and Opportunities: Analysis of CTR collection and delivery points

Conflicts	Opportunities
• Fragility of the cargo itself • Technical means available for the transfer • Backlog of consignments (congestion) • Lack of custody of goods in transit • Weather events • Congestion • Lost or returned shipments	• Availability of retrievable professional packaging • Information transfer systems such as barcodes • Experience of the Post Office • In the same way that bus stops for passengers and rubbish bins for waste have been created, urban docks for the exchange of goods in transit could be created for the last mile.

Source: own elaboration.

4.12. *Remote assistance*

Both citizens and their vehicles, including CTRs, are susceptible to unforeseen incidents that require urgent and specialised assistance. As a result of telecare technology, this service does not need to be permanently available on the street. Instead, it responds to requests from headquarters or simply provides the affected person with instructions for self-help. In the case of CTRs, the question is who should perform this assistance and what the reaction time should be. In the early days, the number of assistance services is likely to be high and the assistance network is likely to be weak, so reaction times will be long. The NUE must be prepared for this.

Once a CTR has been identified (chassis number), the availability of the geographical coordinates facilitates immediate assistance. All that is missing is load identification, which is becoming increasingly common. Until a specific assistance network for CTRs is developed, roadside assistance companies will have to reconfigure themselves to incorporate this customer, which may compensate for the progressive decrease in the number of vehicles in the fleet.

Figures 98-101. Elements and issues on urban space (continuation)

Figure 98: In the event of a breakdown or collision, the assistance provided can be manifold, providing mechanical, health, police, etc. assistance to the CTR and the affected citizen.

Figure 99: In the case of fleet CTRs, remote mechanical, police, fire or medical assistance could be immediate.

A separate case is the transport of goods that may be considered hazardous.

Figure 100: A relevant aspect is the custody and recovery of the shipped cargo, which should be assisted by the consignee.

CTRs should visually display the contact details of the consignee or the contracted alarm centre.

Figure 101: As the specialisation of the CTR service evolves, physical neighbourhood centres could be established for the technical assistance of smaller private CTRs.

Source: Figures 98-101, author-generated and were captured during the fieldwork conducted on the case study.

Table 13 summarises the most relevant conflicts and technical opportunities detected in the fieldwork carried out on the case study.

Table 13. Conflicts and Opportunities: Analysis of CTR remote assistance

Conflicts	Opportunities
• Recovery and maintenance of the load and its value during telecare. • CTR physically blocks the passage and telecare digitally blocks the passage. • Availability of cover. • Looters.	• Availability of vacant places in the NUE to house companies that provide this service. • Some services are already responsible for the telecare of fleets, rental or private vehicles. • Experience of SOS posts in tunnels or on expressways.

Source: own elaboration.

5. Conclusions

The results of this extensive and systematic process of observation and annotation will require in further studies a more in-depth and detailed analysis of the interrelations between aspects that are potentially assessed as negative (conflicts) and those assessed as positive (opportunities). However, certain aspects can already be detected, either because they coincide with those of other vehicles previously incorporated into the NUE, or because of the management of the service provided (private, commercial or public), or because of their capacity to share existing infrastructures with other vehicles. In any case, the main novelty introduced is the intelligent character of these mobile devices governed by AI, a characteristic that will allow them to insert themselves and occupy spaces and times that are currently available but not used by other vehicles.

The technical conflicts that will be sparked by the introduction of CTRs in the NUE will be numerous and of a very diverse nature, as shown in this paper. The intensity and extent of these conflicts will depend on the tenancy and service regime of these devices, and on the progressiveness of their insertion.

Therefore, tools for resolving these conflicts will be somewhat more sophisticated and costlier than in ancient times, in accordance with the technology of digitalisation. A large part of the smooth insertion of CTRs in the urban environment will be to reinforce their predictability and intercommunication with citizens and their institutions, in order to reduce collisions, concurrences and misinformation.

A first overview of the technical opportunities shows that, as on previous historical occasions, the insertion of CTRs is a moment to recover certain urban elements that are in decline. At the same time, it represents an opportunity to reach higher levels of quality in aspects of the NUE that are still pending, such as universal accessibility, environmental comfort or safety. The application of CTRs is seen as advantageous in uses or circumstances that make them unique and useful, such as delivery to areas that are difficult to access, delivery of special cargo or when delivery may go beyond human labour conditions, for example, at night.

The introduction of CTRs will initially arouse surprise, curiosity and tolerance, but will subsequently trigger public alarm, spurred by the quantitative growth of their use and the imbalance between the opportunities and threats posed by each innovation for each of the groups of citizens.

The more than one hundred images compiled show the potential of these autonomous devices to acquire in real time the necessary information to roam efficiently and safely in their immediate urban environment, process it and share it immediately with the rest of the urban agents in order to have up-to-the-minute information on the state of our immediate urban environment, which remains hidden from the main urban studies.

The authors wish to state that this contribution, due to the characteristics of the research project in which it is framed, is a sectorial contribution, and should therefore be considered as a contribution limited to the field of urban studies. However, its development may be a useful contribution for those researchers interested in the impact that the generalised use of new information technologies may soon have on the urban environment of proximity.

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7. Credit authorships contribution statement (CRediT)

The first author was in charge of conceptualization, investigation, methodology, supervision, visualization and writing, the second author was in charge of funding acquisition, project administration, resources and validation, and the third author participate in the investigation.

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