Navigating the Streets

How Geofencing Improved E-scooter Management in Munich

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INTRODUCTION

E-scooters have become a popular mode of transport in cities around the world, but they also present challenges for city officials and residents. In Munich, Germany, geofencing was used to improve the management of e-scooters on city streets. One of the biggest challenges was the problem of e-scooters being left in inappropriate places, such as on pavements, or blocking pedestrian access.

Geofencing is a location-based technology that uses technologies such as GPS or RFID to create a virtual boundary or perimeter around a specific geographic area. This boundary is defined by the coordinates of the area, and when a device or object equipped with geofencing technology enters or leaves this boundary, it triggers an automated action or notification. In the case of e-scooters, geofencing technology is used to create virtual boundaries around areas where e-scooters can be operated and parked, and to limit the speed of e-scooters in certain areas. This helps to ensure the safety of riders and pedestrians and to manage the use of e-scooters in urban environments.

Three different case studies were conducted to evaluate new parking management concepts based on geofencing. The first case study focused on the parking of e-scooters in 43 reserved zones in the old town of Munich. The second case study implemented a new parking concept for the Oktoberfest in 2022 and 2023, including temporary parking zones and time restrictions. The third case study existing zones outside the old town.

Figure 1. E-scooters in Munich.

The use of a mobility data and analysis system in Munich highlights the importance of data-driven decision making in e-scooter management. By analysing parking data and mobility patterns, the city was able to develop parking regulations and use geofencing technology to enforce them. This approach not only helped address the public nuisance and safety hazards caused by improperly parked e-scooters, but also ensured that the rules were enforced in a transparent manner.

The use of geofencing to define parking and no-go zones for e-scooters is a promising solution that can be replicated in other cities around the world. By linking geospatial data to micro-mobility vehicles in the backends of e-scooter service providers, it is possible to enforce established rules and designated zones in a transparent and efficient manner. The effectiveness of geofencing can be measured through surveys, monitoring and evaluation, which can help cities refine their approach and improve e-scooter management over time.

The aim of this document is to provide a comprehensive and accessible assessment of the impact of geofencing technology on urban planning in Munich. As such, this report provides an overview of the project's findings on stakeholder collaboration, the engagement process and governance concerns around the use of geofencing. These findings are described in detail in the final reports for each of the project's work packages.

Background, Motivation and Mandate

Munich, with a population of over 1.5 million, is a transport hub and an urban node at the intersection of two TEN-T corridors. Munich has a strong public transport system connected to the greater The modal split is: 24% public transport, 34% private car, 18% cycling, 24% walking. There is a wide variety of shared mobility modes (cars, bicycles, e-mopeds, and e-scooters). The city of Munich is one of the 100 Climate Neutral and Smart Cities and has an approved Mobility Strategy 2035 with 19 sub-strategies, including Sustainable Logistics Strategy, Digitalisation, Innovation Management. One of the concrete goals of the mobility strategy is that by 2025, at least 80 per cent of traffic in the city of Munich will be covered by zero-emission vehicles, public transport, walking and cycling.

Background

Shared micro-mobility services are key to promoting sustainable individual mobility and achieving environmental benefits in urban development. These services provide a convenient means of transport for short distances, particularly at the start and end of a journey. When used in conjunction with public transport, they provide an alternative to private car use, which can lead to reduced emissions, more efficient use of space and improved urban liveability.

Since 2019, e-scooters have been a hot topic in Munich, causing both excitement and frustration. There are concerns about pedestrians being put at risk by improperly parked e-scooters. Despite this, e-scooters have become a popular mode of transport, with four companies (Bolt, Lime, Tier and Voi) operating around 13,500 vehicles in Munich by 2023, as shown in Table 1. Shortly after the first e-scooters appeared in the city, a forum was established with shared mobility service providers to address the issue of incorrectly parked e-scooters and to establish regulations for e-scooters as a new mode of transport.

Furthermore, a recent study[1] conducted by the city of Munich in 2021 and 2022 has shown that e-scooters are becoming increasingly popular for commuting,

Table 1: Average number of e-scooter rentals and vehicles per year in the city of Munich.

	2019	2020	2021	2022	2023
Rented vehicles	1.959.492	2.213.289	4.832.657	6.263.309	7.469.556
Number of vehicles	2.747	4.567	7.322	10.194	13.323

[1] https://muenchenunterwegs.de/content/1423/download/220530-bericht-eva-et-final-web.pdf

visiting friends and leisure activities. In Munich, e-scooters are used most during the summer months and at peak times in the afternoon. On average, trips last between seven and eight minutes and tend to start and end in the city centre near public transport stations. E-scooters also have the potential to replace up to 14% of car journeys and are particularly useful for the first and last leg of a journey when combined with public transport. E-scooters offer Munich residents a practical and environmentally friendly alternative to private cars, contributing to the overall efficiency of public transport in the city.

However, the study also identified problems associated with the use of e-scooters. To improve road safety, the study recommends that Munich should create more parking zones for e-scooters. The study also recommends integrating e-scooters into the public transport system and developing them as "last mile" vehicles.

As mentioned twice, improper parking of e-scooters proved to be a problem. While free-floating gives users a great deal of flexibility, it can also lead to parked e-scooters blocking the sidewalk. To address this, Munich took further steps to improve the situation prior to the GeoSence project. The city set up 30 physically marked parking zones between 2020 and 2021. But without proper digital enforcement and knowledge of where to place these zones, many of these spaces were under-utilised. This led to negotiations with e-scooter service providers in 2022, resulting in a new voluntary commitment for e-scooters and data sharing agreements between the city and the service providers to regulate this form of mobility and to monitor and understand the use of e-scooters in the city by analysing parking data.

Voluntary commitment between city and e-scooter service providers

- At any one location, no more than four e-scooters may be offered.
- If they are parked on the pavement, at least 1.80 metres must remain free.
- The pedestrian zone and green areas are taboo for parking.
- E-scooter service providers must remove incorrectly parked e-scooters within 24 hours.

Pilot motivation and mandate

Munich looked at geofencing as a way to improve enforcement of parking rules for e-scooters. For the city, geofencing had the potential to ensure that e-scooters were parked in designated zones, while still providing a convenient mobility option for users. The study also aimed to assess user acceptance and potential challenges in implementing geofencing, as the use case aimed to understand how geofencing affects traffic and mobility behaviour, such as e-scooter parking.

As the city's Mobility Strategy 2035 provides a framework for the development of mobility in Munich over the next decade, and as the top priority is to ensure safety with an integrated Vision Zero, there is also a clear mandate to improve the parking situation for e-scooters to ensure road safety.

Munich GeoSence Case Studies

Three case studies were conducted in Munich to evaluate the effectiveness of geofencing in reducing incorrect parking of e-scooters and improving road safety.

Case Study A

From May to October 2022, 43 parking zones were installed in Munich's old town (see image in Annex 1). These new zones aimed to improve parking conditions in this busy pedestrian area. The designated zones were clearly marked with signs and road markings. E-scooter service providers also integrated them into their systems after the city sent them digital geofences. In the end, the entire old town was declared a no-parking zone, with the exception of the newly designated parking zones. As a result of the success of this case study in improving the parking situation, these new parking regulations will be made permanent in November 2023, when the study is completed.

Case Study B

During the Oktoberfest in 2022 and 2023, the city used geofencing to create temporary parking zones (see image in Annex 2) in the event area to improve parking and discourage drunk driving. The three-week Oktoberfest is a peak period for e-scooters, with high usage. Special traffic restrictions have been put in place to ensure safety and minimise incorrectly parked e-scooters during the event. From 5pm to 6am the following day, no e-scooters could be rented in the designated no rental zones. Parking was only allowed in the designated parking zones at all times. Although overcrowded parking remained a problem in 2022 when the scheme was first introduced, data analysis the following year showed that the situation had improved as the city adjusted the rules. In addition, the police reported fewer cases of drink-driving in 2023, when the rental ban was added to the scheme.

Case Study C

In addition, the final case study digitally defined 30 parking zones using geofencing to enforce a 100 metre no parking zone around them. The aim was to see if people would use them more if the zones were implemented in the e-scooter rental apps. As mentioned above, these parking zones existed prior to the project, but were not geofenced and were underused. The geofences were installed in October 2023 and tested until March 2024. The evaluation is therefore still ongoing, but initial results show that the use of these zones has improved. However, as a result of a recent decision by the Council to further improve parking, all of the nearly 100 existing parking zones should be geofenced by the end of 2023, while a surrounding no-parking zone of at least 100 metres should be introduced to increase their use.

Implementation Process and Barriers

Prior to the project, the e-scooter no-riding and parking zones were sent to the providers using a GIS-based map that was exported as a .pdf file and emailed to the e-scooter service providers. The providers then integrated these zones into their systems.

Implementation process

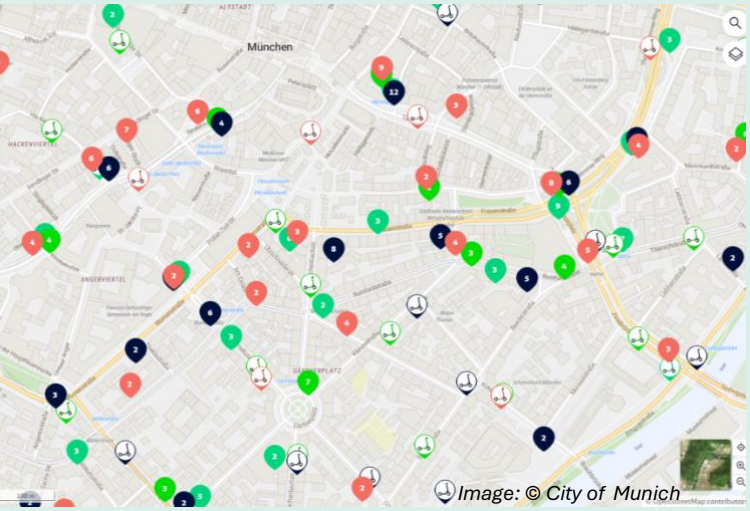


Figure 2. Overview of parked e-scooters in an area in Munich.

The aim of the GeoSence project was to use a software-as-a-service geofencing solution to define the geofences and send them to the e-scooter service providers via a digital channel as real-time two-way communication using the MDS standard[2]. The providers would then be able to integrate them directly into their back ends. A monitoring and analysis system was procured for this purpose. As compliance monitoring is essential to ensure that e-scooters comply with traffic regulations, it was also important that the system could also analyse parking metrics.

The necessary data was provided voluntarily by the e-scooter service providers, who signed a data contract with the city and connected to the procured system, allowing the city to analyse e-scooter parking data in real time. Overall, a key to the successful implementation and operation of the three case studies was the involvement of e-scooter service providers and other stakeholders, such as local politicians, at an early stage of the project. For example, they were asked for their views on where the parking zones should be located. This approach led to a trusting partnership between all stakeholders.

In addition to the digital deployment of geofences, ground markings and signage also play an important role in improving the parking situation for e-scooters. As a visual design element, they help to identify parking zones. The design of these parking areas helps to create an organised parking situation in public spaces and allows for better orientation when returning vehicles. A flat and smooth surface, such as asphalt, is preferred to avoid structural changes. Parking zones are also not allowed in front of historic buildings, fire stations and market areas, and may only be installed on streets with speed limits over 30 km/h if there is a continuous marked cycle lane between the street and the parking zone.

When designing parking zones, it is also important to consider the different space requirements of different vehicles. For example, e-scooters require approximately 0.75 m^2 of space per vehicle. The average parking zone for e-scooters in Munich, for example, is 10 metres wide and 2 metres deep, the equivalent of almost 2 car parking spaces. Installing such a parking zone can cost almost €8,000.

Barriers for implementation

During the project, Munich was not able to fully test all the things that were foreseen in the GeoSence project description. For example, the feasibility of virtual parking zones, which could pose new challenges in terms of usability

[2] https://github.com/openmobilityfoundation/mobility-data-specification

and acceptance by both e-scooter users and other road users, was not tested. One reason for not testing this was the advice from almost all e-scooter service providers that virtual zones alone would not have much impact on improving the parking situation. However, some e-scooter service providers, such as Bolt, have tested virtual parking zones around Olympia Park, specifically targeting events such as music festivals where there may be a spike in demand for e-scooter parking. The city is keen to work with these providers to learn from the results of this trial.

The city also recognises that inaccurate GNSS technology makes it difficult to implement geofencing-based parking systems, as GNSS inaccuracies can lead to false positives and false negatives in detecting e-scooters parked in designated parking zones. However, internal challenges and integration issues have hindered the implementation of sensor technologies that could improve the accuracy of e-scooter location data. These challenges included a lack of capacity to procure the necessary sensors and ongoing negotiations over whether it was permissible to install sensors on the posts of existing road signs. However, testing the use of these sensors is still considered necessary to minimise GNSS inaccuracy.

The project also aimed to automate the monitoring of the geofenced parking zones in order to respond much more quickly to incorrectly parked vehicles. However, almost no e-scooter service providers were able to connect to the monitoring data and analysis system via the MDS Policy API interface. As a result, automated enforcement of parking rules could not be tested.

Barriers analysis

- Lack of automated communication and monitoring of parking policies.
- Lack of standardised data formats and accurate data quality, as a valid database is required to create and enforce viable rules.
- Lack of procurement capacity to procure technology to reduce GNSS inaccuracy.

There are a number of other limitations to implementation. For example, privacy laws may prevent access to individual trip data to analyse where e-scooters are being ridden to find the most appropriate parking zone. Funding sources may also be limited for the installation of physical parking zones and the procurement of a monitoring data and analysis system. The installation of these parking zones and the potential reduction in parking spaces could also have an impact on public perception. Tighter regulations on free-floating modes of transport could also have a negative impact on the profits of e-scooter companies. As a result, there may be a trend towards exploring other types of micro-mobility and transport options.

BEHAVIOURAL CHANGE AND ACCEPTANCE

Behavioural change

In case study A, a survey was conducted to analyse the use of e-scooter parking zones and locations. Data provided by e-

scooter providers in Munich for September 2020-2023 was used for the analysis. The figures in Table 2 show the parking locations of returned e-scooters in the old town area. Black dots indicate locations within 30m of a parking zone, blue dots indicate locations outside of a parking zone, and cyan dots indicate locations outside of a parking zone but close (30m) to the boundary of the old town without a parking zone.

While in 2020 and 2021, e-scooter parking was scattered across most streets in the Old Town, in 2022 and 2023, following the introduction of the new parking scheme, parking was more concentrated within/around the designated parking zones. Note that all locations were actually confirmed by the provider as compliant parking. As there are still some blue dots in the figures in 2022 and 2023, this means that our estimate of compliant parking is stricter than that applied by the providers.

It is assumed that the providers use additional information or larger tolerances to detect compliant parking. Non-compliant parking is concentrated in areas around the parking zones, the old town boundary and some areas north of the old town. The latter may be related to inconsistent enforcement by one of the operators. The remaining rare incidents of parking far from the parking zones are probably related to technical problems, such as a low battery that occurred during a trip with an e-scooter.

Table 2. Estimates of e-scooter parking spaces and parking zone utilisation for 2020 - 2023.

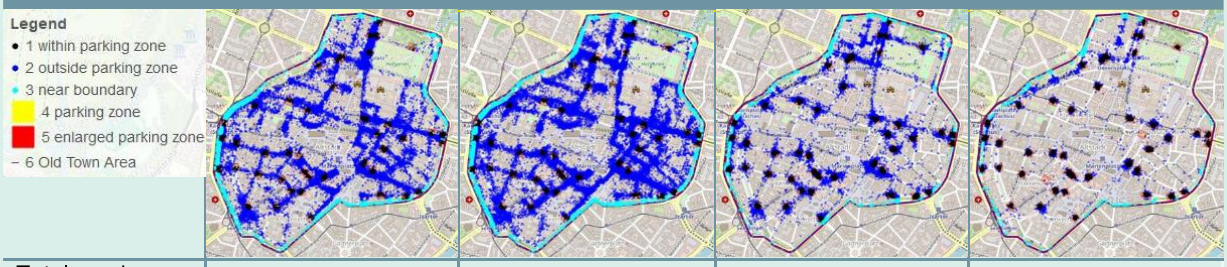
	2020	2021	2022	2023
				
Total number vehicles	32.686	51.026	39.928	28.004
Within parking zone (black)	18,1%	19,6%	71,0%	88,2%
Outside parking zone (blue)	72,3%	71,0%	23,5%	7,5%
Border (cyan)	9,4%	9,3%	5,5%	4,2%

Figure 3. Parking an e-scooter.

The remaining rare incidents of parking far from the parking zones are probably related to technical problems, such as a low battery that occurred during a trip with an e-scooter.

Table 2 also shows some more detailed figures to describe the parking behaviour. The total number of returned e-scooters in the Old Town was highest in 2021 and decreased significantly thereafter. This is despite the fact that the total number of e-scooter rentals in the whole city area increased. The effect is likely to be related to the quantitative limit of 400 vehicles allowed in the Old Town area at any one time, which is part of the voluntary commitment between the city and the providers from 2022. Whether the reduced number is the result of a change in user behaviour (e.g. more e-scooters parked in the area outside the Old Town) or is enforced by some measures and incentives from the providers remains to be investigated.

The percentage of e-scooters parked within the parking zone increased from around 19% in 2022/21 to 88% in 2023. Conversely, the percentage of e-scooters parked outside the parking zone decreased from around 72% in 2020 to 7.5% in 2023. Similarly, the number of vehicles close to the Old Town boundary decreased from around 9% in 2020 to 4% in 2023, suggesting an improvement and reduction in non-compliant e-scooter parking in this area, despite the challenges of enforcing correct parking in this area.

Overall, the data suggests a strong improvement in e-scooter parking. Fewer e-scooters are parked in the Old Town, and those that are were in most cases parked in/near a parking zone. It

should be noted, however, that the figures are an estimate and do not reflect the true situation of where e-scooters are parked due to the inaccuracy of the GNSS signal.

Acceptance survey

The main purpose of the acceptance survey was to evaluate the new parking regulation for e-scooters in the Old Town. Three groups that were in some way affected by the regulation were approached. First, an online survey (March 2023) was conducted among e-scooter users and completed by 346 participants. Second, a group of pedestrians visiting the Old Town was surveyed both with an on-site structured interview in the pedestrian zone of Munich's Old Town (September 2023, N = 52) and with an online survey in May 2024 (N = 703). As a third group, we surveyed business stakeholders (shop owners and craftsmen, 2024, N = 88) with an online survey. The 2024 pedestrian survey also included a significant number of participants who reported using e-scooters themselves (N = 218). This gave us the opportunity to analyse acceptance among e-scooter users again one year after the first evaluation.

Our survey design was based on an acceptability model previously used to evaluate travel demand management measures, but significantly shortened to capture only the most relevant aspects for the present use case. It included a direct assessment of acceptability (agreement with the scheme in the Old Town and other parts of the city) and the most influential factors such as perceived effectiveness (in improving e-scooter parking) and perceived usefulness. For the group of e-scooter users, we also included a question about the ease of use of the parking zones, which also addressed problems in using the parking zones. Knowledge of the new scheme and awareness of e-scooter parking issues were also assessed, as well as respondents' opinions on where and how e-scooter parking zones should be located, in order to guide the development of future solutions. The main findings from the surveys of the different groups are presented in Table 3.

The introduction of the scheme was most acceptable to the pedestrian group, followed by the business stakeholder group, and least acceptable to the e-scooter user group, although a majority of this group were still in favour of the scheme.

Acceptance of a similar scheme in other parts of the city was slightly lower among the pedestrian group and much lower among the e-scooter user group, where almost 50% were opposed. Acceptance among the business stakeholder group

Table 3. Key findings from the acceptance survey

	E-scooter user 2023 (N=346)		Pedestrians (N=755)		Business stakeholder (N=88)		E-scooter user 2024 (N=218)*	
Acceptance	**Pro:**	**Con:**	**Pro:**	**Con:**	**Pro:**	**Con:**	**Pro:**	**Con:**
Old Town	56%	14%	80%	8%	62%	16%	75%	15%
Other districts	40%	49%	83%	12%	74%	18%	68%	23%
Effectiveness to improve e-scooter parking	80%		75%		78%		84%	
Usefulness								
Advantages	25%		50%		40%		46%	
Disadvantages	53%		11%		12%		12%	

was again in between, interestingly slightly higher for other neighbourhoods than for the Old Town. Another interesting fact was observed when considering only e-scooter users in the pedestrian sample (last column in Table 3). Compared to the survey with e-scooter users in 2023, the acceptance rating for both the Old Town and other districts showed a strong improvement.

A similar number of respondents (around 80%) in all three groups considered the scheme to be at least somewhat effective in improving the situation with illegally parked e-scooters. Effectiveness was rated slightly higher by e-scooter users than by the other two groups.

Respondents in the pedestrian and business stakeholder groups were more likely than the e-scooter user group to find the scheme useful, and few of these respondents found it to be a personal or business disadvantage. In contrast, the majority of e-scooter users initially perceived the regulation as a personal disadvantage. We suggest that this is strongly related to the experience that important aspects of e-scooter use (e.g. flexibility and convenience of use, travel time and cost) have deteriorated as a result of having to comply with the scheme. At the same time, pedestrians and business stakeholders recognise the positive effects on safety and reduced potential for conflict.

The disadvantages for e-scooter users are at least partly related to problems encountered when trying to return an e-scooter in a compliant manner. One third of e-scooter users reported such problems and almost two thirds had problems finding a parking zone near their destination. Additional comments in the survey suggest that e-scooter users experienced technical problems that sometimes prevented the seamless return of e-scooters despite being in a parking zone. They also reported problems with insufficient or inaccurate information about parking rules/zones in operator apps.

Overall, the acceptance survey showed that a majority of respondents in each of the three groups surveyed accepted the introduction of the scheme in the Old Town. This is a promising result and indicates that the solution is a good approach to mitigating the problems associated with e-scooter parking. The survey results also show that the solution is not yet perfect, but provides valuable information and direction for future development and action on the technical and organisational aspects of a geofenced scheme. Although the current project has shown significant progress, further improvements are needed to reduce remaining public scepticism/rejection and to promote acceptance of both geofencing technology and micro-mobility offerings such as e-scooters.

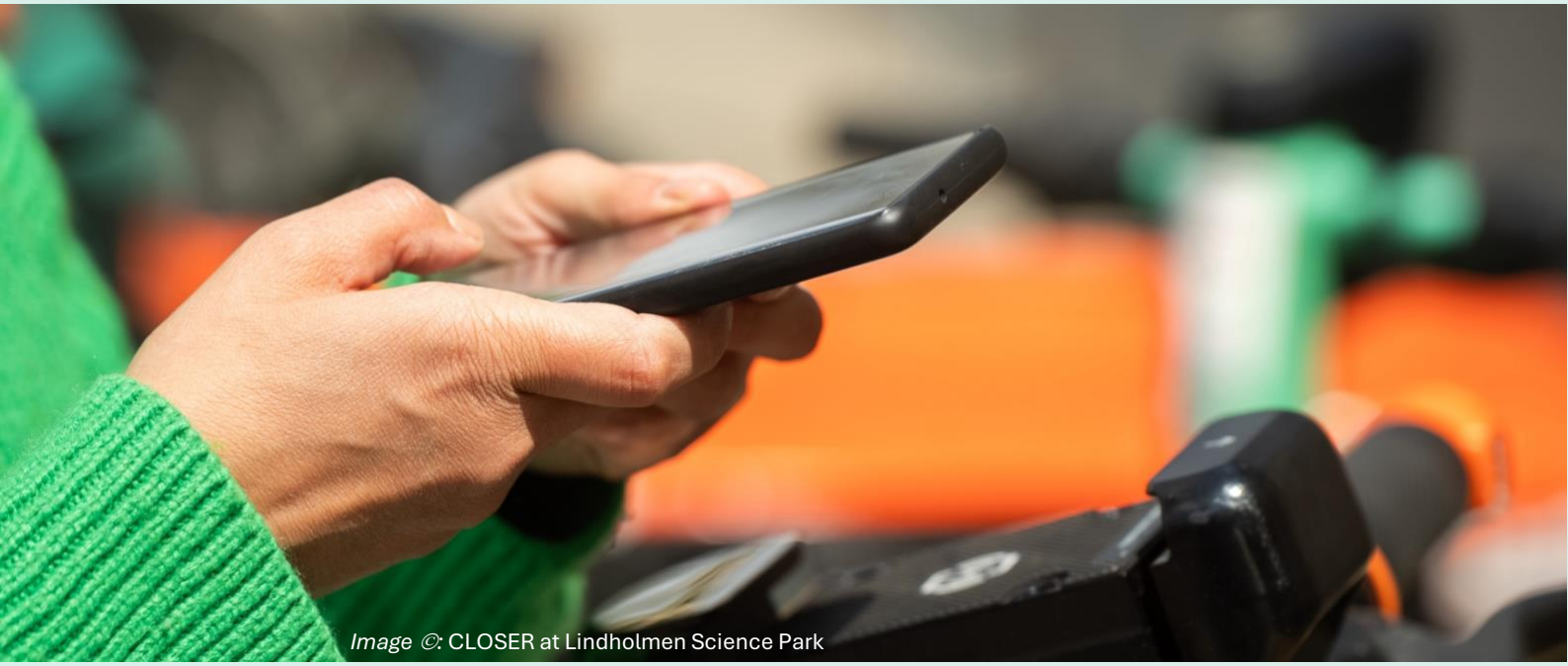


Figure 4. A person renting an e-scooter.

GOVERNANCE AND REGULATION

Developing better, smarter and more intelligent regulation is where geofencing comes in. It is helping cities like Munich to effectively manage new mobility technologies by facilitating dynamic, data-driven decision-making. Cities can improve public safety, efficiency and overall urban mobility by learning from pilot projects and continuously improving their regulatory approach.

Managing e-scooters

E-scooters appeared in Munich in 2019 without any prior data, leading to initial regulations driven by public complaints rather than evidence. Subsequently, Munich moved towards evidence-based regulation by facilitating data sharing agreements with e-scooter service providers. This trust building facilitated better regulation, allowing the city to allocate resources efficiently and plan new parking zones based on actual data.

Munich's approach has evolved into smart regulation, using e-scooter parking data to optimise parking zone locations. Although the city has not yet deployed data analytics algorithms, it recognises the potential for smarter regulation. This could include identifying areas with limited public transport where e-scooters could be a viable alternative.

Legal framework in Germany

The legal framework for the use of e-scooters and their participation in road traffic in Germany is set at federal level. If e-scooters comply with the regulations for small electric vehicles (eKFV), they can be ridden on roads and cycle paths. However, they are not allowed to be ridden on sidewalks or in pedestrianised areas. E-scooters must comply with a maximum speed limit of 20 km/h. They must be equipped with safety features such as brakes, lights and a bell.

All vehicles must be insured. They must also have a number plate and a separate unique identification number. This number is the main way of identifying

reported wrongly parked e-scooters. This is sometimes difficult as not all e-scooter operators use a universal identification number. Some also use the number plate to identify the vehicle. For this reason, citizens are asked to always send a location and a picture when reporting a vehicle. This makes it easier to identify the vehicle in question. To automate this process in the future, the city and the e-scooter service providers need to agree on a unique number to identify the vehicles.

To use an e-scooter on a public road, the rider must be at least 14 years old. No driving licence is required. Only one person can ride an e-scooter at a time. Riders must also obey traffic laws. This includes a low blood alcohol limit of 0.5 promille for driving an e-scooter. In terms of geofencing, it's also interesting to note

that in Germany, it's not allowed to regulate the speed of e-scooters in certain geofenced zones.

Special use or common use

There are no uniform laws governing the parking of e-scooters in Germany. The legal framework for e-scooters is therefore complex and varies from state to state and city to city. Munich, like many other cities in Germany, had classified station-independent sharing schemes such as e-scooters as shared use of public space. This has simplified implementation and reduced the administrative burden of introducing and using e-scooters. Shared use of public space allows e-scooter service providers to offer their e-scooters for hire on public roads without a special permit, within the limits of dedication and traffic regulations. However, cities may not benefit financially from public spaces used for rental services due to limited revenue streams as e-scooters are classified as shared use. Controlling the number and distribution of e-scooters and their use, as well as enforcing parking regulations, can also be challenging in this context.

The city of Munich has therefore entered into a voluntary agreement with the e-scooter service providers. Voluntary agreements cover a range of issues including data sharing, parking regulations, operating areas and fleet size limits. However, these agreements can be difficult to enforce if operators are unable to meet the requirements, as there are fewer ways to sanction non-compliance.

Recent developments have shown that as the number of e-scooters increases, so do concerns about road safety. To address this issue, recent court rulings have recommended that e-scooters be classified as a special use, for example in North Rhine-Westphalia. This allows cities to regulate the number of vehicles and operators in the city.

It remains to be seen how Munich will deal with common use and special use in the future. If common use continues to be regulated as it is now, the advantage is that new forms of mobility will be easily accessible. But there is also the disadvantage of limited control by the city. Classification as a special use has the advantage of regulating land use and charging fees. However, the bureaucracy is very high as a detailed concept is needed to introduce regulations based on special use classification.

Enforcement of parking violations

Enforcing parking offences related to e-scooters can be quite costly and labour

intensive. It is usually the responsibility of the police or local authorities to enforce offences relating to incorrectly parked e-scooters with a fine, usually around €30. In the case of parking offences, the fines are usually paid by the e-scooter service providers, as the authorities can't attribute an e-scooter to a single person and it is uncertain whether these costs will ultimately be passed on to the offenders. GPDR issues and rider liability also raise concerns about the ability of e-scooter service providers to pass the fine on to their users. After all, the user as offender is often not subject to a fine, and there is no opportunity for a learning effect when a fine is imposed for incorrect parking.

Governance

Geofencing is a powerful tool for regulators looking to become smarter, data-driven regulators. It allows for the collection and analysis of data from specific areas, enabling tailored regulation. Geofencing serves as an entry point for cities to experiment with smarter regulation, using data to predict trends and needs and develop alternative scenarios. The Munich use case is an example of how cities can gain regulatory competence and capacity through collaboration with stakeholders such as researchers and operators. The GeoSence project helped Munich to manage emerging technologies, for example by implementing temporary regulations on e-scooters during the Oktoberfest to address human risk behaviours such as drunk driving.

These regulatory approaches can be either top-down or bottom-up. The top-down method imposes immediate changes with little public input and is suitable for straightforward adjustments such as tax changes. The bottom-up method aims to change human behaviour and relies on gradual public acceptance and compliance. The Munich use case combined these approaches by using geofencing to influence parking and drink-driving behaviour, combining regulatory control (top-down) with behavioural change (bottom-up).

Overall, it is advisable to monitor and understand usage statistics in order to develop future regulations that take into account infrastructure challenges, safety concerns and environmental impacts. In order to develop sensible regulations, it is important to know your data in order to create sensible regulations. There must also be sufficient capacity to review them. It is also necessary to involve users, as they are responsible for the majority of parking offences.

IMPACT AND LESSONS LEARNED

Figure 5. E-scooter at public transport hubs.

Location-based services, such as geofencing applications, have the potential to improve urban planning. To achieve this, it is important to develop and test these services for use in the field and to integrate them into a holistic

transport policy. Small-scale testing is crucial to evaluate these new technologies, but a high potential for scalability should be kept in mind.

Impact of the study

To address the challenges posed by incorrectly parked e-scooters, Munich implemented geofencing technology. The three case studies were successful overall, but geofencing and policy evaluation need further improvement. The communication tools failed because automated parking enforcement was not possible and GNSS signals are still limited. However, parking zones for e-scooters and geofencing improved parking behaviour and road safety, leading to the permanent installation of parking zones in the Old Town. In addition, a temporary parking concept was successfully tested during the Oktoberfest, leading to the decision to develop temporary concepts for all major events in Munich. Overall, geofencing technology has made parking management more efficient for e-scoters and reduced the number of conflicts, as a significant level of parking compliance can be achieved based on the specific location.

Lessons learned

Geofencing has the potential to minimise the negative impacts of e-scooters in urban areas, as demonstrated in Munich. However, better regulation through geofencing requires stakeholder engagement and must ensure transparency and accountability in data collection and enforcement.

In particular, access to high-quality, relevant data is essential for smarter regulation. Munich learned that the volume of data is less important than its accuracy and relevance. To successfully implement geofencing, it's important to thoroughly analyse the data to create useful geofences and ensure their effectiveness. In addition to good data quality, geofencing policies must be consistently enforced, which can require significant resources. Munich has faced challenges in its attempts to automate parking enforcement to save resources. Ultimately, the most advanced geofencing technology for regulating e-scooter services is worthless if it's not properly implemented and enforced, and if the rules set are not appropriate for the use of e-scooters in the city. To achieve this, it's essential to have well-trained staff in city administrations and to follow the implementation cycle in Figure 6.

Implementing an MDS-based geofence regulatory zone can also be challenging due to unreliable supplier data and manual integration. Standardisation of technical APIs and processes is required to improve implementation and enforcement. International standards such as MDS therefore play a critical role in the assignment of geofenced zones and the implementation of traffic policies for e-scooters. However, these standards need to be further developed. Successful implementation of geofencing will also require local authorities and e-scooter service providers to establish collaborative relationships to ensure long-term viability and to fully utilise data for urban mobility. Smart regulation should also simplify administrative procedures to minimise the burden on e-scooter service providers. Effective regulation also includes public consultation and participation to ensure that policies are based on rigorous evidence and analysis. Munich aims to promote public

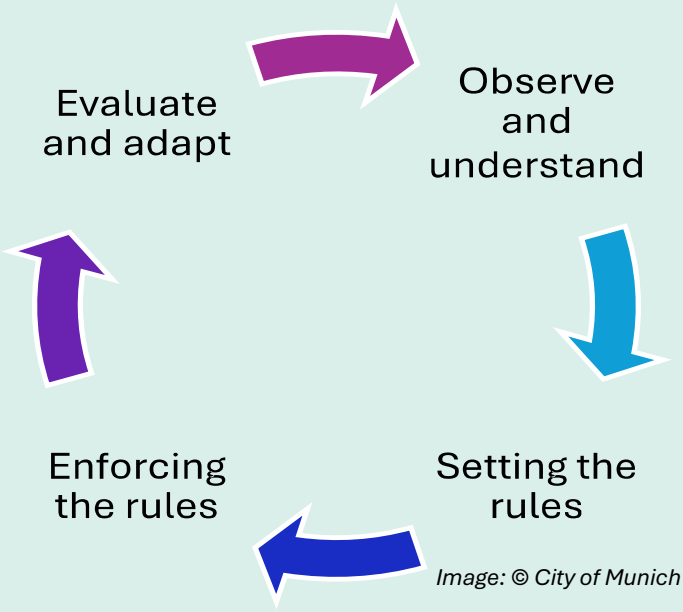


Figure 6. Munich model of the geofencing implementation circle.

Lessons learned

- Digital governance can be improved through a better understanding of geofencing.
- Data standards for receiving usage data and sending geofences need to be defined at European level.
- Visualise and work with data, get help when you need it and reduce the amount of data.
- Stakeholder cooperation at eye level is key.
- Regulations also need to be enforced, so you need the capacity to do that.
- Automation can help with enforcement, but it takes time to implement.
- GNSS inaccuracy is still an issue that needs to be addressed.

trust and understanding of the regulatory process, and to address the potential challenge of rapid rule changes that may outpace citizen engagement.

LOOKING TO THE FUTURE

Shared micro-mobility services, such as e-scooters, are an important element in meeting citizens' individual mobility needs. As a means of transport, especially for the first and last mile and in combination with public transport, they can help people to reduce the use of private cars. In doing so, they make a significant contribution to reducing emissions, improving space efficiency and making cities more liveable. To make e-scooters widely available and improve the parking situation, the city will create a comprehensive parking network. This will build on the experience of the GeoSence project.

Image: © N+P Innovation Design GmbH

Figure 7. Design of a new mobility hub.

Specifically, following a decision by the City Council in November 2023[3] , the Department of Mobility is planning to set up an e-scooter parking network throughout the city, with 675 e-scooter parking zones. Each designated parking zone will be surrounded by a 100 metre no-parking zone to ensure a better parking situation. This will be done in particular in the areas where the parking data shows a high parking density and will take into account the results of case studies A and C. In addition, a temporary parking concept for major events will be developed until 2025. This will take into account the results of Case Study B.

To enable a more data-driven approach in the future, all types of geofences will be made available through the city's geoportal[4]. E-scooter parking data will also be analysed as part of the city's MDAS project[5]. The aim is to have automated processes for sending new geofences with parking zones to e-scooter service providers, as well as assessing incorrectly parked e-scooters or overcrowded parking zones and reporting back to providers for action.

To reduce the number of incorrectly parked vehicles, the Department of Mobility is also working with the four providers in Munich to improve the visibility of no-parking and parking zones in rental apps. Part of the plan is to complete the trial of sensors to improve the accuracy of the vehicle's GNSS.

The city is also testing how geofencing can be used to efficiently manage the use of parking zones for e-scooters or other vehicles as part of another European project called metaCCAZE[6]. In this project, the city will test the digitalisation of parking management, such as dynamic parking space usage.

Overall, the use of geofencing in Munich is an excellent example of how technology can be used to address the challenges associated with e-scooters. By combining data-driven decision making with geofencing technology, cities can ensure that e-scooters are a safe and convenient mode of transport for all. As e-scooters continue to grow in popularity in cities around the world, geofencing is likely to become an increasingly important tool for managing this mode of transport.

[3] https://muenchenunterwegs.de/news/regionales-bikesharing-system-und-mehr-abstellflaechen-fuer-mikromobilitaet

[4] https://geoportal.muenchen.de/portal/opendata/

[5] https://muenchen.digital/digitalisierungsradar/Mobilit-t.html

[6] https://www.metaccaze-project.eu/

ANNEX 1 PARKING ZONES IN THE OLD TOWN, MUNICH

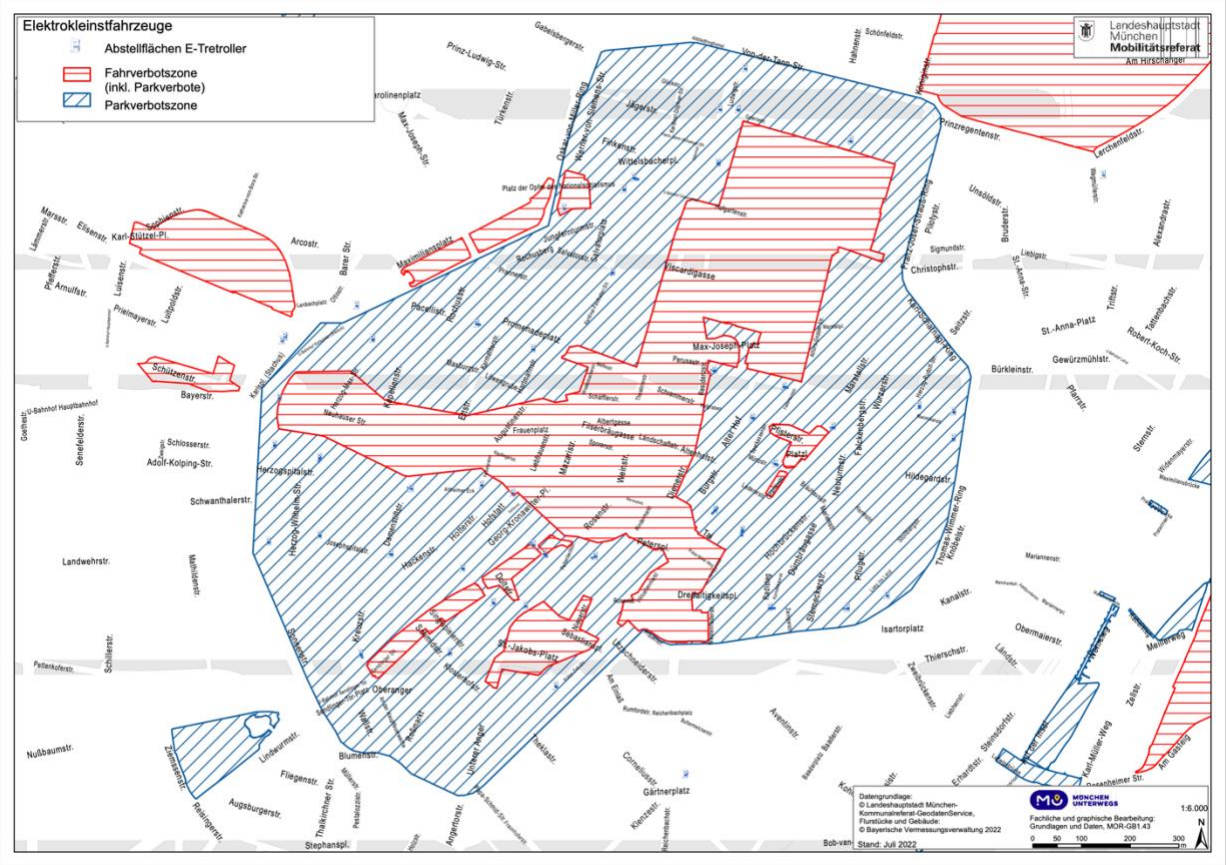


Image: © City of Munich

ANNEX 2 TEMPORARY CONCEPT DURING THE OKTOBERFEST, MUNICH

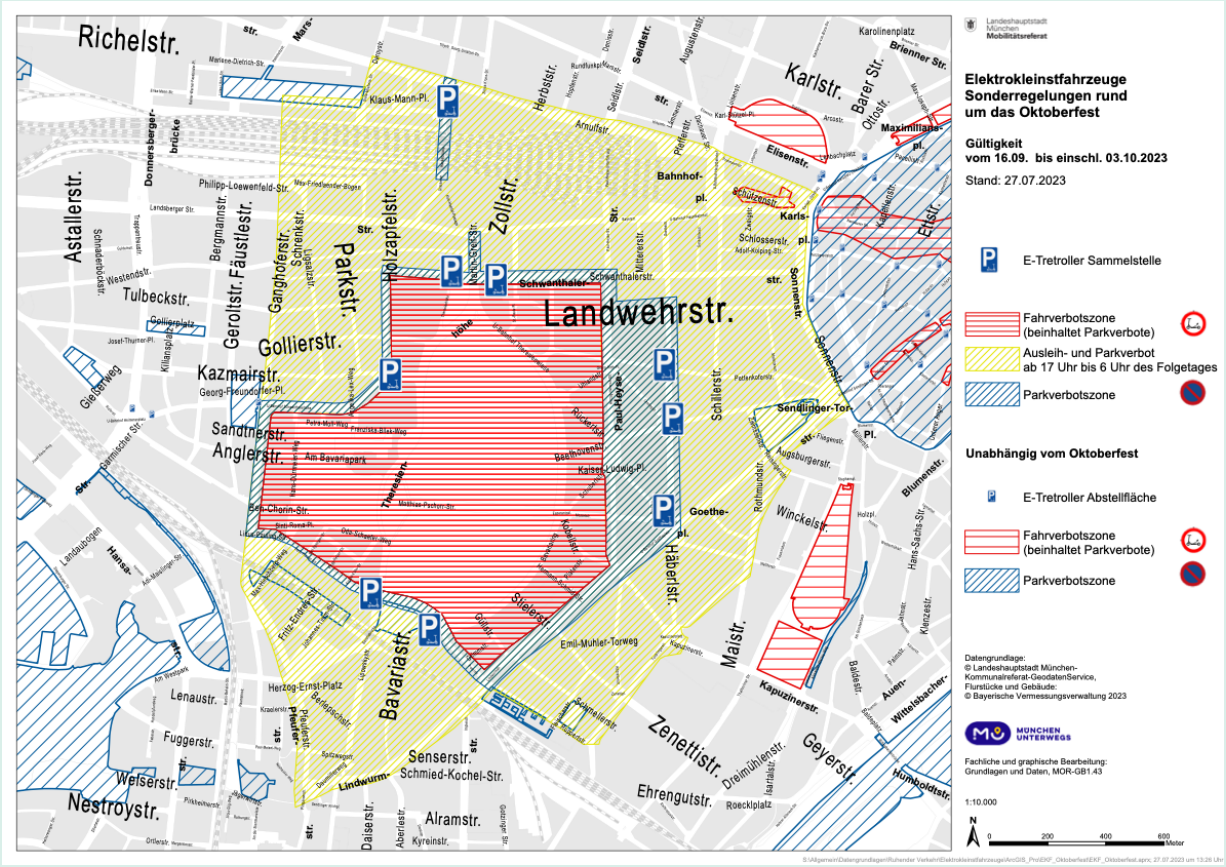


Image: © City of Munich