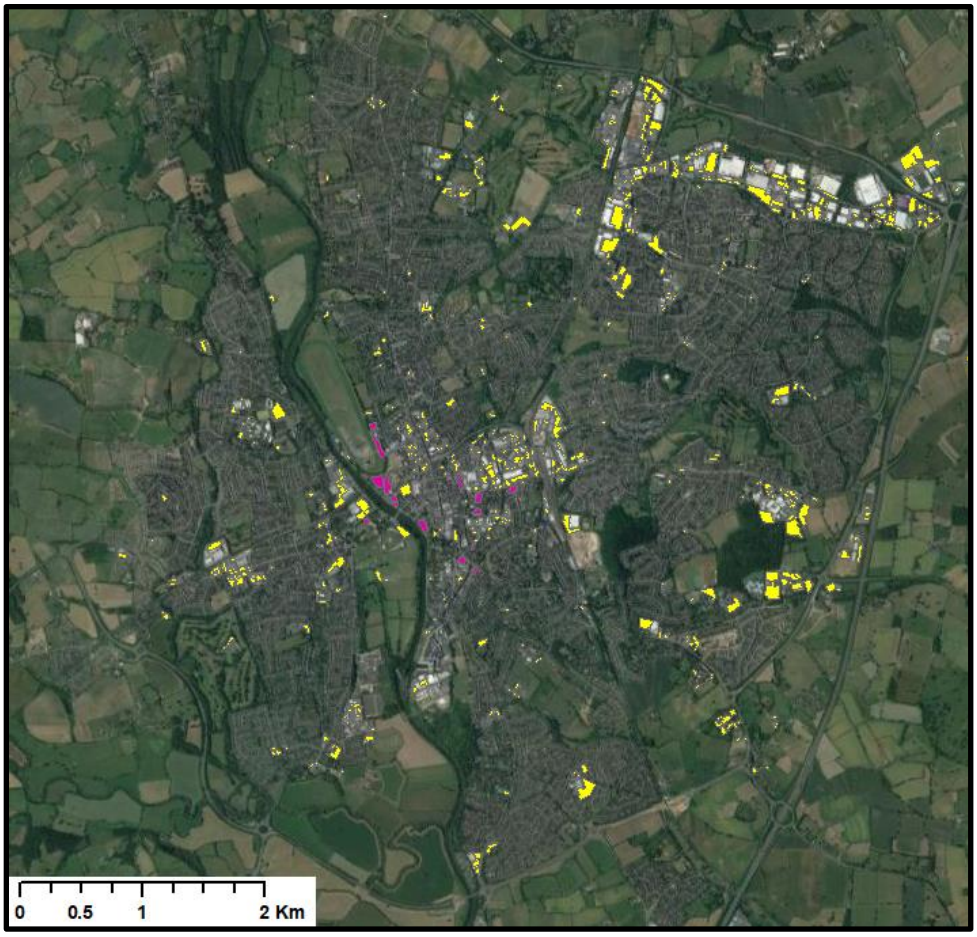
MAPPING PRIVATE NON-RESIDENTIAL PARKING IN WORCESTER ENGLAND



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WPI University of Worcester

Mapping Private Non-Residential Parking in Worcester, England

An Interactive Qualifying Project
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfilment of the requirements for
the degree of Bachelor of Science

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ABSTRACT

With changes in travel patterns in the UK, as much as 30% of current parking space may be underutilized in the future. Many cities are exploring how such unused parking might be repurposed but lack good data on current parking provision. Using ArcGIS software and Google Satellite imagery, we found that Worcester has 429 Private Non-Residential (PNR) carparks providing 54,905 parking spaces, which far exceeds the 2,440 spaces provided by the 14 municipal car parks. We tested our procedures in Gloucester and believe these protocols could be easily applied to assess parking in other cities. Knowledge of PNR parking will help local governments repurpose underused carparks and following the example of Nottingham implement workplace parking levies as a means to improve public transportation.

ACKNOWLEDGEMENTS

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Thank you.

EXECUTIVE SUMMARY

Worcester has set a goal of carbon neutrality by 2030 which means it needs to take a significant look at how people travel. The recent pandemic has contributed to the already growing trend of people working, shopping, and pursuing other activities from home which means there are less cars on the road. This correlates with an expected 30% decrease in need for parking space and the work and store areas where people would have left parked cars before is now going unused. However, PNR parking in unregulated in Worcester and many other cities which means city officials have no idea where parking is located and how much it is being used – or unused. Additionally, an overabundance of PNR parking makes it too easy for people to drive walkable distances to the city center and disincentivizes the use of public transportation.

Therefore, the goal of this project was to develop a procedure to assess, quantify, and map private non-residential (PNR) parking to expose the potential for the reuse and redevelopment of excess parking to promote more efficient and sustainable use of scarce transport network capacity. To complete this goal, we developed several intermediate steps:

1. Develop preliminary guidelines to map the PNR parking in Worcester.
2. interview field experts about the reuse and redevelopment of current parking areas in Worcester and how to increase the use of public transportation.
3. Write a detailed procedure such that our work can be completed by other groups for other cities.

Through our mapping process, we found that the number of PNR carparks totaled 429 and contained a total of 55,000 parking spaces which occupied an area of almost one square kilometer within the city (Figure 1). If 10% of this space were to be converted into houses, nearly 1000 three-bedroom homes could be built within the city. In contrast to the number of PNR parking spaces, there are approximately 2,500 municipal parking spaces in the city of Worcester. These spaces account for a miniscule 4.4% of all non-residential parking spaces in the city.

Once all of the PNR carparks had been located and mapped in Worcester, we completed an analysis on the location of these carparks. One of Worcester's long-standing goals has been to decrease car traffic within the city center due to the congestion and air quality problems that this traffic causes. This brought our focus to the city center since a small number of parking spaces within this area would discourage car traffic, since commuters would have difficulty parking. From our analysis, we found that the center of the city, in spite of the city's effort to reduce car traffic, actually contained the most PNR carparks (a total 114) and the second most parking spaces. The location in the city with the most PNR parking spaces was determined to be in the area located between 2km and 3km of the city center. In this section, there are approximately 28k parking spaces, totaling around 33% of the city's total PNR parking provision.

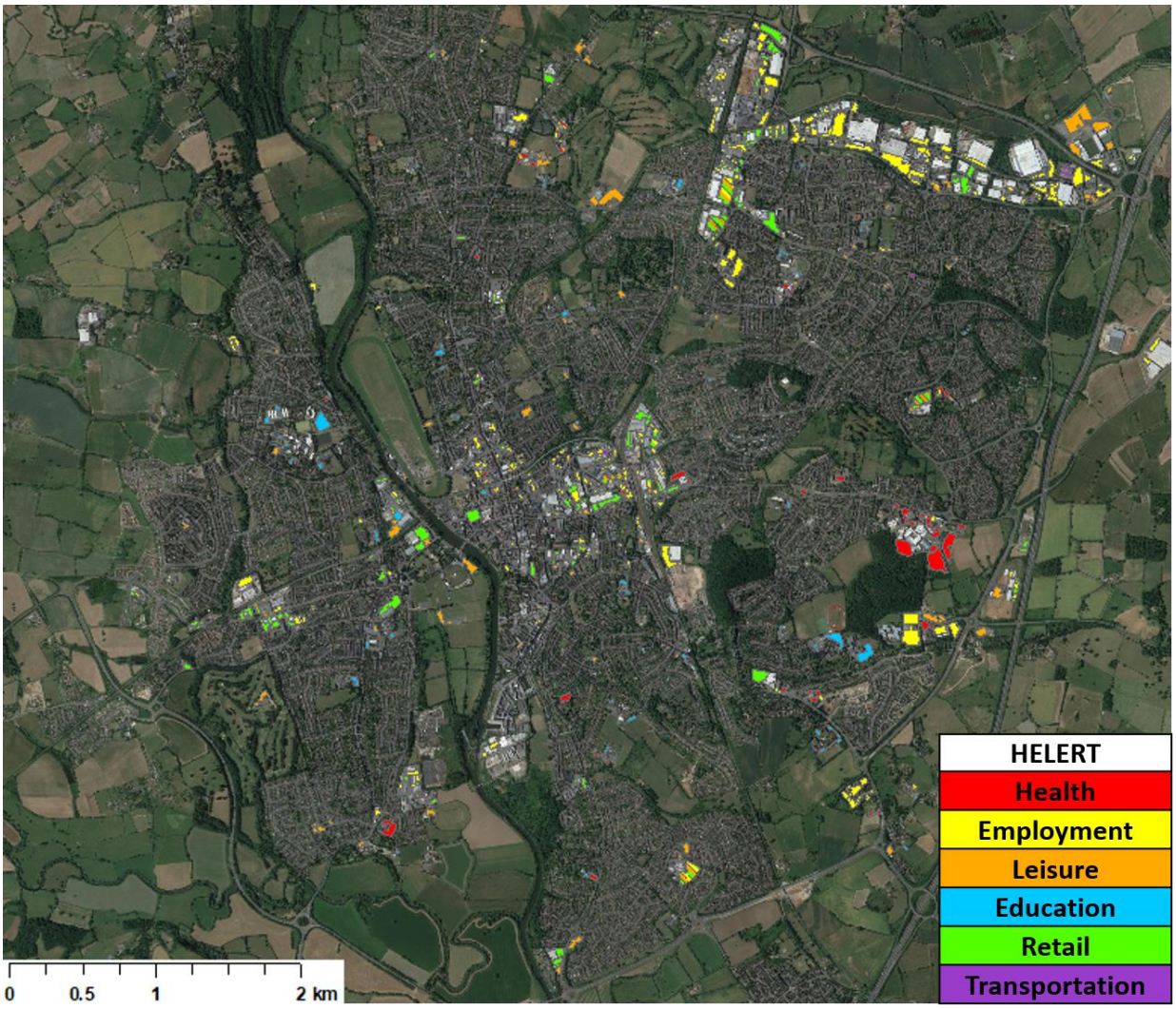

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Figure 1. Worcester PNR carparks color coded by their associated HELERT use class(es).

Following the location analysis, we completed an analysis of the carparks' use, which can be used to propel further research into the times of carpark peak use and commuter stay lengths. From this, we found that the most common use for PNR carparks is employment with nearly 48% of the city's total PNR parking space being used completely or partially for employee parking. The second most common use of PNR parking space is retail, at nearly 32% (

Table 1). Carparks with employment and/or retail uses will likely see the greatest underutilization in the future as an increasing number of people switch to shopping online and working from home. This means there will be significant space available for reuse.

Table 1. Statistics on the distribution of Worcester PNR carparks based on their HELERT classifications.

HELERT	Carparks Number	Carparks Percent	Parking Spaces Number	Parking Spaces Percent
Health	39	9.03 %	5,445	9.92 %
Employment	205	47.45 %	26,246	47.80 %
Leisure	126	29.17 %	15,886	28.93 %
Education	58	13.43 %	4,602	8.38 %
Retail	112	25.93 %	17,362	31.62 %
Transportation	2	0.46 %	60	0.11 %

After mapping all the PNR parking in Worcester and adding additional data to each lot including the surrounding businesses and use class(es), we created a detailed procedure outlining our process. This procedure gives step-by-step instruction on how to use ArcGIS to map PNR parking and guidelines about what information to include. This procedure will allow future teams to map, analyze, and update the PNR parking in any city around the world. To test our procedure, we strictly followed the procedure to map Gloucester UK in to check for discrepancies between our mapping actions and our written instructions. With this information, we were able to eliminate any discrepancies from the procedure.

Across the interviews that we performed, there were five topics which surfaced repeatedly: congestion, consolidated parking, repurposing carparks, improving public transportation, and the implementation of a workplace parking levy. Congestion in the city center is a big problem partially due to the amount small carparks spread through the city. By consolidating these carparks into larger carparks on the outskirts of the city, the congestion would improve as commuters could park in the larger lots and take public transportation to the center of the city. This would allow some of the small lots to be repurposed into parklets, housing, bike storage, and more and would create a need to improve the public transportation system. All interviewees thought implementing a workplace parking levy would help fix these problems.

From our research, we propose three courses of action regarding repurposing underused carparks, completing the mapping process, and use of our procedure. There are 429 PNR carparks and 55,000 parking spaces in Worcester; with the assumption of a 30% decrease in parking post-pandemic, roughly 16,500 of these parking spaces underutilized. Therefore, we recommend the repurposing of these unused parking areas as parklets, bike storage, housing, or other useful spaces. This would help reduce the congestion currently in the center of the city. Another way to reduce the congestion is by implementing a workplace parking levy to create a cash flow for improving public transportation or repurposing the underused lots. Together repurposing the smaller underutilized carparks and using the WPL revenue to improve the public transportation network the congestion of privately owned vehicles in the city center will decrease. Secondly, mapping took a total of 80 hours. It is our assumption that these maps will need to be updated every few years as businesses come and leave the city and new carparks are created. Therefore, city council could hire students over the summer to update the maps following the detailed procedure we have provided. Lastly, after testing our procedure in Gloucester, we learned that by following our procedure we can cut the mapping time down to about 60 hours for a city larger than Worcester. Based on this information, we recommend that our procedure be used when mapping the PNR parking in cities because it is proven to be faster than mapping a city without any guidelines.

AUTHORSHIP

The report was written by Joshua Geyster, Rowan Labaugh, Mary Marquette, and Daniel Trainor. The breakdown of authorship by section is shown below.

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Abstract	All	Rowan Labaugh
Acknowledgements	Mary Marquette	
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2.2. Parking in the UK	Joshua Geyster	Mary Marquette
2.3 Parking Policy Case Studies	Mary Marquette	
2.4. The Need for Decarbonization	Daniel Trainor	
2.5. Background Summary	Mary Marquette	
3.1. Develop PNR Parking Assessment Tool	Daniel Trainor	Joshua Geyster
3.2. Determine Opinions of Stakeholders & Field Experts	Mary Marquette	
3.3. Create and Test Procedure	Joshua Geyster	
3.4. Methods Summary	Mary Marquette	
4.1. PNR Parking Assessment Procedures	Mary Marquette	
4.2. PNR Parking in Worcester	Joshua Geyster	Daniel Trainor
4.3. PNR Parking in Gloucester	Mary Marquette	Joshua Geyster, Daniel Trainor
4.4. The Workplace Parking Levy	Mary Marquette	
4.5. Stakeholder Perspectives	Mary Marquette	
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1 INTRODUCTION

Over the past few decades, there has been a growing concern about emissions of greenhouse gases and the resulting increase in average global temperatures. If not controlled, such changes could be catastrophic for not only the environment, but also the global economy (Cossutta, Foo, Tan, 2021, pg. 259). In response, the UK government has established two overarching emissions goals. The first is that by 2030, there will be an 80% reduction in carbon emissions compared to that of 1990. The second is that by 2050 the UK will achieve net zero carbon emissions (Cossutta, Foo, Tan, 2021, pg. 266). The City of Worcester has set a more ambitious goal to achieve net zero carbon emissions by 2030, twenty years earlier than the rest of the UK.

To achieve this goal, many in Worcester recognize the need to move away from single-occupancy car use to more sustainable options of public transportation, walking, and biking. Recent trends in the UK and Europe show a decline in travel as more people are working from home and shopping online and this has resulted in less demand for parking. Cities around the world are exploring innovative ways to repurposing underused parking spaces to promote environmental sustainability. Innovative strategies range from using excess parking space for housing, parks, farmers markets, and package delivery storage and staging areas. The City of Worcester is likely facing similar trends and opportunities, but very little is known about the location, amount, and use of parking areas besides municipal facilities.

Therefore, the goal of this project is to develop a procedure to assess, quantify, and map private non-residential (PNR) parking and identify the potential for the reuse and redevelopment of excess parking to promote more efficient and sustainable use of scarce transport network capacity.

To achieve our goal, we developed three objectives:

1. Develop a procedure to assess PNR parking in Worcester, UK.
2. Determine the opinions of stakeholders and field experts about the reuse and redevelopment of current parking areas in Worcester.
3. Modify the parking assessment procedure, based on results in Worcester, and then test the procedure in Gloucester, UK.

We completed these objectives by using ArcGIS and Google to gather data and map private non-residential parking. In addition, we conducted interviews with different members of the community and experts in redeveloping underused parking.

2 BACKGROUND

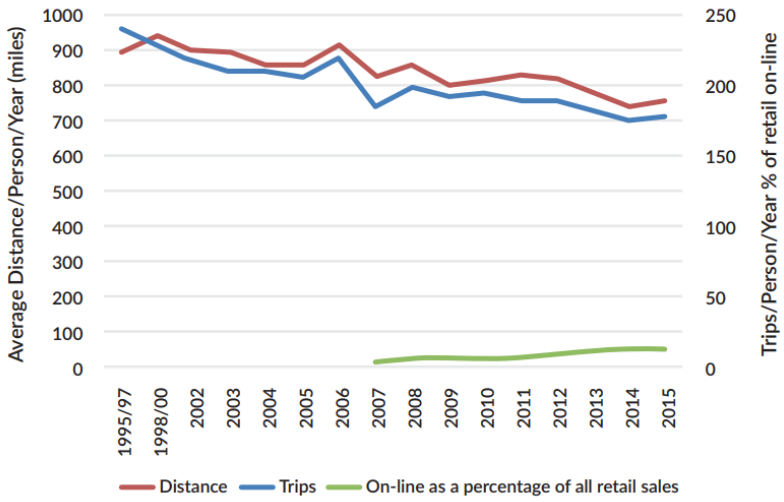
This section reviews current research relevant to parking in the UK. Topics covered include parking and traveling trends, planning guidelines for parking provision, parking provision in Worcester, innovative approaches to repurposing parking in Europe and elsewhere, and efforts to decarbonize surface transport in the UK.

2.1 CHANGING PATTERNS IN TRAVEL AND PARKING

The issue of excess car parking in the UK has been slowly growing for the past 25 years as travel patterns have changed and been accelerated and reshaped in the past year under the pandemic; a decrease in overall travel coupled with an increase in alternative means of travel such as public transportation and bikes means that land formerly packed with parked cars may now be empty for extended periods. As car parks in the UK occupy a significant 15-30% of urban area (Department for Transport, 2019) it is necessary to gain a greater understanding into their current use to ensure land is being used to its greatest potential.

The number of travel trips has been trending down since the late 1990s; UK citizens make 16% fewer trips than they did in 1996 and use motorized transport for almost 14% fewer trips than they did in 2002. Additionally, railway trips have increased by 56% in the past 25 years (Marsden, Dales, Jones, Seagriff, Spurling, 2018).

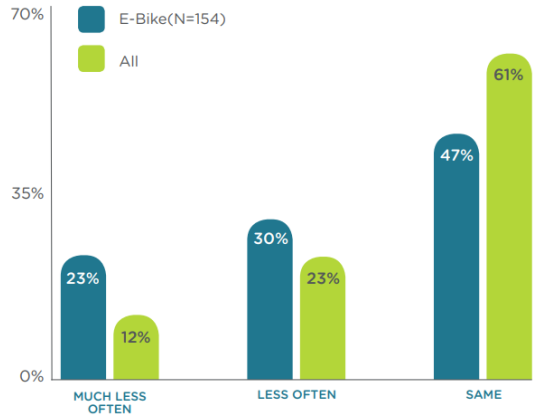
Advances in technology have allowed people to work from home, engage in online shopping, use ridesharing, and find available parking more easily. Many people now opt to shop, as well as work, from home. A survey conducted in 2018 by McKinsey & Co. showed that 20% of UK consumers predominately use online shopping for non-perishable items (Periscope, 2018) while online food orders have increased 50% between 2011 and 2015 (Marsden *et al*., 2018). Overall, the number and distance of shopping trips by car declined 30% between 2005 and 2015 as seen in Figure 2.**Error! Reference source not found.** (Marsden *et al.*, 2018). “Such shifts have implications for parking because parked cars form the interfaces of such activities with road networks. If patterns and overall quantities of trips are changing, there are *likely* parallel changes in parking too” (Spurling, N., 2020, p.2).



(Marsden, G. et al. 2018)

Figure 2. Decline in Physical Shopping Trips

The development of bikeshare programs and the *Last Mile* initiative[1] has begun to encourage commuters to bike, rather than drive personal cars, especially in city centers. The development of electric bikes and scooters makes it easy to travel further and as people are less concerned about their safety and capability due to their fitness level. In the UK 23% of bike share users reported using their cars much less due to ebike sharing as shown in Figure 3 (CoMoUK, 2020).



(CoMoUK, 2020)

Figure 3. Bike share users report using their vehicles less often.

Although bikes and scooters still take up parking space, they occupy drastically less space than a car. Often, cycle parking provision is included in the construction of footways and other dead space around cities, where there is not enough space for regular vehicle parking.

[1] The Last Mile initiative aims to encourage and provide the infrastructure for commuters to travel the "last mile" from a public transportation stop to their end destination without the use of vehicles.

For longer rides requiring a larger motorized vehicle, carpooling offers a green alternative to single occupancy car travel. Carpooling eases impacts on greenhouse gas emissions and traffic, but also on the number of parking spaces required per person. Applications, such as BlaBlaCar and Liftshare, allows users to identify other individuals with whom they might share a ride. Liftshare is the oldest and largest car-sharing program in the UK, and boasts having saved a total of 1.4 billion miles of road traffic since it was started in 1998 (Liftshare for Work, n.d.). BlaBlaCar, which is popular across Europe, had 60 million users as of 2018 (Dillet, 2018).

If one is unable to find a carpool through BlaBlaCar, Uber and Lyft, provide another alternative. The 2010 rise of ride-hailing technology increased the use of such transportation dramatically; their counterpart, taxis, can be difficult to contact and often have long wait times for pickup. A 2019 study conducted in Denver Colorado showed that, had Uber/Lyft not been an option, 26.4% of riders would have instead driven, and had to park, at their destinations (Henao & Marshall, 2018). Thus, use of ride-share negates the need for destination parking and may decrease the need for parking space overall.

Technology has not only helped people to find rides, but also advanced the way in which commuters find parking (Department for Transport, 2019). Parkopedia allows users to find carparks near their destinations before they leave home while the emerging UK companies such as ApplyParking and SmartPark will allow users to identify available parking in real time without having to cruise to park. This decreases congestion on roads as well as allows for decreased parking space because users will be able to see exactly where they need to go.

The rise of technology has allowed UK citizens to take advantage of new ways to work, shop, and pursue leisure activities. This technology has been pushed most noticeably by the Coronavirus pandemic in changing the way people work and shop but has been slowly motivated by a growing concern about greenhouse gas emissions, overcrowded roads, and physical fitness. All such factors have contributed to a number of trends illustrating how people travel shorter distances and make fewer trips the latter of which directly correlates to a greater number of unused parking spaces.

The Coronavirus Pandemic has pushed the use and development of technology, such as conference technologies used for virtual meetings as well as solidified the fact that working from home is possible.

According to McKinsey & Co., “Hybrid models of remote work are likely to persist in the wake of the pandemic,” and up to 33 percent of total worktime for the UK population could be spent working from home with no decrease in productivity (McKinsey Global Institute, 2020). More employees working from home means a lesser need for parking spaces at private businesses, most significantly those in the fields of finance, market research, and other online accessible fields. In the city of Worcester, based on 2019 census data, there may be upwards of 11,650 jobs that can be performed in a remote environment due to the nature of the tasks involved (Nomis, n.d.). These jobs make up about 22% of the total full and part-time jobs within the city (Nomis, n.d.).

These trends are reflected elsewhere in the world and are likely to continue into the far future. While data do not exist to illustrate trends specifically in Worcester, it can be assumed that the decreased travel seen across the UK is reflected in this city. However, to assess the reallocation of Worcester areas currently designated as carparks, additional data must be gathered on the types of parking areas that exist in the city, their physical specifications, and their average and peak occupancies.

2.2 PARKING IN THE UK

Parking in the UK is typically broken down into three different types: Municipal, Residential, and Private Non-residential (PNR). Municipal parking and PNR parking both serve workers, shoppers, and other travelers, but municipal parking is owned by the local government and is a major source of revenue. Residential and private parking guidance is typically set by the Local Highway Authority which under the County Council or Unitary Authority). Residential parking guidance is typically based on the number of bedrooms and private parking guidance is typically based on the Use Class and size of the development in question. Unfortunately, much private parking in the UK is undocumented and unregulated because it predates the planning regulations set forth by the state and local authorities. "An essential preface to any paper on the parking scene in Great Britain must be a caution about the availability of parking statistics … [Parking] supply, usage and pricing are probably the least well researched and documented of any aspect of transport in Great Britain." (Bayliss 2002 qtd. In Bates & Liebling 2012 p.2).

2.2.1 Parking Planning

Private parking is not owned or operated by the local or county authorities, but when new developments or significant renovations are proposed, the developers must seek planning permission from the local council's planning committee (Department for Communities and Local Government, 2015). When an application for planning permission is submitted in a city such as Worcester, the case officer will take both local and national planning policies into account (Department for Communities and Local Government, 2015). Handed down from the national level, the National Planning Policy Framework (NPPF) provides general guidance for developing policies on the provision of parking. In section 105, the NPPF states:

> 105. If setting local parking standards for residential and non-residential development, policies should take into account:
>
> a) the accessibility of the development;
> b) the type, mix and use of development;
> c) the availability of and opportunities for public transport;
> d) local car ownership levels; and
> e) the need to ensure an adequate provision of spaces for charging plug-in and other ultra-low emission vehicles.
>
> (Ministry of Housing, Communities and Local Government 2019)

Based on this framework, the counties and districts assess and provide the cities with guidance on the provision of parking.

2.2.2 Residential Parking Policy

Modern parking policies regarding residential parking, otherwise known as origin parking, are generally based on the number of bedrooms within the associated dwelling ("Suffolk Guidance for Parking", 2019). These recommended number of parking spaces may take the form of on-street parking spaces, garages, or front plots. In the UK, "Four fifths of all dwellings have a front plot... Homes built between 1919 and 1964 are most likely to have a front plot, and houses built after 1965 are least likely to have it paved over as these homes were built with adequate front gardens and sufficient garage or other parking" (Bates & Liebling 2012).

However, due to the wide variety in the age of dwellings, analyzing residential parking solely using bedrooms as a guidance would not be all that useful. Other factors such as local population density, the types of dwellings, and number of dwellings in the building, may be taken into consideration, in addition to the number of bedrooms, when planning parking for a residence. In Buckinghamshire for example, a more comprehensive set of standards for residential parking provision was created. The county was divided into one of three zones and based on the zone and the number of dwellings a number of parking bays was assigned to each dwelling within the development ("Buckinghamshire Countywide Parking Guidance", 2015).

In our assessment of parking within Worcester, residential parking will not be taken into consideration because it is rare that residential parking is left underutilized because "[t]he average car spends about 80% of the time parked at home" (Bates & Liebling 2012). In fact, it is often the case that there is not enough residential parking, especially in urban and densely populated areas (Bates & Liebling 2012).

2.2.3 Private Non-Residential Parking Policy

While residential parking relies heavily on the number of bedrooms and local population metrics, PNR parking, otherwise known as destination parking, is based mainly on the use class of the development ("Suffolk Guidance for Parking", 2019). These use classes were established in the Town and Country Planning (Use Classes) Order 1987, or UCO 1987, to regulate planning permission. This order set out to redefine and replace the land use classes defined in the previous version of this legislation. Under the UCO, planning permission is not required for a building to change from one use within a class to another use within the same class. These use classes, as they were originally defined in 1987 are summed up below in Table 2.

Table 2. Use classes as defined originally when UCO 1979 was enacted.

(The Town and Country Planning (Use Classes) Order 1987)

Class	General Use Description	Class	General Use Description
A1	Shops	B8	Storage or distribution
A2	Financial and professional services	C1	Hotels and hostels
A3	Food and Drink	C2	Residential institutions
B1	Business	C3	Dwellinghouses
B2	General Industrial	D1	Non-residential institutions
B3 – B7	Special Industrial Groups	D2	Assembly and leisure

Over the past 30 years, the UCO 1971 has been amended a total of 12 times (The Town and Country Planning (Use Classes)(Amendment) (England) Regulations 2020). These amendments serve to expand, consolidate, and redefine the original use cases. The most recent of these amendments was enacted on September 1st, 2020. In this new amendment, class A, class D, and parts of class B were omitted. From these three omitted parts, three new classes were created, E, F.1, and F.2 (The Town and

Country Planning (Use Classes)(Amendment) (England) Regulations 2020). These use classes are summarized in Appendix A, where the three new main classes are broken into subclasses for the sake of definition. Planning permission would not be required to swap subclasses if the main use class is preserved. All building types not listed are considered to be Sui Generis, or "in a class of its own"(Planning Portal n.d.).

In counties such as Buckinghamshire, Suffolk, and West Sussex, well defined private parking standards can be easily found. Both Buckinghamshire and Suffolk released their standards prior to the 2020 amendment to the UCO 1979, so their standards include cases A and C. Within each use case, the most common metric for the evaluation of parking across these three counties is the Gross Floor Area or GFA; however, other metrics considered, depending on the use case, include public floor area, staff numbers, and bed numbers. For example, in Buckinghamshire, restaurants should have 1 parking space per 17 m^2, but in Suffolk county, this metric is based off the public space within the establishment (1 space per 5m^2 of public space) ("Buckinghamshire Countywide Parking Guidance", 2015) ("Suffolk Guidance for Parking", 2019). A detailed overview of PNR parking standards in Buckinghamshire, Suffolk, and West Sussex can be found in the tables of Appendix B and Appendix C.

2.2.4 Parking Policy in Worcester

Like other counties, the Worcestershire County Council provides for its local planning authorities, guidance for parking planning. This guidance comes in the form of the 2016 Interim Parking Standards and the newer 2020 Streetscape Design Guide. Both of these documents establish similar rules for the provision of parking within the county and cover both private and residential parking.

In Worcestershire, the residential parking standards are as follows:

- 1 Bedroom Unit - 1 Space, 1 cycle space
- 2 – 3 Bedroom Units – 2 Spaces, 2 cycle spaces
- 4 – 5 Bedroom Units – 3 Spaces, 2 cycle spaces

(Worcestershire County Council 2020)

Since Houses of Multiple Occupancy (HMO's) fall into their own Use Class, they require different standards from the general residential buildings. In Worcestershire, HMO's with less than three bedrooms do not require planning permission, so they have no established standards for the number parking spaces. However, HMO's above 3 bedrooms have the following rules:

- 4 Bedrooms – 3 Required Spaces
- 5 Bedrooms – 3 Required Spaces
- 6 Bedrooms – 3 Required Spaces
- 7 Bedrooms – 4 Required Spaces
- 8 Bedrooms – 4 Required Spaces
- 9+ Bedrooms – Must Demonstrate Provision, but Minimum of 4 Required Spaces

Within Worcestershire, private parking standards are not as detailed as those reviewed above for Buckinghamshire, West Sussex, and Suffolk. Instead, proposed private parking plans are assessed on a case-by-case basis, where "commercial operators should have a good understanding of the needs of their business and will determine how land under their control could be managed" (Worcestershire

County Council, 2020). As part of their planning application the landowner must provide an evidence base to demonstrate the appropriateness of the proposed minimum parking provision (Worcester County Council, 2020).

2.2.5 Parking Provision in Worcester

In Worcester, there are a total of 14 municipal carparks managed by the Worcester City Council, 13 of which are surface lots with the additional one being a multi-story carpark, St. Martin's Gate (Worcester City Council Parking and Enforcement Services, 2019). The 14 off-street carparks are broken down into three groups, red, amber, and green based on the park's proximity to the city center. Parking fees are then assigned accordingly to each zone, with red being the most expensive and green being the least expensive. Across the city's 14 off-street carparks, there are a total of 2,440 regular parking spaces, 78 blue badge spaces, and 8 coach/lorry spaces. This distribution of zones and lot sizes for the 14 off-street carparks is shown below in Table 3.

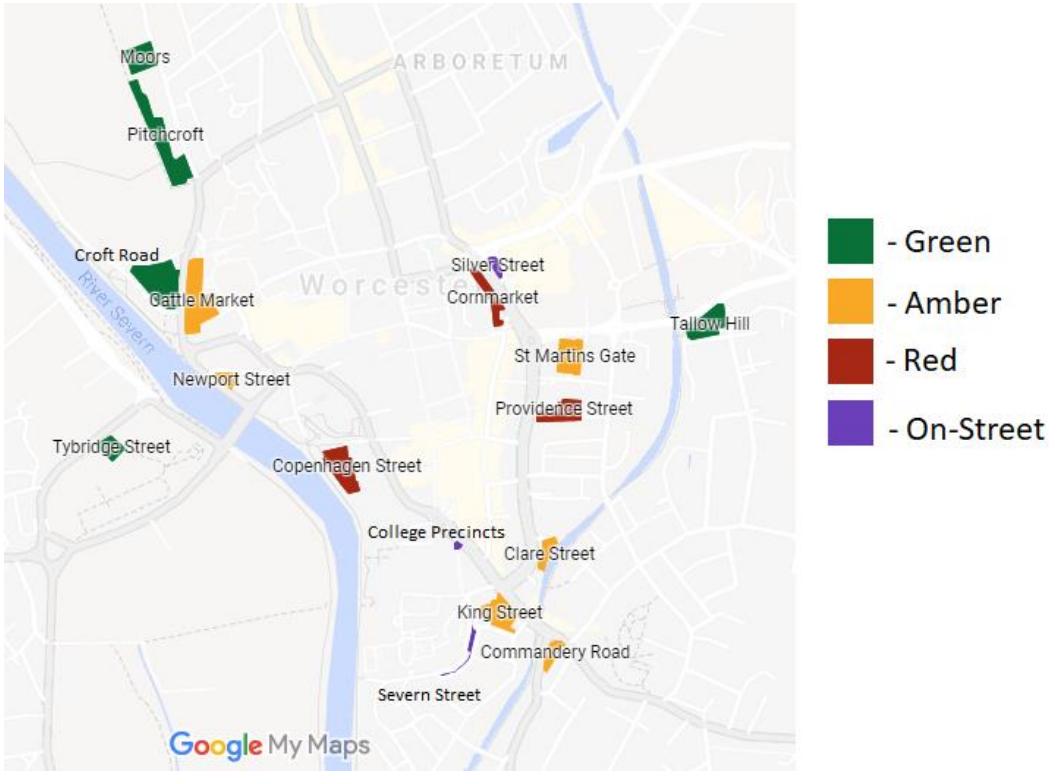
Table 3. Off street parking municipal parking distribution for the city of Worcester from 1 April 2018.

(Worcester City Council Parking and Enforcement Services, 2019)

Zone	Location	Regular Spaces	Blue Badge Spaces	Coach/Lorry Spaces
Red	Copenhagen Street	161	3	0
Red	Cornmarket	80	5	0
Red	Providence Street	58	3	0
Amber	Cattle Market	186	24	0
Amber	King Street	108	3	0
Amber	Newport Street	138	3	0
Amber	St. Martin's Gate	780	16	0
Amber	Clare Street	48	3	0
Amber	Commandery Road	40	3	0
Green	Pitchcroft / The Moors	435	6	0
Green	Tallow Hill	105	3	0
Green	Tybridge Street	70	3	0
Green	Croft Road	231	3	8
Total		**2440**	**78**	**8**

In addition to the off-street carparks mentioned, the Worcester City Council manages three on-street parking locations on behalf of the Worcestershire County Council. These on-street locations are

Silver Street, Severn Street, and College Precincts (Worcester City Council Parking and Enforcement Services, 2019). A map showing the locations for the city's 14 off-street and 3 on-street parking areas shown below in Figure 4. in this figure, the color of each carpark represents its zone, as assigned by the Worcester City Council (Red, Amber, or Green). In this map, the three on-street locations are shown in purple.



Maps Data: Google, ©2021

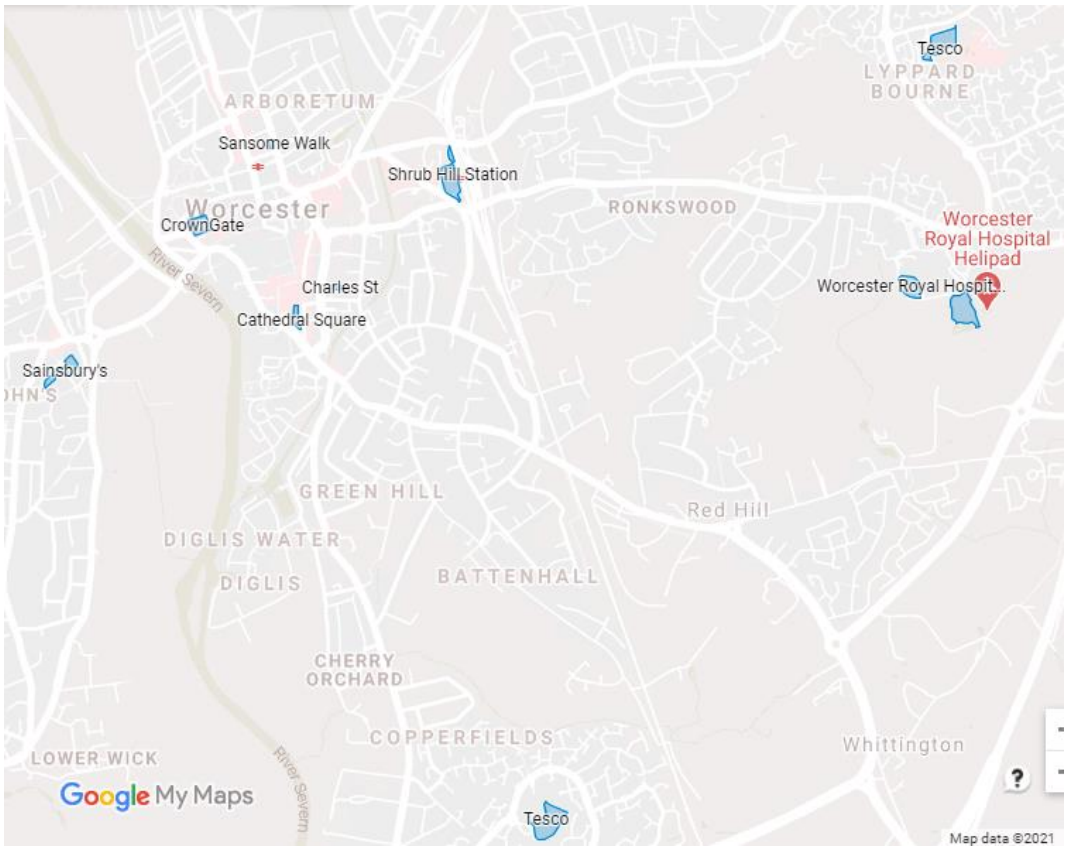
Figure 4. Map of Municipal Parking Locations within Worcester.

In Worcester, private parking locations and sizes are not well documented, thus there is a need to quantify this provision so future development and policy within the city can be better assessed. Parkopedia lists some of the larger private carparks available to the public. For example, National Carparks (NCP) operates a large multi-story at Cathedral Square with 325 parking spaces. Tesco and Sainsbury's offer a total of 1626 spaces across their four locations around the city. These statistics are summarized in Table 4. A map showing the locations of the Parkopedia listed carparks is shown in Figure 5. In this figure, Parkopedia. The Windermere Drive Sainsbury's is not shown as it is too far North.

Table 4. PNR carparks in Worcester as recorded by Parkopedia.

(https://en.parkopedia.co.uk/)

Name	Type	Location	Parking Spaces
Cathedral Square	General Use	College Street	325
Charles Street	General Use	10 Charles St	29
Crowngate Shopping Centre	Shopping Center	54 Friary Walk	750
Sainsbury's	Supermarket	Swanpool Walk	270
Sainsbury's	Supermarket	Windermere Drive	326
Sansome Walk	General Use	10 Sansome Walk	32
Tesco	Supermarket	St Peters Drive	520
Tesco	Supermarket	Mill Wood Drive	510
Worcester Shrub Hill Station	Railway Station	Shrub Hill Road	105
Worcestershire Royal Hospital - Green Carpark	Hospital	Charles Hastings Way	240
Worcestershire Royal Hospital - Yellow Carpark	Hospital	Charles Hastings Way	530
		Total Parking Spaces	**3637**



Maps Data: Google, ©2021

Figure 5. Location of selected PNR carparks in Worcester listed by Parkopedia.

2.2.6 Parking Policy Refinement in UK Cities

Many cities and counties in the UK have started changing their policies and standards with regard to parking provision associated with new developments. For example, in Buckinghamshire, "if a developer believes the stated standard is not appropriate for the new development … [they] must provide sufficient evidence … that a different level of parking would be more appropriate" ("Buckinghamshire Countywide Parking Guidance", 2015). Even once evidence is provided, the city still has the final say in giving permission for the extra space. Further, "the local planning authority must take account of carparks as a shared resource … by encouraging shared use [of] parking between neighbouring developments" instead of making multiple small carparks adjacent to each other ("Buckinghamshire Countywide Parking Guidance", 2015). Similar policies are evident in other counties around the UK including Suffolk and West Sussex.

Along with the policies regarding the minimum and maximum sizes of new carparks, new policies also specify bicycle space requirements. Each of the abovementioned counties, has introduced a policy stipulating the number of bicycle spaces needed for each type of carpark, as can be seen in the table in Appendix D.

Each of these counties emphasizes decarbonization as the rationale for the policy. For example, the Suffolk Guidance for Parking states "the number of spaces required … [is] expressed as minimum standards to reflect the sustainable nature of this mode of travel and its importance of it meeting Suffolk County Council's commitment to make the county of Suffolk carbon neutral by 2030" ("Suffolk Guidance for Parking", 2019). Similarly, the West Sussex Transport Plan states, "businesses should promote sustainable travel behavior by encouraging employees to travel by non-car modes and reducing the number of single occupancy car journeys" ("West Sussex County Council Guidance on Parking at New Developments", 2020). In conclusion, the Worcestershire County Council and Worcester City Council might usefully review and adopt transport and parking policies that are being promoted by many other local authorities in the UK in an effort to meet similar net-zero carbon goals.

2.3 Parking Policy Case Studies

As parking and traveling patterns change in the UK and elsewhere, many carparks are becoming underused. Cities and towns in several countries are starting to repurpose underused parking in innovative ways. In the following subsections, we discuss some of the ways parking spaces are being repurposed and redeveloped to promote environmental sustainability in particular.

2.3.1 Repurposing Carparks in Other Countries

As many countries strive to achieve net-zero carbon emissions, they are exploring ways to improve the sustainability of their transportation system. Tom Rye and Robert Hrelja conducted a case study of "policies for reducing car traffic and their problematization" in thirteen different European cities (Rye & Hrelja 2020). Table 5 shows the thirteen different cities from Denmark, the UK, the Netherlands, and Sweden and the different aspects of the transportation system that they wish to improve. Based on the information below, most of the cities want to add more cycle routes, reduce on-street parking, and improve the public transportation system in general and many aim to reduce levels of car use.

Table 5: Improvements each city wants to make to their transportation system.

City	Car reduced City Centre, with Further Reallocation of Space from Car	Reduced on-Street Parking	Cycle Routes	New Road Building Supported/ Planned	Cut Road Space for Car Outside Centre	Maintain Car Accessibility	Better Public Transport	Lower Speed Limits	Explicit Aim to Reduce Levels of Car Use
Aachen DE	X	X	X		X		X	X	X
Bath UK	X	X	X		X		X	X	X
Darlington UK			X	X		X	X	X	
Eindhoven NL	X	X	X		X		X	X	X
Eskilstuna SE			X	X		X	X		
Groningen NL	X	X	X	X		X	X		
Herrenberg DE	X	X	X	X		X	X	X	X
Jönköping SE		X	X	X		X			X
Lindau DE			X	X		X	X	X	X
Lund SE	X	X	X				X	X	X
Malmö SE	X	X	X				X	X	
Nottingham UK	X	X	X	X	X		X	X	X
Tilburg NL	X	X	X	X		X	X	X	

In the following subsections, we will discuss some of the strategies countries around the world are using to repurpose their unused parking spaces and reduce carbon emissions. Specifically, we will be looking closer at the efforts being made by Germany, France, the Netherlands, and Australia.

2.3.2 Germany & France

In Berlin and Paris, there has recently been a move to convert underground parking facilities into "last mile logistics consolidation centres" ("Underground parking repurposing", n.d.). These facilities will be a place for all deliveries to be dropped off from the larger distribution centers outside the city; then packages will be taken the last mile through the city by environmentally friendly cargo bikes. Paris has already implemented these centers, however "the packages [are] sent to final destinations via electric vans" ("Underground parking repurposing", n.d.). There is speculation that these underground facilities will soon be brought to the larger cities in the UK in the future.

In Berlin, they have a slightly different approach to these logistics centers. With the KoMoDo project, the city has placed shipping containers at a central open location in the city, these containers are filled with goods from the major delivery services. "Cargo bikes arrive at the shipping containers for loading and then do the last mile delivery" (Amstel, 2018). If the pilot with the shipping containers is successful, Berlin plans to repurpose underused space in selected underground carparks for such staging areas and expects "extensive new use of these [underground] spaces by 2040" ("Underground parking repurposing", n.d.).

2.3.3 Netherlands

The Netherlands has been on the leading edge of sustainability initiatives for many years, and so it is no surprise to find it is leading the movement to reduce parking spaces within its cities. In April of 2019, "Cycling city Amsterdam" announced that they were going to start removing parking spaces from inner city streets to "give the space back to cyclists" (Fien, 2019). Amsterdam plans to remove 11,200 parking spaces from the center of the city by 2025. Additionally, the number of parking permits distributed will be reduced by 1,500 permits per year in the city center (Fien, 2019). As the number of parking spaces and permits decrease, the cost to obtain a parking permit is growing and is approaching "€500 a year for the inner-city streets" (Fien, 2019). Passing these new policies is giving underused "car space … back to the majority of the road users: cyclists, pedestrians, and public transit users" (Fien, 2019). Overall, the steps being taken by the Netherlands and specifically Amsterdam to reduce parking and repurpose the space in more sustainable ways are good practices for other countries to follow in their goal of net-zero carbon emissions.

2.3.4 Australia

There are also countries outside of Europe that are innovatively converting their extra parking spaces into usable public spaces to improve the quality of city life, most notably Australia. In Australia, change to parking complexes have taken place all over the country. In Sydney, several parking spaces at the EY Centre (Sydney's tallest building) have been converted into "an urban farm complete with vegetable patches, a vertical hydroponic farm, and a Farmwall" ("The future ready commuter carpark", n.d.). Such pop-up urban farms have become quite popular in parking garages throughout the city. The parking footprint has been reduced to half of its initial volume in the Central Park Precinct, now "accommodate[ing] car sharing as well as water recycling facilities" ("The future ready commuter carpark", n.d.). Throughout the country, Williams Sale Partnership Limited (WSP) is helping parking garages convert into many different things as people start to utilize public transportation more. Recently, the WSP has assisted at the Brisbane Airport working with the "International Terminal Carpark … the largest parking facility in the southern hemisphere"; some of their recommendations included "shopping and entertainment, aviation activities, warehousing, accommodation, education and health, vertical and intensive farming as well as other connecting transport uses" ("The future ready commuter carpark", n.d.).

Figure 6. Urban farm located in Green Gully, Australia

2.3.5 Parking Innovations in the UK

Currently, there are few cases in the UK of cities repurposing parking. However, London has started making an effort to repurpose underused parking and Nottingham has added a Workplace Parking Levy (WPL) to help reduce congestion. In Peckham in 2007 "a former multistorey carpark was saved from demolition and [the] … Southwark council leased the top floor to the organization Bold Tendencies. … [They] opened a rooftop bar called Frank's Café" (Rees 2019). Other top floors of this carpark were used to host different events such as "a performance of Stravinsky's Rite of Spring by the Multi-Story Orchestra" (Rees 2019). The middle levels were bought by Make Shift who changed their levels into bars, recreation spaces, and offices for businesses. In Hackney, parklets have started popping up in curbside parking. Parklets are created when curbside parking is converted to community space. Parklets usually include benches, seats, planter, and more. These parklets are usually used for repurposing residential parking that is not being used as car storage for the residents.

Nottingham is currently the only city is the UK to have implemented a WPL which "is a charge on employers who provide workplace parking" (*Workplace parking,* n.d.). The profit from the WPL received by the city has allowed improvement of their "major transport infrastructure initiatives and [act] as an incentive for employers to manage their workplace parking provision" (Workplace parking, n.d.). Since introducing their WPL, Nottingham has inspired many other cities in the UK and around the world to create a workplace parking levy including Birmingham, Leicester, and several London boroughs.

2.4 The Need for Decarbonization

In recent years, travel has decreased and there has been a greater push to become more sustainable and environmentally friendly in Worcester, England. The City of Worcester has an aggressive goal to reach carbon neutrality by 2030 (Corrall, n.d., pg. 1). Since "17 of the 18 warmest years on record have occurred in the 21st Century (Corrall, n.d., pg. 7)," Worcester has declared a climate emergency. Any time that a massive change is to be implemented, it requires creative approaches and "out-of-the-box" thinking. This has been seen in Worcester's approach to energy efficiency.

The county is…taking the lead in sustainable construction and energy, such as…*The Hive,* built to exacting environmental standards using river water cooling and biomass heating; and a groundbreaking heating scheme using excess heat from the Redditch Crematorium to warm a nearby sports center. (Worcestershire Climate Change Strategy 2012-2020, n.d., pg. 2)

In addition, 42% of the city council's carbon emissions are due to their fleet of vehicles. However, this service had a 12% decrease in carbon emissions from 2013-2014 to 2018-2019 (Corrall, n.d., pg. 14). The concern about climate change is higher among Worcestershire residents compared to the rest of the UK. A recent survey conducted by the Worcestershire County Council found that out of people surveyed 98% recycle, 64% of people said they are working to improve the energy efficiency of their homes, and 57% of the participants said they are reducing their car use. From these surveys and the parking trends discussed above we can assume that less people will be driving into the city.

2.5 Background Summary

Based on the decreasing trends of vehicle transportation and carpark occupancy, we plan to investigate the private non-residential sector of parking policy to gain a better understanding on how much of the parking space is being underused. Currently, there is little documentation of this type of

parking, so we have established the goal to quantify the PNR parking within the city of Worcester. Using the collected carpark data, sustainable decisions can be made in the planning process of future developments, as was done in Australia, the Netherlands, and Nottingham to improve the carbon footprint within their cities.

3 METHODS

The goal of this project was to develop a procedure to assess, quantify, and map private non-residential (PNR) parking to expose the potential for the reuse and redevelopment of excess parking to promote more efficient and sustainable use of scarce transport network capacity.

To achieve our goal, we developed three objectives:

1. Develop a procedure to assess PNR parking in Worcester, UK.
2. Determine the opinions of stakeholders and field experts about the reuse and redevelopment of current parking areas in Worcester.
3. Modify the parking assessment procedure, based on results in Worcester, and then test the procedure in Gloucester, UK.

The strategies used to achieve these objectives and collect information on parking in Worcester are summarized in Figure 7.

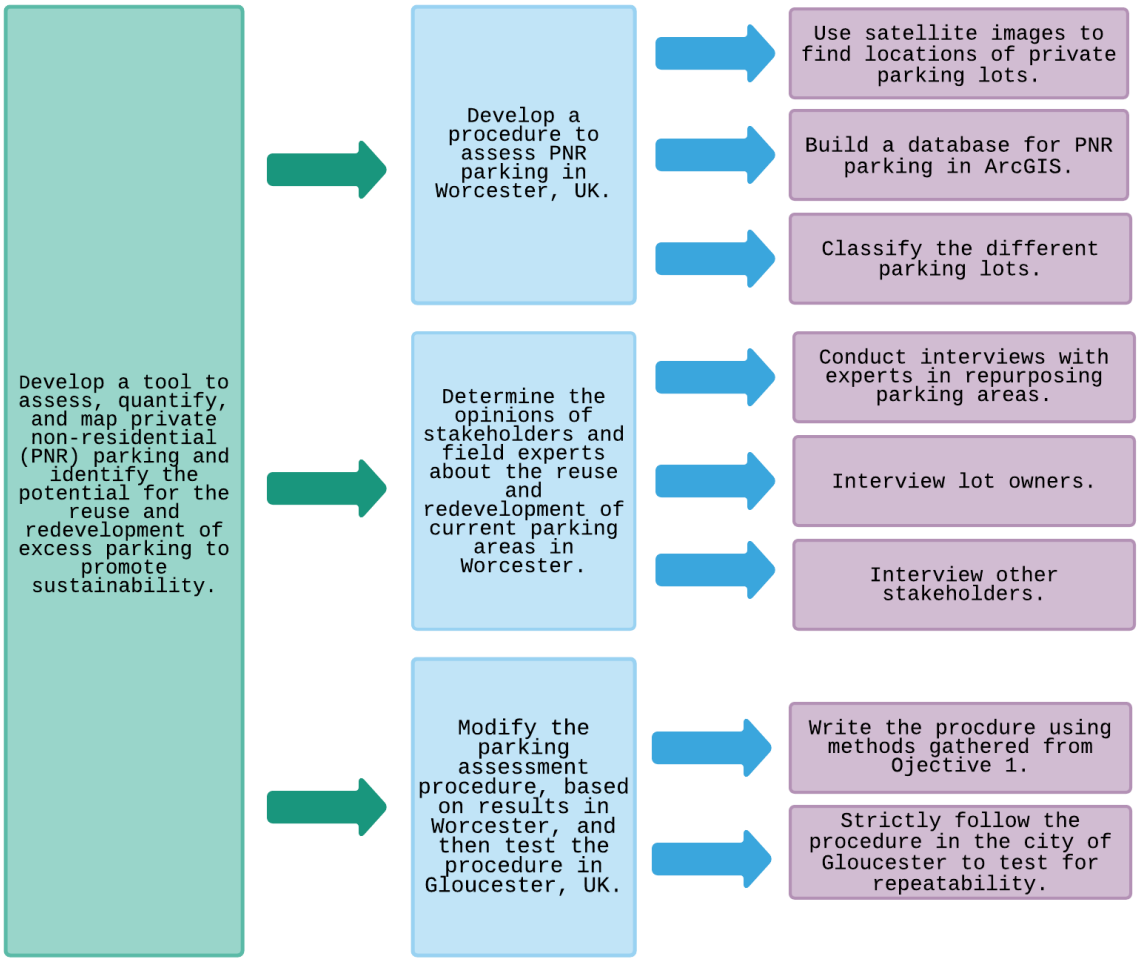


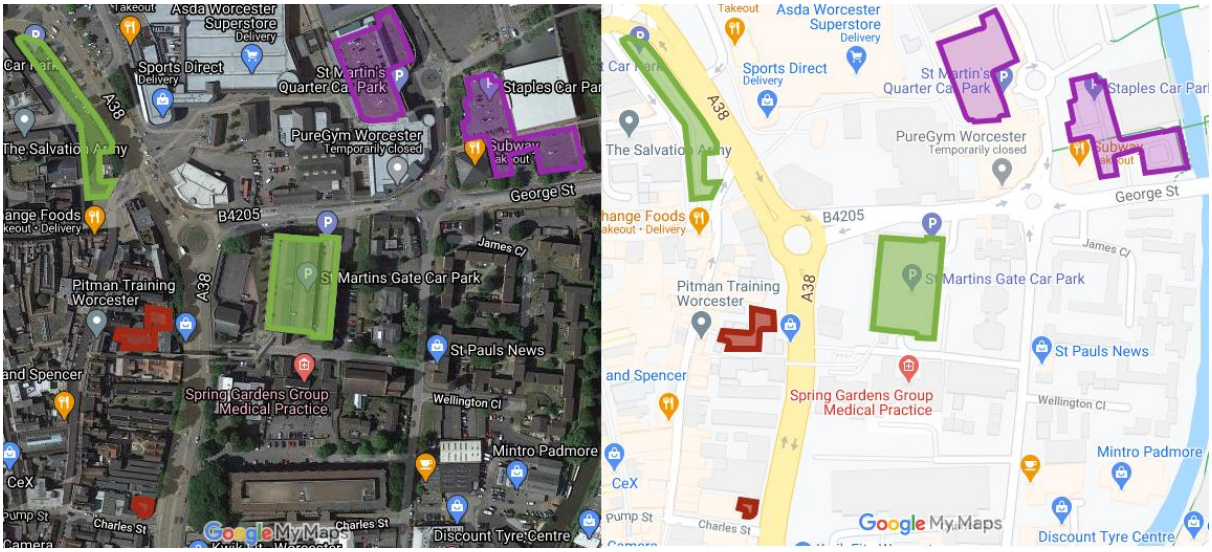
Figure 7. Flowchart of Goal, Objective, and Task

3.1 Objective 1: Develop PNR Parking Assessment Tools

We designed a procedure to identify and map the pertinent features of PNR carparks in the city of Worcester. Features included size, location, names of abutting businesses, and type of use. We used the HELERT scale to classify type of use. The HELERT scale is a business classification used commonly by transport planners and is an acronym for the broad categories of Health, Employment, Leisure, Education, Retail, and Transportation.

Identifying the location and footprint of the carparks was the first and most important step of our project. Since neither the city nor county have parking area data available in digitized form, we conducted the assessment manually. We visually inspected satellite imagery available form Google Maps and drew polygons around carparks using ArcGIS. In this fashion we created an ArcGIS data layer with an associated attribute table that includes details on the features of each parking area. In the data collection phase, we tried to only focus on PNR parking areas with greater than 15-20 parking spaces. This was for two reasons: (1) to limit the number of parking areas in the dataset and (2) because very small parking areas offer fewer opportunities for reuse and redevelopment. We included municipal carparks in the data layer to provide a more complete and comprehensive assessment of parking availability, but we did not include residential parking which is beyond the scope of this project.

A simple example of such identification created using Google MyMaps is shown in Figure 8. In this example, municipal lots are shown by a green polygon, large private lots are shown by purple polygons, and small private lots are shown by red polygons. Throughout the search procedure, we verified information such as parking area type and abutting businesses by navigating the urban landscape using Google Street View. For example, this helped us classify and differentiate single and multistory carparks.



Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Maxar Technologies

Figure 8. Parking Zone Example

To organize the process of data collection, we subdivided the city into zones based on geographic landmarks, such as major roads and rivers. This enabled us to complete the identification of carparks systematically by assigning zones to specific team members to be completed by certain dates. These zones are shown below in Figure 9.

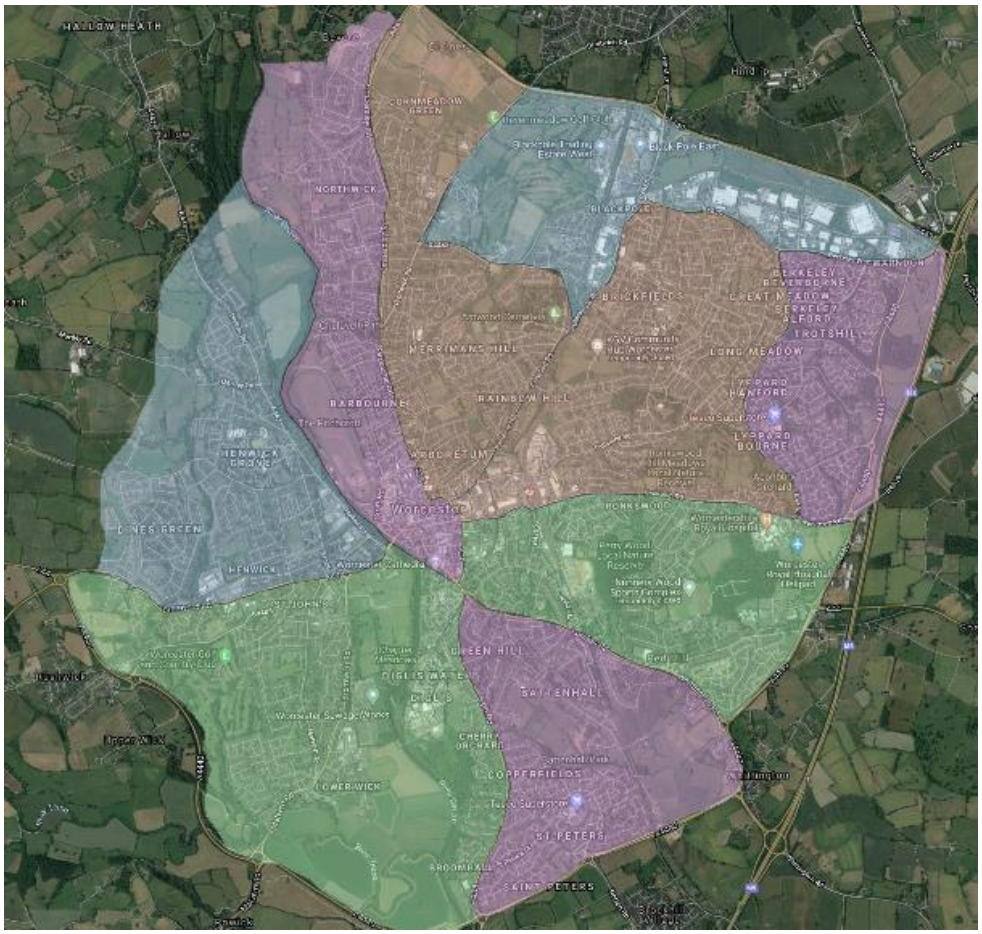


Figure 9. City of Worcester divided into zones based on some major roads and rivers.

After identifying a carpark, we classified the location according to different attributes, such as size, ownership, and address, within the layer's attribute table. These attributes were obtained mainly through the Google hybrid layer and Google Streetview because ownership data for land parcels are not publicly available in digital form for the City of Worcester. We also consulted with our sponsor liaisons who have an intimate knowledge of the geographic area. Then, based on the lot size measurements we estimated the number of parking spaces by multiplying the measured area by 2/3, to account for turning space and green space, and then dividing that result by 11.52m^2, the average size of a UK parking space.

3.2 Objective 2: Determine Opinions Field Experts

Determining the opinions of field experts is an essential step to be able to provide meaningful recommendations based on the carpark data we collected. These individuals include members of the Worcester City and Worcestershire County Councils and parking and transportation planning experts.

These individuals will play a major role in the future of this initiative to repurpose underutilized parking and help promote sustainability within the City of Worcester.

Drawing from our review of the literature and suggestions from our sponsors, we identified a list of stakeholders and field experts. We reached out to identified experts by email or phone introducing ourselves, our project, and trying to set up a secondary meeting to interview them to inquire more about their opinions surrounding PNR parking and their knowledge of future plans. The exact wording of our preamble and interview questions was tailored to the specific interviewee and their knowledge of the topic we were be discussing; however, a general interview preamble can be found in Appendix E. The secondary meeting took place over either Teams. In this meeting we discussed the interview questions detailed in any of the following appendices depending on the interviewee: Appendix F and Appendix H. The interviews did not last more than 30 minutes and consisted of the interviewer, interviewee, and three scribes. We recorded the interviews to refer to at a later date if the interviewee was comfortable with it; otherwise, we took detailed notes. Similarly, we sent questions be email to Worcester City and County Council members because with the current election going on in Worcester, they would not have much time for interviews; a copy of the email we sent to them can be seen in Appendix G.

3.3 Objective 3: Create and Test Procedure

Prior to mapping the City of Worcester, we began by selecting a small subsection of the city center to serve as a test. For this test, all four group members individually mapped the test zone after which the polygon shapes were compared. This allowed us to develop a uniform style of mapping that could be utilized across all group members' work. This test zone and the drawn polygons are shown in Figure 10.

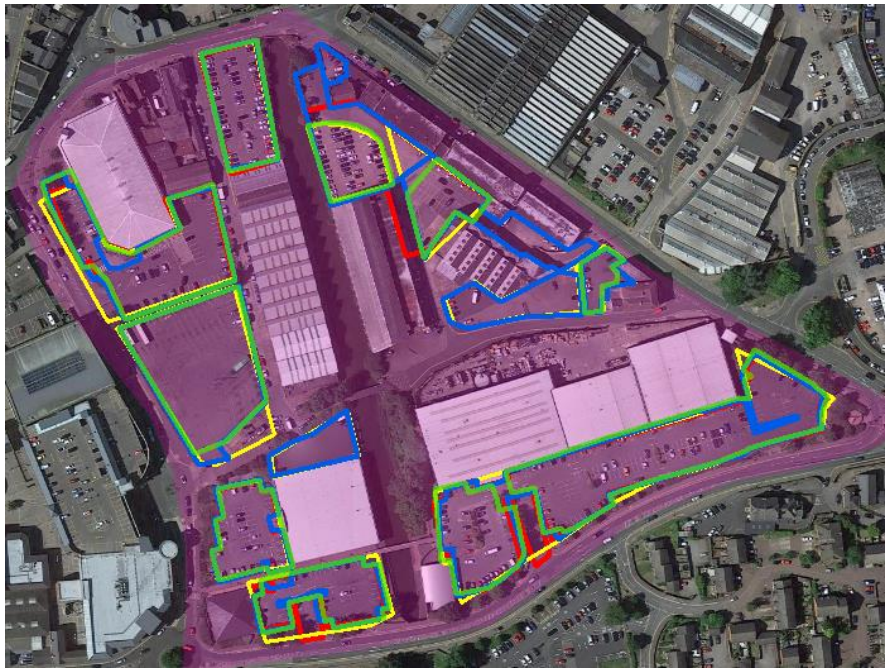


Image Data: ©2021 CNES / Airbus, Getmapping plc, Infoterra Ltd. & Bluesky, Maxar Technologies. Map Data ©2021 Google

Figure 10. Test Section Used to Standardize Mapping Procedure

Using the experience gained from mapping the carparks in Worcester, we modified our original procedure, so our work could be replicated both within Worcester and across the UK in the future by other researchers. Modifications included polygon creation procedure and carpark classification. A description of the complete, modified procedure is included in Appendix J.

Our sponsors recommended we test the written procedure to ensure it would work when mapping other UK cities. We selected Gloucester to test our procedure on based on its long industrial heritage, more complex infrastructure, and its slightly larger population compared to that of Worcester. Through mapping Gloucester, we determined outline the steps to map PNR parking well to ensure sufficient gage repeatability and reproducibility.

4 RESULTS

This section will present our data and findings as a result of the activities detailed in the Methods section above. The results are organized into five different categories discussing our written mapping procedure, PNR parking in Worcester and Gloucester, and interviews we have conducted.

4.1 PNR PARKING ASSESSMENT PROCEDURES

We started writing our procedure after mapping all the PNR parking in Worcester. Based on what we learned from that mapping, we were able to create an easy-to-follow procedure for other people to use in the future. This procedure can be found in the Procedural Guide supplemented with this report.

When we were setting up our base map, we decided to use Google satellite imagery for the analysis because we had difficulty gaining access to the ordinance survey imagery; however, both sets of imagery would work well and provide the data needed to successfully map a city. It is important to note that if Google satellite imagery is chosen for the base map there is a workaround for proper integration into ArcGIS; information on how to do this can be found in our mapping procedure in the Procedural Guide supplemented with this report. Any mapping program can be used, we chose to use ArcGIS because it was accessible to us and is the program that the city of Worcester uses; we recommend using a program that is easily compatible with the preexisting data layers developed by the local authorities.

Because four of us were working on mapping Worcester at the same time, we decided to zone a test section to calibrate our procedures and reduce inter-individual variation in interpretation before applying the standardized procedures to the rest of the city. This test section led us to the conclusion that we should not include long access roads leading to carparks because that would bias the calculation of the number of parking spaces in the carpark. Further we also realized an issue with trees covering the edges of the carparks making them harder to zone. In this case, we just decided to do our best to decipher where the boundaries would be. This should not lead to a significant increase in the area of the carpark, therefore the calculations for the number of parking spaces should be reasonably consistent. Similarly, we cross-checked each other's assessments to make sure we did not miss any carparks and help fill out any missing information in the attribute tables.

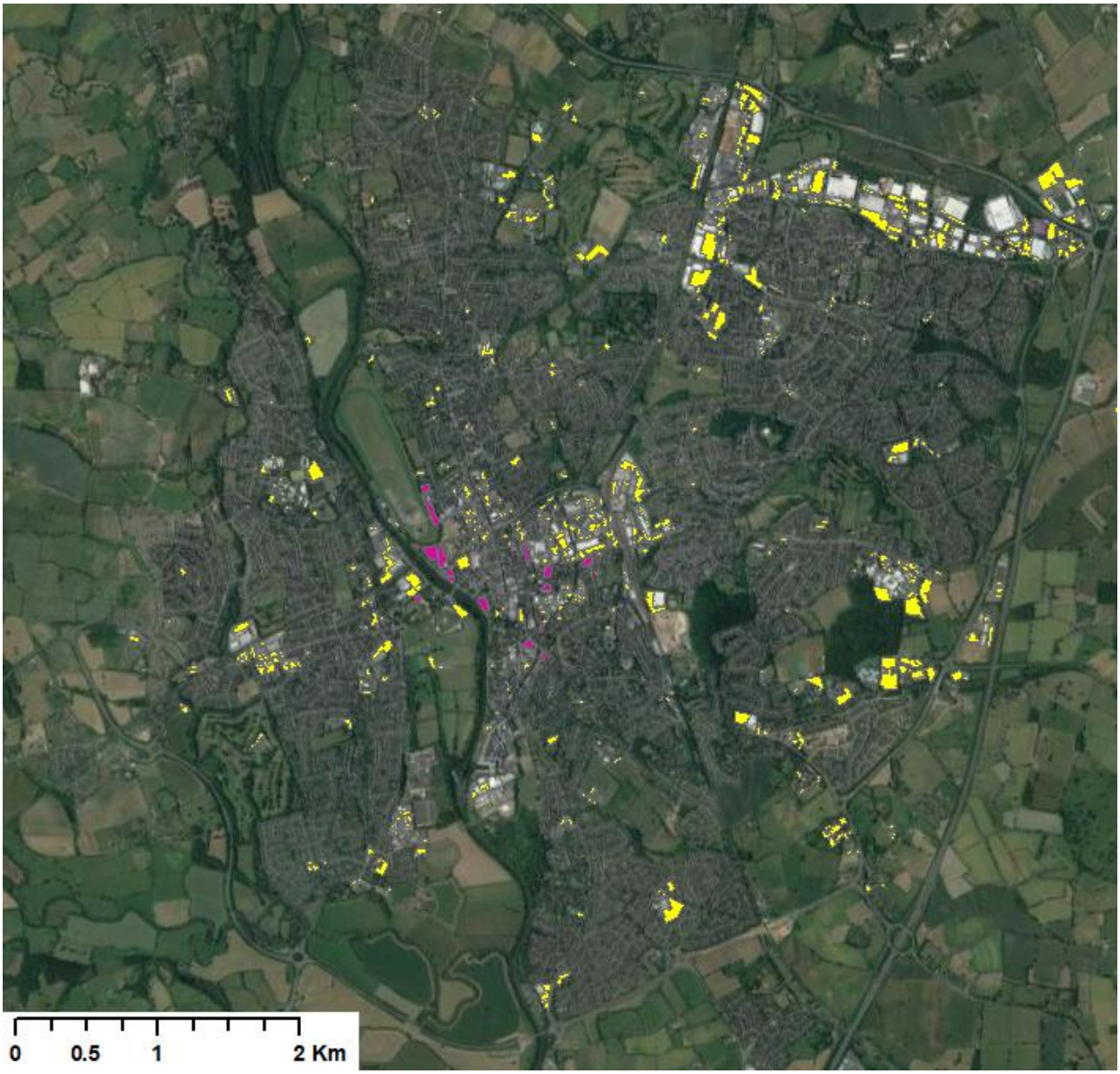
It took roughly, 20 hours per person (or 80 person-hours) to finish mapping the PNR parking in Worcester. Based on the information we gathered from this mapping session, we were able to add tips to our procedure that ultimately made it faster to map the PNR parking in Gloucester. Even though Gloucester is larger than Worcester, it took only 60 person-hours to map the PNR parking areas. We anticipate that updating the maps and attribute files for both cities will require substantially less effort, since the changes are likely to be modest and incremental.

4.2 PNR PARKING IN WORCESTER

The city of Worcester encompasses 36km^2. Of that total surface area, we found about 0.95km^2 to be occupied by private non-residential carparks. Despite only being 2.6% of the total surface of the city, this area represents a staggering 54,905 parking spaces, especially when compared to the total

municipal parking provision within the city, 0.12km^2 of space totaling about 2,518 parking spaces. Figure 11 shows the distribution of PNR carparks (yellow) and the city's municipal carparks (pink).

Not surprisingly the municipal carparks are clustered in the city center, along with a sizeable number of PNR carparks, including those associated with the Shrub Hill Industrial Estate, Perry Wood Trading Estate and Tolladine Good Yard Industrial Estate. There is a notable cluster of PNR parking in the northeast of the city associated with the city's retail and industrial sector. Other notable clusters occur on the east side of the city around the hospital and the Worcestershire County Council offices, and on the west side associated with the St. John's Campus of the University of Worcester and the Everoak Trading Estate. In the process of mapping carparks, we recorded the nearby businesses that may utilize the carpark. In an analysis of these tags, we found that 269 (62.7%) of the city's 429 PNR carparks have a single associated business, and 160 (37.3%) carparks have two or more associated business.



Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Landsat / Copernicus, Maxar Technologies

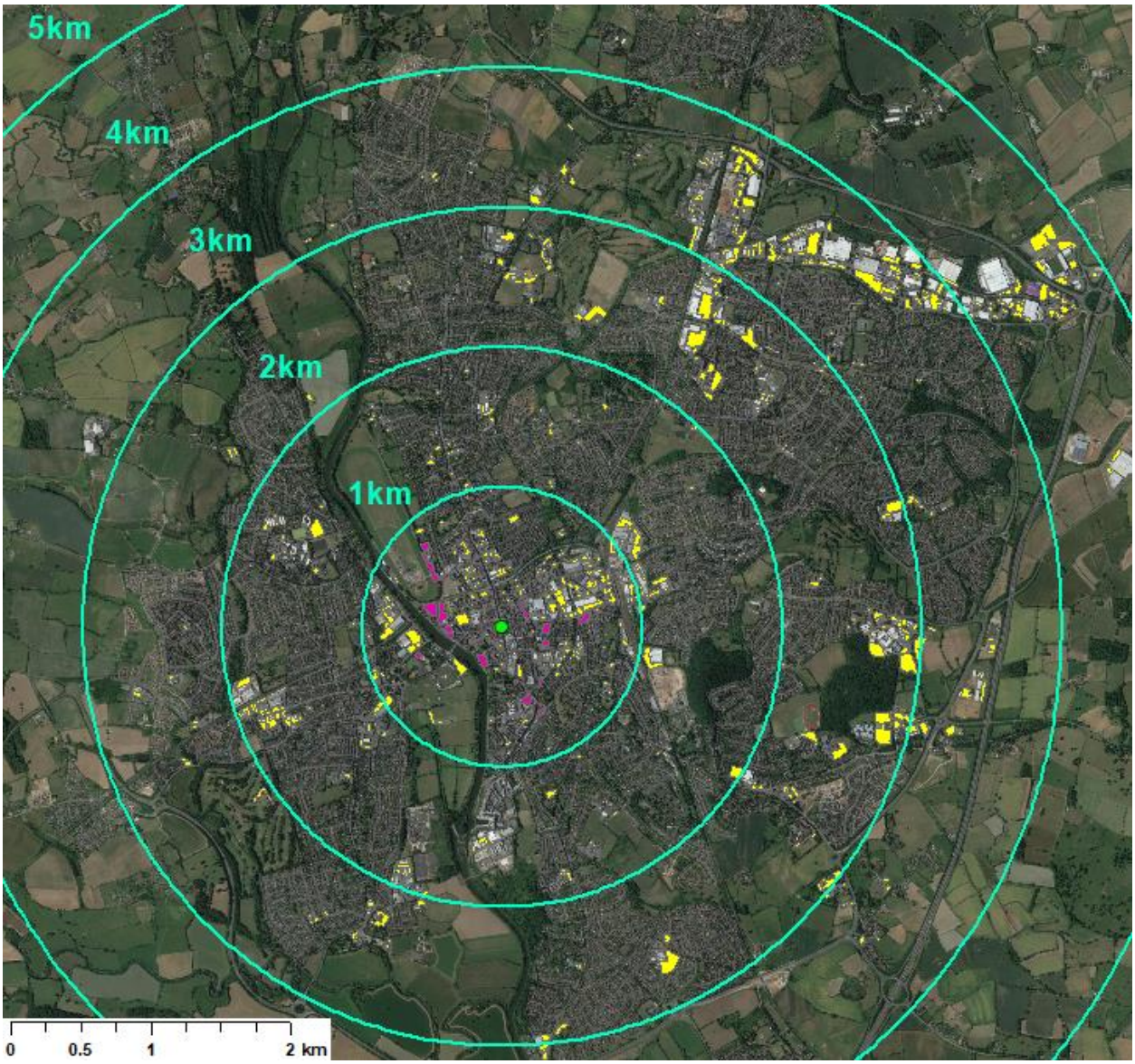
Figure 11. PNR (yellow) and Municipal (Pink) carparks within the city of Worcester, UK.

Across the 429 mapped carparks, the average number of parking spaces was about 128 spaces, with the largest carpark being the former Sixways Park-and-Ride. This large carpark, shown in Figure 12, was originally built with funding from central government and contains an estimated 1,106 parking spaces.

Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Maxar Technologies

Figure 12. Largest recorded carpark within the city of Worcester.

We estimated parking provision in 1-kilometer rings using the intersection of High Street and Church Street to represent the city center (see Figure 13). The innermost kilometer has approximately 114 PNR carparks representing a total surface area of 0.1804 km^2 (Table 6). However, despite having the most carparks of any ring, the city center has the lowest average number of parking spaces per carpark at about 92 parking spaces per carpark. As you move further away from the center of the city, the average number of parking spaces per carpark increases. Between 2km and 3km, both the average number of parking spaces per carpark and the total number of parking spaces reach their peak values of 192 parking spaces per carparks and 17,888 total parking spaces. This sector alone accounts for nearly a third of the parking within the entirety of the City of Worcester. The main reason that this zone has so much parking space is because it includes the Worcester Royal Hospital, the Worcester County Council Hall, and a portion of the city's industrial zone to the North. This is shown in Figure 13.



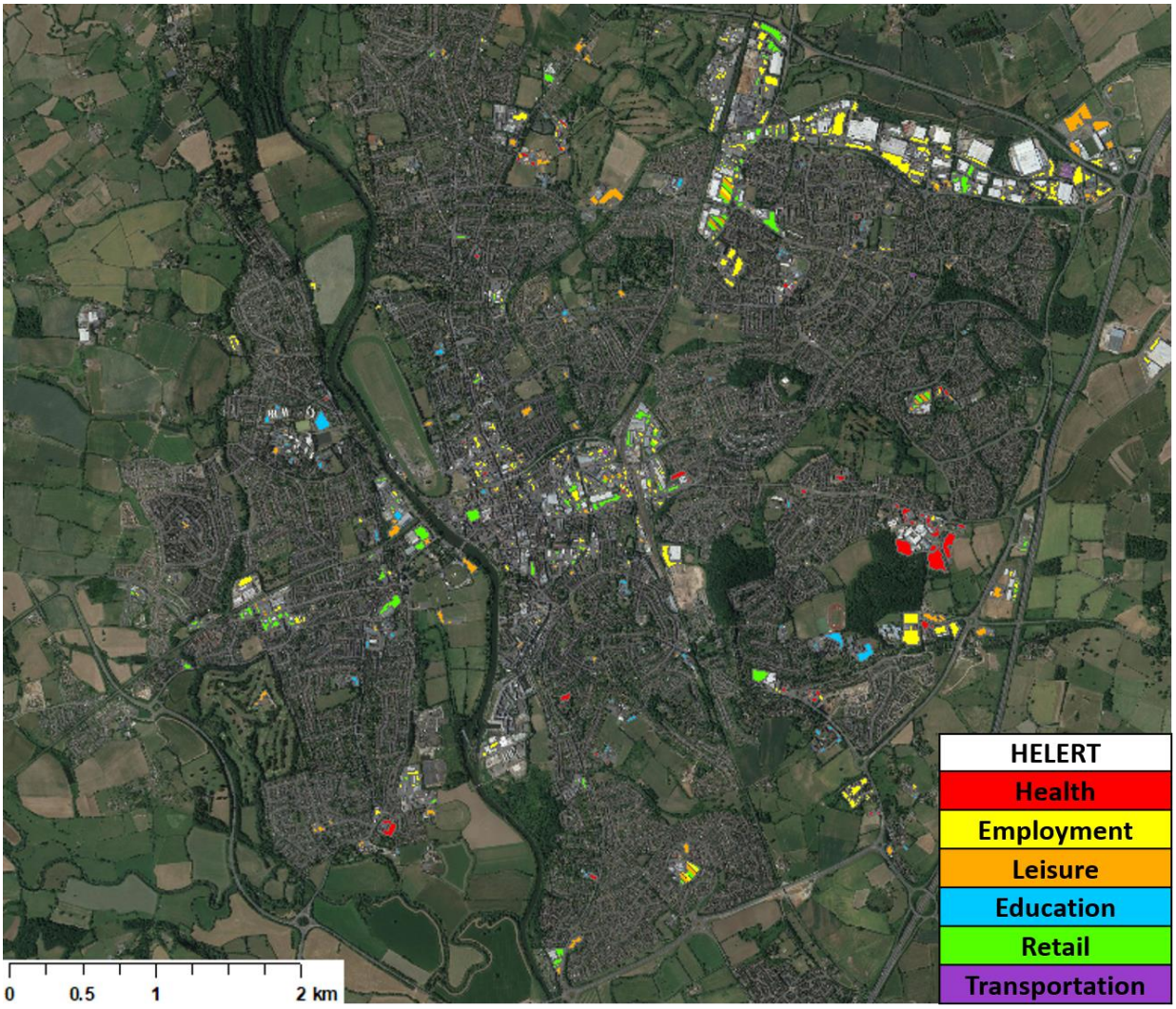
Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Landsat / Copernicus, Maxar Technologies

Figure 13. Kilometer rings centered on the intersection of High St. and Church St.

Table 6. Distributions of Worcester's PNR carparks based on their distance from the center of the city.

Radius	Total Carparks	Total Parking Spaces	Average Parking Spaces	Total Area (km^2)	Carpark %	Parking Spaces %
Less than 1km	114	10,437	92	0.1804	26.57 %	19.03 %
1km – 2km	93	9,254	100	0.1599	21.68 %	16.87 %
2km – 3km	93	17,888	192	0.3090	21.68 %	32.61 %
3km – 4km	100	12,428	124	0.2148	23.31 %	22.66 %
4km – 5km	28	4,800	171	0.0829	6.53 %	8.75 %
Greater than 5km	1	45	45	0.0008	0.23 %	0.08 %

For every carpark that we mapped, we assigned one or more values from the HELERT scheme of use classification. Carparks can have more than one assigned HELERT use classification. Based on these assigned HELERT use classes, we were able to determine which broad type of use classification within the city possess the most PNR carparks and the most PNR parking spaces. Noting the uses categories of carparks may prove quite helpful for future planning purposes. This is because some types of parking, such as Retail and Employment, are likely to be more affected by changing travel patterns and may present different opportunities for repurposing. Additionally, by color coding carparks within the maps by their HELERT classes, we were able to determine which sections of the city have more or less of each type. The results of mapping the HELERT classes are shown in Table 7 and Figure 14.



Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Landsat / Copernicus, Maxar Technologies

Figure 14. Worcester PNR carparks color coded by their associated HELERT use class(es).

Table 7. Statistics on the distribution of Worcester PNR carparks based on their HELERT classifications.

HELERT	Carparks Number	Carparks Percent	Parking Spaces Number	Parking Spaces Percent
Health	39	9.03 %	5,445	9.92 %
Employment	205	47.45 %	26,246	47.80 %
Leisure	126	29.17 %	15,886	28.93 %
Education	58	13.43 %	4,602	8.38 %
Retail	112	25.93 %	17,362	31.62 %
Transportation	2	0.46 %	60	0.11 %

In the color-coded map of Worcester's PNR carparks (Figure 14), carparks with more than one HELERT use class are shaded with multiple colors, representing the use classes it covers. Of the carparks that we mapped nearly a quarter of the city's PNR carparks have multiple HELERT use classes. The distribution of the number of use classes per carpark is shown in Figure 15.

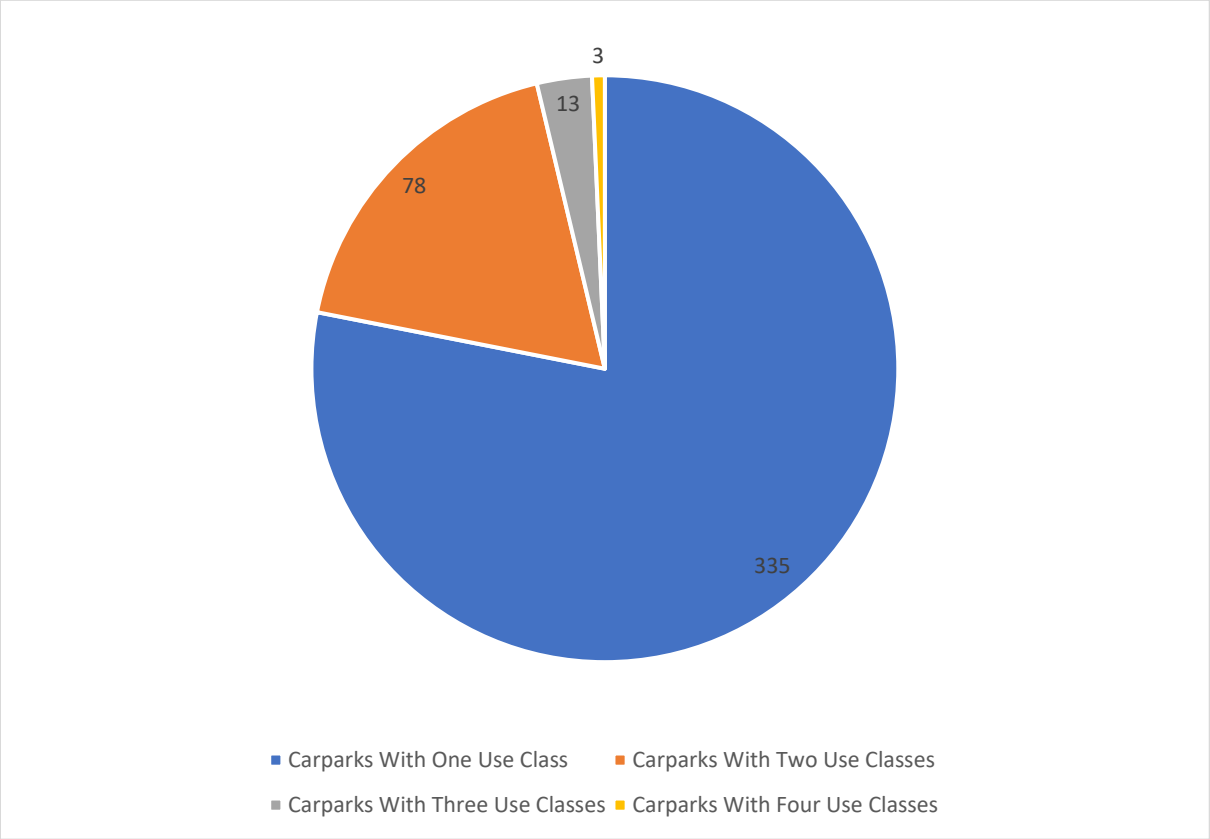


Figure 15. Number of HELERT use classes each carpark serves.

Of the carparks with two HELERT uses, we found that Employment and Retail most often share the same parking space. This occurred in 40 of the 78 lots that had more than one use classification. Following Employment and Retail, Employment and Leisure shared the second most carparks, with 17 out of 78. These results are shown in Figure 16.

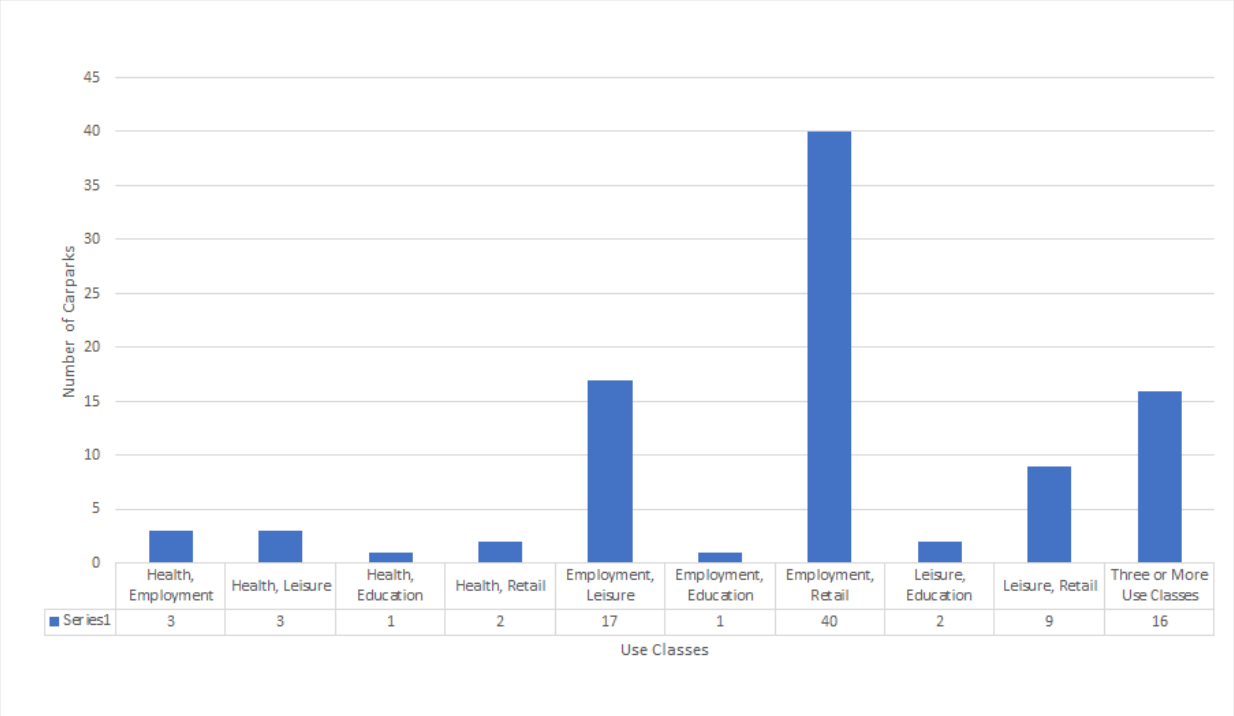
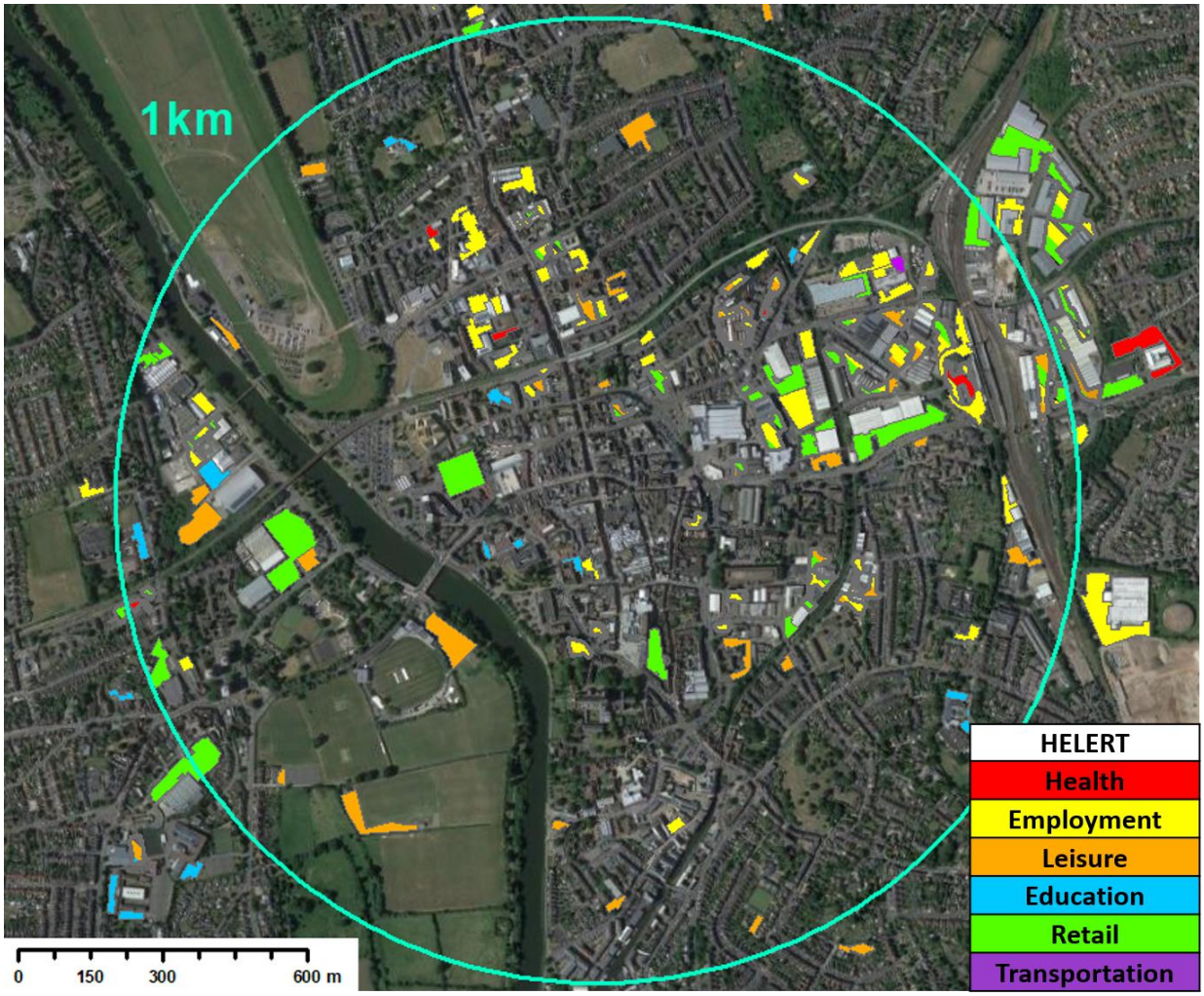


Figure 16. Frequency of carparks with two or more HELERT use classes.

From this analysis, we determined that Employment, by quite a margin, is the most common type of use classification within the city of Worcester. Since Employment type businesses make up nearly half of the carparks identified, they are spread all over the city, but there are significant concentrations of them both within the city center and to the North in the city's industrial sector. Retail and Leisure, to a degree, also share a similar distribution. From the color-coded maps of Worcester, you can see where parking concentrations associated with Health and Educational institutions lie. Parking for Health institutions is scattered throughout the city with a large cluster to the East of the city associated with the Worcester Royal Hospital. The smaller more scattered Health carparks are typically associated with dentistry, veterinary, or small surgical offices. A closer look at the Worcester Royal Hospital's carparks and the carparks of the surrounding area is discussed below. Similar to how the Health carparks are distributed, Educational carparks are fairly scattered with a few spots of significant concentration. The more spread-out Educational lots are typically associated with the Worcester neighborhood schools. A concentration of Educational lots, seen in blue, can be found on the West side of the city, across the River Severn from the Worcester Racecourse. This cluster of carparks are those belonging to the University of Worcester's St. John's campus.

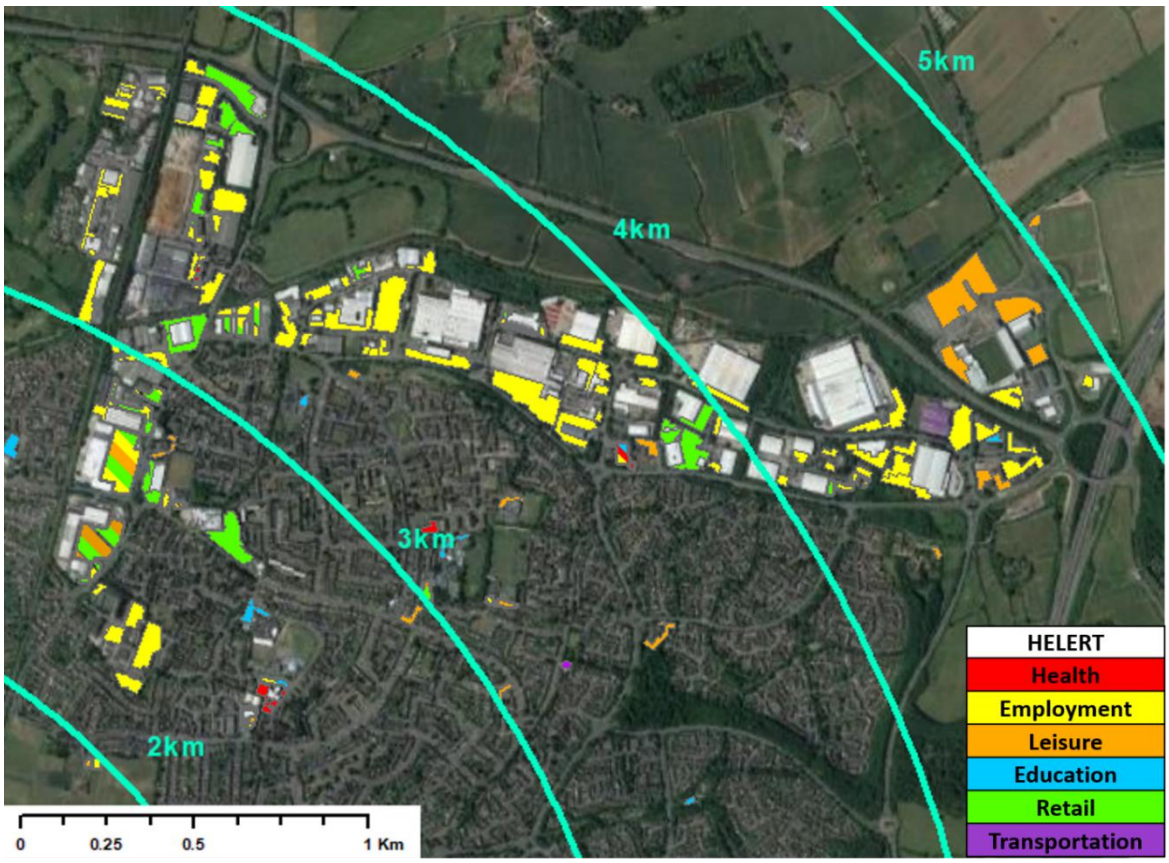
Taking a closer look at a few of the areas within the city with a higher concentration of PNR lots. The city center (Figure 17), has many of carparks of varying size and uses. Some of the larger carparks that make significant contributions to this sector's total parking provision are those associated with the Shrub Hill Industrial Estate, the Asda Superstore, the Range home goods store, the Crowngate shopping center, and the University of Worcester's city center and Severn campuses.



Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Maxar Technologies

Figure 17. Use Classification of PNR carparks in the city center.

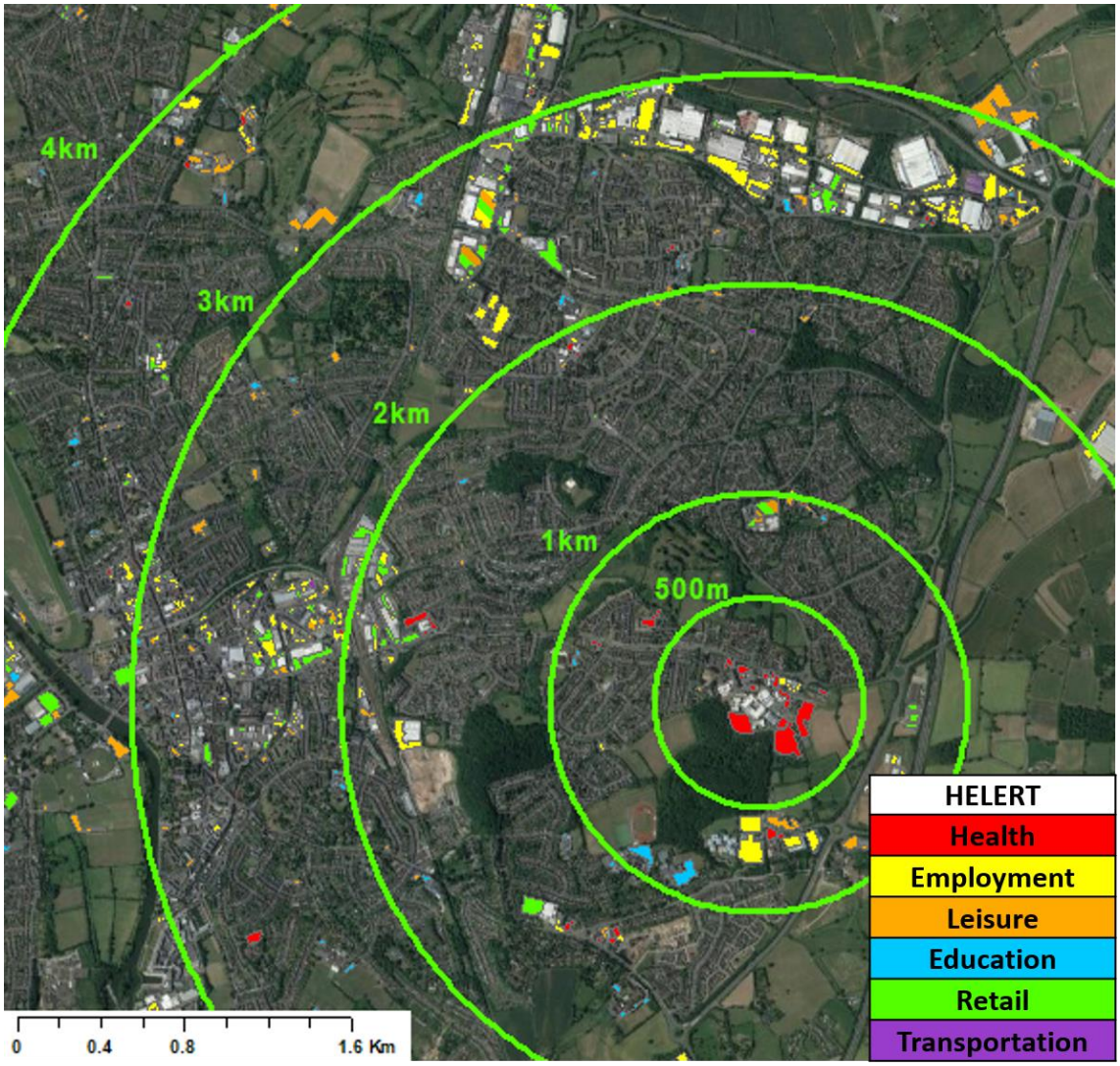
Another key area in the city for PNR parking is the city's industrial sector to the North (Figure 18). In this area, there are many large Carparks that are used by the various retail and business parks. This area is home to the Shire Business Park, the Warndon Business Park, the Elgar Retail Park, the Blackpole Retail Park, and the Blackpole Trading Estate. Additionally, as can be seen in the upper right corner of Figure 18, there are several large lots used for leisure purposes. These lots are situated at Sixways stadium, home of the Worcester Warriors rugby and football clubs. Just outside of the stadium parking lies the largest carpark in the city, the former Sixway's Park-and-Ride car park. This location was originally designed with government support to provide a parking place for people commuting into the city; however, it has not seen much use since its development.



Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Maxar Technologies

Figure 18. PNR carparks within Worcester's industrial sector.

The Worcester Royal Hospital is a peculiar case because despite its large amount of parking, it often does not have an adequate amount to accommodate all its employees and its visitors. Relative to the Worcester Royal Hospital, there are about 24 PNR carparks between 500m and 1km away. These 24 carparks supply the community with about 4,944 parking spaces with the average carpark containing about 206 spaces. Between 1km and 2km outside of the Royal hospital, there are about 50 additional carparks providing about 5,866 more parking spaces. Most of these are associated with the Worcestershire County Council offices and the Countryside Centre. Each of these carpark's averages about 117 spaces. These carparks and more are shown relative to the Worcester Royal Hospital in Figure 19 and statistics are provided in Table 8.



Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Landsat / Copernicus, Maxar Technologies

Figure 19. Distribution of PNR carparks relative to the Worcester Royal Hospital.

Table 8. Statistics on the distribution of PNR carparks based on their distance to the Worcester Royal Hospital.

Radius	Total Carparks	Total Parking Spaces	Average Parking Spaces	Total Area (km^2)	Carpark %	Parking Spaces %
500m – 1km	24	4,944	206	0.0854	5.59 %	9.01 %
1km – 2km	50	5,866	117	0.1013	11.66 %	10.69 %
2km – 3km	185	23,384	126	0.4041	43.12 %	42.63 %
3km – 4km	107	12,460	116	0.2153	24.94 %	22.72 %
4km – 5km	46	5,026	109	0.0868	10.72 %	9.16 %
Greater than 5km	6	420	70	0.0073	1.40 %	0.77 %

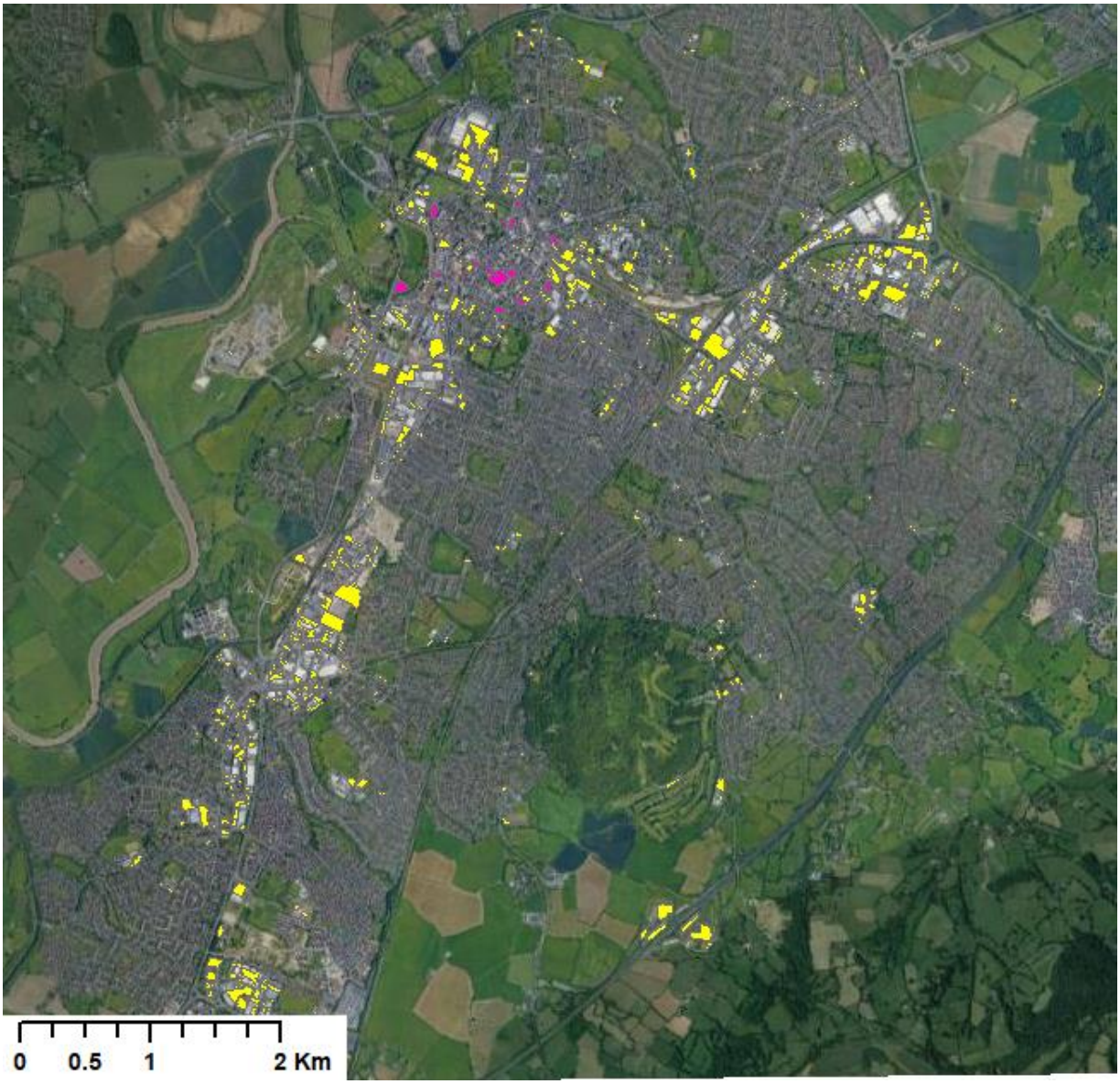
Within the area 500m and 2km from the hospital, approximately 41.89% of the total carparks and about 48.87% of the total PNR parking spaces are used for Employment in some capacity. Additionally, 20.27% of the carparks and 27.37% of the parking spaces are used, to some degree, for Retail. Both these Employment and Retail lots present a potential for future reuse as the parking and travel trends within the city change. Statistics for the distribution of PNR carparks between 500m and 2km of the Worcester Royal Hospital, based on their use classification, are shown in Table 9.

Table 9. Statistics on the distribution of PNR carparks between 500m and 2km of the Worcester Royal Hospital, based on their associated HELERT use classifications.

HELERT	Total Carparks	Total Parking Spaces	Average Parking Spaces	Total Area (km^2)	Carpark %	Parking Spaces %
Health	13	1,467	112.85	0.0254	17.57 %	13.57 %
Employment	31	5,283	170.42	0.0912	41.89 %	48.87 %
Leisure	24	2,783	115.96	0.0481	32.43 %	25.74 %
Education	13	1,400	107.69	0.0242	17.57 %	12.95 %
Retail	15	2,959	197.27	0.0511	20.27 %	27.37 %
Transportation	1	22	22.00	0.0004	1.35 %	0.20 %

4.3 PNR Parking in Gloucester

We mapped the PNR parking in Gloucester after creating our procedure to test if our procedure worked on a different and larger UK city. We found that the procedure was easily applied to Gloucester and no amendments to the protocols were necessary. We found the city of Gloucester has 584 carparks and 74,727 parking spaces. This compares to their 14 municipal carparks that provide 2,757 parking spaces. As in Worcester, the PNR parking provision massively exceeds the municipal provision. Figure 20 shows all the PNR carparks in yellow, and the municipal carparks in pink.



Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Landsat / Copernicus, Maxar Technologies, The Geoinformation Group

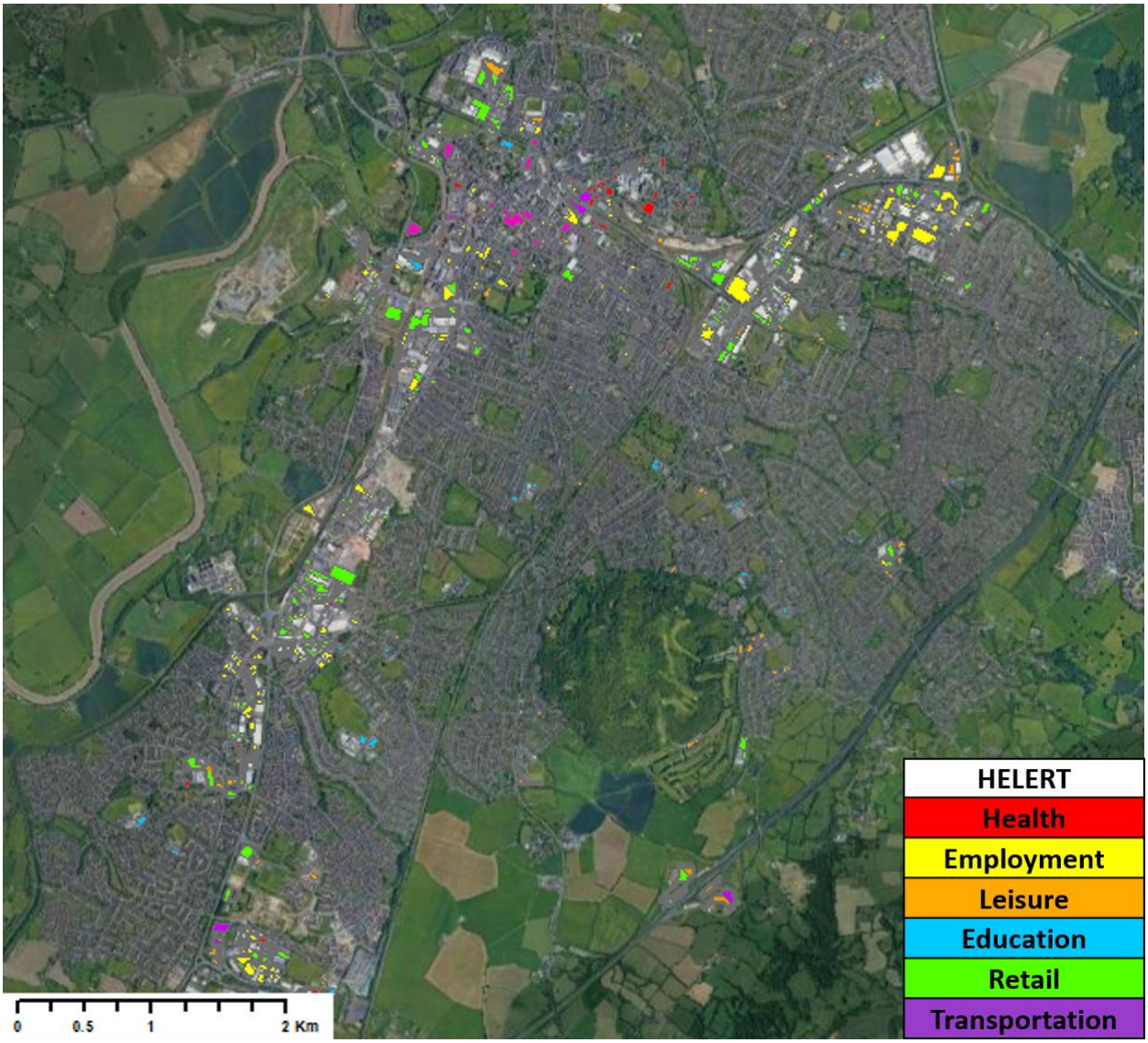
Figure 20. All PNR Parking in Gloucester

In Gloucester, there are about 20,000 parking spaces and 155 carparks more than Worcester which makes sense given that the city and population of Gloucester is slightly larger than that of Worcester. It is also worth noting that the number of parking spaces in municipal lots of the two cities are about the same. A breakdown of which HELERT categories all these carparks fall into can be seen in Table 10. When looking at the differences in the HELERT breakdown between Worcester and Gloucester there are a few significant differences. Most notably, the top category is different in each, Gloucester largest category is Retail where Worcester is Employment. As in Worcester, the Health and Education categories are about equal in Gloucester also. Another difference is that there are ten more Transportation carparks in Gloucester than in Worcester and the number of parking spaces is much greater.

Table 10. HELERT Breakdown of PNR Parking in Gloucester

HELERT	Carparks Number	Carparks Percent	Parking Spaces Number	Parking Spaces Percent
Health	53	9.01 %	5,361	7.17 %
Employment	198	33.67 %	26,249	35.10 %
Leisure	161	27.38 %	20,263	27.10 %
Education	62	10.54 %	5,389	7.21 %
Retail	215	36.56 %	35,050	46.87 %
Transportation	12	2.04 %	3,822	5.11 %

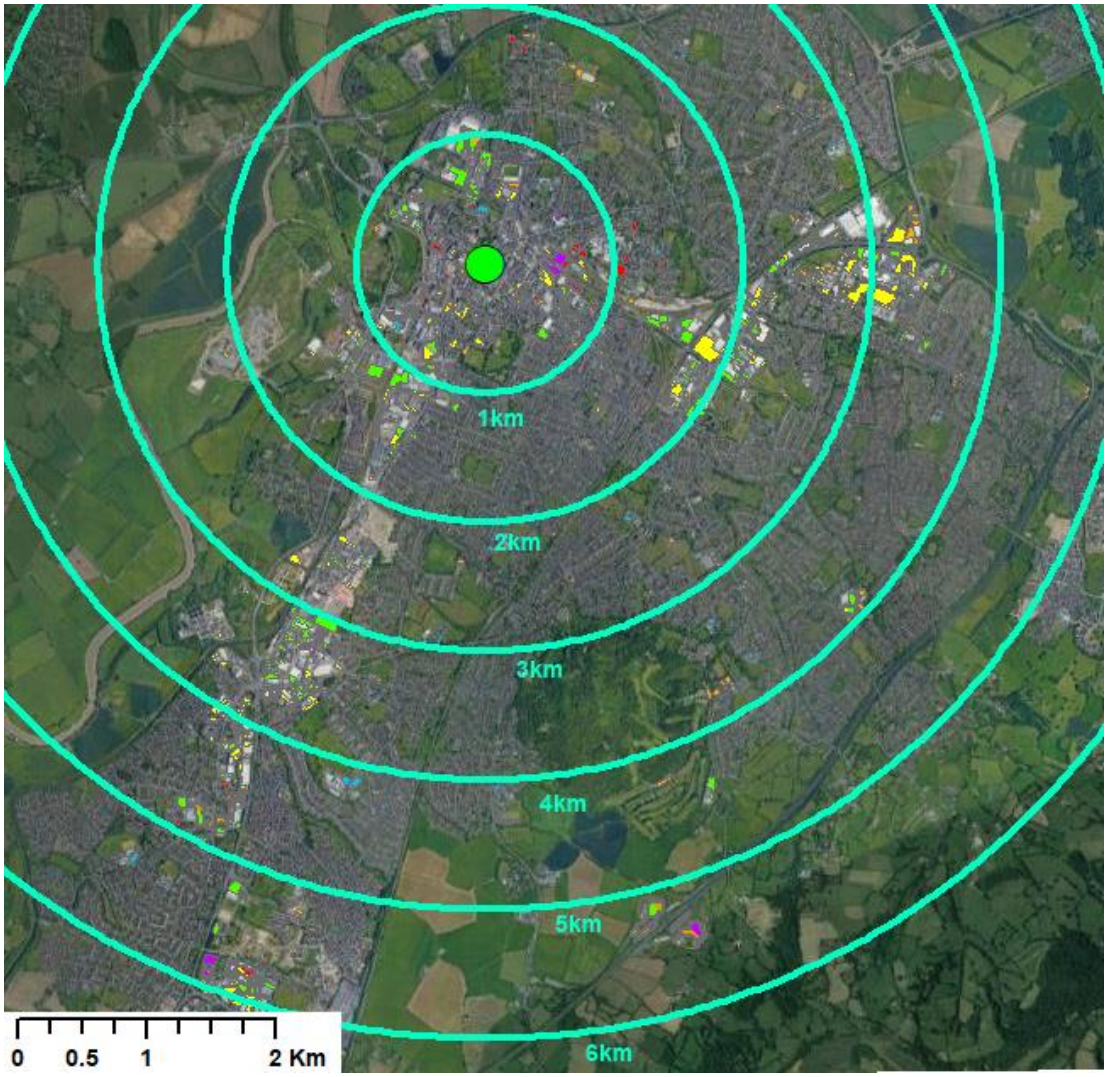
The image in Figure 21 shows all the carparks in Gloucester colored to match their HELERT category. From the figure, you can see that the Health carpark are all generally located near each other, whereas the Employment, Retail, and Leisure carparks can be seen all over the city.



Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Landsat / Copernicus, Maxar Technologies, The Geoinformation Group

Figure 21. PNR carparks in Gloucester color coded by their corresponding HELERT use classes.

As we did in Worcester, we calculated how far the carparks were from the Gloucester city center. For this analysis, the city center was taken to be at the intersections of Northgate, Eastgate, Southgate, and Westgate streets. This information is used to show the distribution of carparks in relation to the city center. As shown in Figure 22 and Table 11, the zone with the most carparks is the zone situated 2km to 3km from the city center. Additionally, this zone has the most PNR parking spaces. However, the city center follows close behind as the zone with the second most parking spaces, having just barely lost by a mere 82 parking spaces, less than one lot's worth of space.



Maps & Image Data: Google, ©2021 CNES / Airbus, Getmapping plc, Infoterra Lt & Bluesky, Landsat / Copernicus, Maxar Technologies, The Geoinformation Group

Figure 22. Gloucester PNR Carparks relative to the city center.

Table 11. Distributions of Gloucester's PNR carparks based on their distance from the center of the city.

Radius	Total Carparks	Total Parking Spaces	Average Parking Spaces	Total Area (km^2)	Carpark %	Parking Spaces %
Less than 1km	120	15,989	133	0.2764	20.41 %	21.38 %
1km – 2km	118	14,935	127	0.2581	20.07 %	19.97 %
2km – 3km	126	16,071	128	0.2777	21.43 %	21.49 %
3km – 4km	113	12,585	111	0.2175	19.22 %	16.83 %
4km – 5km	64	6,542	102	0.1131	10.88 %	8.75 %
5km – 6km	34	7,511	221	0.1298	5.78 %	10.04 %
Greater than 6km	9	1,094	122	0.0189	1.53 %	1.46 %

Finally, we looked at how many carparks are being shared by multiple businesses. Of the 584 carparks 394 or 67 % of them are shared between multiple businesses. The most common pair of shared categories was Retail and Employment making up 45 of the carparks. This makes sense because spread throughout the city there are many small industrial sectors that contain mostly Retail and Employment businesses.

When mapping the PNR parking in Gloucester, one major difference between that and Worcester was that Gloucester has many industrial zones throughout the city whereas in Worcester there is only one industrial area to the north of the city. Because Gloucester is a more industrial city, this difference makes sense and is part of the reason we chose to use Gloucester as our test city.

4.4 The Workplace Parking Levy

As discussed in the background section, many towns and cities in Europe and elsewhere are exploring new ways to reduce and reuse parking space. The workplace parking levy introduced by Nottingham in 2012 has been particularly successful in not only reducing the amount of parking in the city by also in generating a revenue stream that has allowed the city to enhance its public transport infrastructure. Other cities, such as Birmingham and Leicester, are also exploring this approach. The purpose of their WPL is "to constrain congestion growth by placing a modest charge upon the use of commuter parking places, to encourage employers to manage and potentially reduce the amount of free workplace parking places they provide and promote the use of sustainable modes of transport as a means of reducing congestion" (WPL in Nottingham, n.d.). The WPL was officially put into place on October 1st, 2011 when all employers providing workplace parking were required to obtain a WPL license, charging commenced on April 1st, 2012 for all employers providing 11 or more liable workplace parking places. The cost of the levy for each liable parking place has increased with inflation over the last eight years and as of April 1st, 2021 was set to £428 per liable parking place per year. The WPL has "raised around £79 million of revenue" since the start of the scheme (WPL in Nottingham, n.d.). With this money, Nottingham has been able to create a "tram network with 17.5km of new tramlines", "redevelop Nottingham Station into a 21st century transport hub", "support and expand [their] Link bus network", and "provide match funding to access grants to deliver one of the largest fleets of electric buses in Europe" (WPL commercial flyer, n.d.). With the basis of this newfound information, we interviewed Nigel Hallam, the Workplace Parking Levy Service Manager from Nottingham's City Council. When interviewing Nigel, the three main topics we discussed were setting the price of the WPL, deciding which businesses pay for which parking places in business parks, and the businesses' reluctance to the tax.

When Nottingham was initially planning their WPL scheme, they had to work backwards to decide what the cost per parking place should be. This amount was determined through many factors, including the cost of the project they wanted to complete and the potential opinions of the businesses in city regarding the levy. In Nottingham's situation, they wanted to be able to fund one-third of the cost of transforming their tramline into a tram network. With this goal in mind, they started to work backwards to determine how much money they needed to charge per parking place per year. They also needed to keep in mind that if they made the cost of the WPL too high it could potentially cause businesses to leave the city. This plan worked successfully because every liable business in Nottingham has always been in 100% compliance with the WPL. Further, even with the levy in place and rising with

inflation more businesses from outside the city are trying to move in. Businesses are attracted by the accessible, high quality and affordable public transport options in the city.

As noted in our analysis of Worcester and Gloucester above, many carparks are used by more than one business, especially larger carparks associated with business parks. When deciding who was accountable for these spaces and how to allocate the parking levy, the Nottingham WPL Team would set up a meeting with a representative from each company in the business park. At this meeting they would discuss how the parking was used; for example, how much each business used for employees or customers and in some cases how much of the parking was not being used by companies in the business park, but rather by other businesses in the area. After discussing how the carpark was being used, they would decide who was responsible for which parking spaces. If needed, they would create a whitelist of who should be parking there in case any problems were to arise. Overall, the WPL Team tries to make all aspects of the levy and the licensing of carparks as easy for the businesses as possible.

Lastly, we discussed how Nottingham addressed business reluctance about the WPL. When Nottingham City Council was first trying to create the scheme, they met with business representatives to explain how congestion in the city was costing both the city and the businesses money and how the scheme might ultimately reduce both congestion and costs. These conversations revealed that local businesses and the city council were in close agreement about how to improve public transport, and businesses have generally been pleased with the progress to date. The council continues to work very hard to support the businesses in improving their carparks by funding grants to provide electric car charging infrastructure, sheltered bike storage, showers and drying cabinets to encourage active travel.

4.5 Stakeholder Perspectives

We reached out to many different Worcester City Council Members and Councilors, as well as, transport planners, and other field experts. Unfortunately, because of Purdah, the pre-election period in the UK, many councilors and council members were very busy and unwilling to talk until after the election on May 6. Nevertheless, Councilor Matthew Jenkins did respond to our question via email, and we were able to conduct an interview over Teams with Emily Walsh, an Associate Director from SYSTRA, a public transport and mobility solutions company. Cllr Jenkins and Ms. Walsh expressed similar opinions regarding Worcester's approach to public transportation and implementing Nottingham's WPL.

4.5.1 Councilor Matthew Jenkins

We asked Cllr. Matthew Jenkins for his thoughts on changing Worcester's parking provision, repurposing parking, and parking generating the city revenue. First, the councilors believes that one of the main problems with current transportation in Worcester is the congestion from the number of cars entering the city. This is partially because there are "a large number of carparks dotted around the city … this often leads to people driving around the city to find a parking space" (M. Jenkins, personal communication, May 3, 2021). Cllr. Jenkins believes that this issue could be combatted by creating a few large multi-story carparks and getting rid of some of the many small lots sprinkled around the city. Another solution to this problem of congestion would be improving the walking, cycling, and bus provision pair with charging for on-street parking. If all these actions took place, Cllr. Jenkins believes the congestion in the city would decrease or stop growing as the city the city grows.

On the topic of many carparks becoming underutilized, Cllr. Jenkins thinks that additional residential housing would be the most beneficial addition to the city. Currently, “Worcester has a low number of people living withing the city center compared to other cities” (M. Jenkins, personal communication, May 3, 2021). Unfortunately, current plans are to build new housing on the green spaces surrounding the city rather than in the city. If some of the underused carparks could be used for housing, green space would be preserved, and people might be encouraged to move in to the city center instead.

Cllr. Jenkins also brought up the workplace parking levy in Nottingham, saying the money gained from that tax, would be able to help the city provide cheaper and better public transportation. This would help the city work towards their net-zero carbon emission goal of 2030. It would also help to lower the growth of congestion within the city, making travel into the city easier for commuters.

4.5.2 Emily Walsh

Emily Walsh met with us to discuss some of our questions regarding the expected decrease in parking usage, challenges in changing the current parking provision, and reusing excess parking in the future.

While parking usage has declined during the pandemic and as a result of remote working and online shopping, some transport planners, like Ms. Walsh, still expect that similar numbers of people come to the city center in the future to shop, dine, and relax. That being said, planners would like to limit the amount of driving into the city center by having large carparks on the outskirts of the city where people can park their cars and shift to a more sustainable method of transportation.

While there is a need to shift to more sustainable transportation, especially with Worcester’s goal to be carbon net-zero by 2030, underused parking spaces cannot be removed or repurposed until there are other ways for people to get around. Once these sustainable transportation methods are in place it will be easier to facilitate a change in travel behavior. Ms. Walsh also thought a parking levy like that of Nottingham’s could be useful because the city could set up a scheme to tax parking where it is not necessary or where public transportation is readily available.

Finally, we discussed repurposing carparks after public transit is more developed. Some of Ms. Walsh’s ideas reflect those mentioned in our background section, such as pop-up shops, parklets, and additional bike parking. As ever, it is the age-old chicken-and-egg problem: before any underused carparks can be repurposed, the city must first improve their public transportation system to provide commuters with other travel opportunities other than their cars.

5 CONCLUSIONS & RECOMMENDATIONS

5.1 REPURPOSING & REPROVISIONING PARKING

Our first conclusion is that to almost everyone's surprise, there are 429 PNR carparks in Worcester, which provide 54,905 parking spaces. These carparks total nearly 1km^2, or 2.6% of the city. In striking contrast, the 14 municipal carparks provide a total of 2,518 spaces. However, these municipal spaces—although small in number—provide a sizeable revenue stream for the city. Approximately 30% of parking is likely to be underutilized post-pandemic (M. Rowe, personal communication, March 29, 2021). This will result in about 16,471 PNR parking spaces or 0.285km^2 of surface space that will be underutilized. The Worcester City Council and Worcestershire County Council need to consider the implications this will have on future transportation and parking policy.

We recommend that the Worcestershire County Council and Worcester City Council closely consider how PNR parking might be more effectively integrated into transportation planning, especially with regard to decarbonization initiatives. The Worcester City Council and Worcestershire County Council should consult with local businesses to explore how underutilized parking might be repurposed, especially to provide more environmentally friendly options such as park and rides, bike share space or green space and parks. As Cllr. Matthew Jenkins mentioned, underutilized PNR parking within the city center might also be used for additional residential living. Our analysis reveals other opportunities that the city might pursue, such as repurposing under-utilized PNR parking to provide additional parking for the Worcestershire Royal Hospital and re-imagining uses for the former Sixways Park-and-Ride.

5.2 WORKPLACE PARKING LEVY

Many cities in Europe and elsewhere are exploring new ways to repurpose underused parking space to promote more sustainable transport and living options. Cities and towns in the UK are only just beginning to look at these options. One successful strategy adopted by Nottingham City Council and being considered by other cities such as Birmingham and Leicester, is the use of a workplace parking levy (WPL). The Workplace Parking Levy (WPL) has dramatically improved transportation and parking in Nottingham. The WPL encourages fewer people to use personal transportation and seek more sustainable options. It also provided a source of income which the city could then use to improve the public transportation. Local businesses in Nottingham have supported the strategy as they realize the financial benefits of reduced congestion and the promotion of more sustainable forms of travel, including walking, cycling, and public transport.

We recommend that the Worcestershire County Council and Worcester City Council consult with local business groups and others to explore the potential for a Workplace Parking Levy in Worcester. The Nottingham City Council has indicated a willingness to assist other towns in developing such approaches and is currently consulting with several other cities and towns.

5.3 FUTURE MAPPING EFFORTS

The manual identification and mapping PNR carparks in a city such as Worcester is eminently feasible using satellite imagery and GIS software, but requires considerable time, about 80 person-hours. Using the process outlined in the Procedural Guide supplemented with this report can cut that

time down to 60 person-hours mapping a city the size of Gloucester; however, it is still extremely labor-intensive. In addition to it taking a long time to map, parking within the city is frequently changing; therefore, the maps would need to be updated every one or two years. While it should be easier to remap the city because the location of the carparks is already known, it will still be time consuming to update which businesses now own the lots. Further, any new lots that are created will also need to be discovered and mapped.

In order to make the mapping process faster and more efficient we suggest automating the process. This could be done if land parcel data (e.g., location, property boundaries, ownership, and land use type) is readily available in digital form. However, if digitized land parcel data is not available or cannot be accessed, then automation would require a heavy investment in artificial intelligence. The artificial intelligence would be used to find the carparks on a satellite image and create discrete polygons with associated data tables in a GIS format. This would require a large financial investment and lots of time training the AI to differentiate between areas that appear very similar to parking areas on a satellite image (such as a large, flat roof of a building). Because of these two drawbacks, using AI to map the PNR parking may not be a realistic option for any local authority. Nevertheless, the manual process for mapping and remapping PNR parking using ArcGIS is outlined in the Procedural Guide supplemented with this report, and does not require many skills or prior knowledge of parking in a city or of the software. Remapping the city's parking every few years could be outsourced to university or local high school students as a placement activity. This would be a cheap and efficient way for the City Council to keep the maps up to date and provide a valuable educational experience for students at the same time.

5.4 Mapping Parking in Other Cities

Whilst cities and towns are acutely aware of the number and locations of their municipal car parks, most cities and towns in the UK have little information about the provision of PNR parking. It is likely that other towns and cities have an abundance of PNR parking comparable to Worcester and Gloucester, and that a sizeable fraction of this space will be underused in the future.

Accordingly, we recommend that other cities and towns consider implementing the procedures we have developed to map their PNR parking provision. To minimize resources in this effort, they might consider recruiting local university or high school students. Alternatively, several towns and cities might consider combining resources to develop a more automated system using digital data and/or artificial intelligence.

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7 APPENDIX

The appendix includes useful tables on building use classes, private parking provision, bicycle storage space, and interview questions referenced in the main text.

APPENDIX TABLE OF CONTENTS

Appendix A. BUILDING USE CLASSES AS OF SEPT. 1ST, 2020

Subclasses are denoted with letters for the sake of definition.

Class	General Use Description	Class	General Use Description
C1	Hotels	F1(a)	Provision of education
C2	Residential Institutions	F1(b)	Display of works of art
C2A	Secure Residential Institutions	F1(c)	Museums
C3	Dwellinghouses	F1(d)	Public libraries or public reading rooms
C4	Houses in multiple occupation	F1(e)	Public Halls or exhibition halls
E(a)	Display or retail sale of goods	F1(f)	Public worship or religious instruction
E(b)	Sale of food and drink for consumption (mostly) on premises	F1(g)	Law courts
E(c)	Financial Services, Professional Services, & other appropriate services in a commercial, business, or service locality	F2(a)	Small shops selling mostly essential goods.
E(d)	Indoor Sport, Recreation or fitness	F2(b)	Halls or meeting places for local community
E(e)	Medical or health services	F2(c)	Areas or places for outdoor sport or recreation
E(f)	Creche, day nursery, or day center	F2(d)	Indoor or outdoor swimming pools or skating rinks
E(g)	Offices, Research and development, and industrial processes (In a residential area)		

Appendix B. PRIVATE PARKING PROVISION IN BIRMINGHAM AND SUFFOLK

Class of Development	Standard Use	Buckingham (2015)	Suffolk (2019)
A1	Food stores > 1000 m^2	1 space per 17 m^2	1 space per 14 m^2
	Food stores < 1000 m^2	1 space per 23 m^2	1 space per 16 m^2
	Non-Food Retail > 1000 m^2	1 space per 38 m^2	1 space per 20 m^2
	Non-Food Retail < 1000 m^2	1 space per 23 m^2	1 space per 20 m^2
A2	Financial and professional services	1 space per 20 m^2	1 space per 25 m^2
A3	Restaurants	1 space per 17 m^2	1 space per 5 m^2 public space
A4	Drinking Establishments	1 space per 25 m^2	1 space per 5 m^2 public space
A5	Takeaways	1 space per 23 m^2	1 space per 3 m^2 public space + 1 space per 4 employees normally present
B1	Business	1 space per 25 m^2	1 space per 30 m^2
B2	General Industrial	1 space per 64 m^2	1 space per 30 m^2
	Motor Vehicle Service and Repair	1 space per 62 m^2	3 spaces per service bay
B8	General Warehouse	1 space per 150 m^2	1 space per 130 m^2
C1	Hotels and Hostels	1 space per bedroom	1 space per bedroom
C2	Hospitals	Case by Case	1 space per 4 staff + 1 space per bed
	Care Homes	1 space per 3 residents	1 space per staff + 1 space per 3 beds
D1	Art Galleries / Museums	1 space per 89 m^2	1 space per 25 m^2
	Exhibition Halls	1 space per 25 m^2	1 space per 25 m^2
	Places of Worship	1 space per 25 m^2	1 space per 10 m^2 public space
	Libraries	1 space per 50 m^2	1 space per 40 m^2 public space
	Primary / Secondary Schools	1 space per staff	2 spaces per 20 pupils
	Higher Education	1 space per staff + student parking to be assessed	2 spaces per 15 students
D2	Cinemas	1 space per 12 seats	1 space per 5 seats
	Leisure Centers / Swimming Pools	1 space per 62 m^2	1 space per 10 m^2 public area

Appendix C. PRIVATE PARKING PROVISION IN WEST SUSSEX

Class of Development	Standard Use	Parking Provision
B2	General Industrial	1 space per 40m^2
B8	Storage	1 space per 100m^2
C1	Hotels	1 space per bedroom
C2	Residential Care Homes	Site-specific assessment
E(a)	Shops and Retail	1 space per 14m^2
E(b)	Food and Drink	1 space per 5m^2 public area
E(c)	Financial and Professional Services	1 space per 30m^2
E(d)	Assembly and Leisure	1 space per 22m^2
E(e) & E(f)	Non-residential institutions (medical or health services, crèches, day nurseries and centers)	Site-specific assessment
E(g)	Business (office, R&D, light industry)	Site-specific assessment
F1	Non-residential institutions (education, art gallery, museum, public library, public exhibition hall, places of worship, law courts)	Site-specific assessment
F2	Small shop, community hall, outdoor sport/recreation area, indoor or outdoor swimming pool, skating rink	1 space per 14 m^2
Sui Generis	Public House, wine bar, drinking establishment	1 space per 5m^2 public area
	Hot Food Takeaway	1 space per 5m^2 public area
	Cinema, Concert Hall, Bingo Hall, Dance Hall, Live music venue	1 space per 22 m^2

Appendix D. NUMBER OF STORAGE SPACES REQUIRED FOR BICYCLES

Land use- new developments		BCC recommended number of cycle space
Residential dwelling	1 bedroom 2 bedroom 3 bedroom 4 bedroom 5+ bedroom	Storage space for 1 bicycle Storage space for 2 bicycles Storage space for 2 bicycles Storage space for 3 bicycles Storage space for 4 bicycles
	Flats/apartments	1 space per flat/apartment
	Sheltered and retirement accommodation	1 space per 10 residents, plus 1 space per 5 staff on duty
	Multiple occupancy	0.5 spaces per bedroom, plus 1 visitor space per 10 bedrooms
A1. Retail		1 space per 150 sqm (<1000sqm) 1 space per 250 sqm (>1000sqm)
Storage/distribution warehouse		1 space per 500 sqm up to 10,000 sqm. After 10,000sqm, 1 additional space per 20,000 sqm
Garden centre		Case by case
A3. Food and drink (inc pub, restaurant)		1 space per 100 sqm
Business	B1 Business offices	1 space per 250 sqm
	Industrial unit	1 space per 500 sqm
	Industrial estate	1 space per 500 sqm
C1. Hotel and hostels		1 space per 15 bedrooms plus 1 space per 7 staff
D1. Surgeries/health centres		1 space per 5 staff
D2. Assembly and leisure	Cinema	1 space per 100 seats
	Leisure centres/ pools	1 space per 400 sqm
Schools (Please note, standards reflect use of scooters plus bikes) D1e. Primary D1f. Secondary		 1 space per 10 staff and students 1 space per 7 staff and students
D1e. Colleges		1 space per 7 full time staff and students
D1. Libraries		1 space per 200 sqm
Sui Generis. Theatres		1 space per 100 seats
Transport	Bus station	Case by case
	Train station	Case by case

Appendix E. **PREAMBLE TO INTERVIEWS**

We are four students from Worcester Polytechnic Institute in Massachusetts, USA collaborating with the University of Worcester to explore the potential reuse and redevelopment of excess private non-residential (PNR) parking in the city of Worcester. As an expert in this field, we would like to learn more about your opinions on these issues.

Participation in this interview is voluntary, if we ask any questions that you do not want to answer, you can choose to opt out of that question, and we will move on to the next one. Are you comfortable with us recording this interview? Do you mind if we quote you in any materials we publish, or would you like to remain anonymous? Whichever you decide, we will still give you the opportunity to review any materials used from this interview before publication.

Our current research suggests that there are approximately 429 private non-residential carparks containing a total of 54,905 parking spaces in the city. These carparks take up approximately 95 hectares of surface space within the city. As reference, there are about 2,518 municipal parking spaces, with the municipal carparks occupying about 4.8 hectares of surface space.

Appendix F. NOTTINGHAM WORKPLACE PARKING LEVY INTERVIEW

1. How are you involved with the WPL in Nottingham?
2. How was the cost of the WPL chosen? What factors were considered in choosing the amount of £428?
3. How do the parking charges work for businesses that share parking areas, such as with business parks? Do the landowners distribute the charges or do the business typically work it out amongst themselves?
4. Do the parking charges usually fall upon the employees or is it usually handled by the business owners?
5. How receptive to the WPL were the businesses when it was first introduced?
6. How long after putting the WPL in place did it take for commuters to start transitioning to public transportation?
7. Has the number of commuters ever been a problem for the Nottingham public transport system, after the WPL had gone into effect?
8. Would you recommend a WPL be put in place in Worcester, England? Why or why not?

Appendix G. WORCESTER CITY COUNCILOR EMAIL

Dear _____,

We are members of a student research team from Worcester Polytechnic Institute in the United States partnering with the University of Worcester to explore the quantity and potential repurposing of private non-residential parking within the city of Worcester.
Our current research suggests that there are approximately 439 private non-residential carparks containing a total of 55,346 parking spaces in the city. These carparks take up approximately 95 hectares of surface space within the city. As reference, there are about 2518 municipal parking spaces, with the municipal carparks occupying about 4.8 hectares of surface space.
In order to aid with our assessment of these numbers and potential changes in use for a portion of the land occupied by our carparks, we are reaching out to several people of knowledge and hope you will take the time to answer the following questions.

- Given the increase in the numbers of people working remotely and shopping online, how do you think that the City of Worcester may need to change its parking provision and policies in the future?
- As more people work remotely given the pandemic and changes in technology, it is likely that many businesses and other organizations will find they have an excess of parking space. How might this excess space be most effectively repurposed, and what role might the City Council play in this effort?
- How might the City Council incentivize businesses and landowners to repurpose their excess parking space?
- Expecting the decreased parking usage to affect all non-residential lots, how might the decreased usage of municipal lots affect the City's generation of revenue. How might municipal parking provision evolve in the future as a result of this trend?
- What will be some of the biggest challenges in changing current parking provision to better meet future needs in the City?

Please let us know if you are comfortable with your responses being quoted and/or paraphrased in our final report, and if so, if you are comfortable with your name being associated with them. If you answer yes to any or all the above, please know that we will send you a copy of our report to review and comment on before it is publication.
We thank you for your time, and we look forward to hearing back from you. If you feel there is any other information that may be helpful to our research, we would love to hear about it.

Sincerely,

Joshua Geyster
Dan Trainor
Mary Marquette
Rowan Labaugh
WPI PNR Parking Research Team

Appendix H. TRANSPORTATION PLANNER INTERVIEW

1. Given the increase in the numbers of people working remotely and shopping online, how do you think that the City of Worcester may need to change its parking provision and policies in the future?
2. Expecting the decreased parking usage to affect all non-residential lots, how might the decreased usage of municipal lots affect the City's generation of revenue. How might municipal parking provision evolve in the future as a result of this trend?
3. What will be some of the biggest challenges in changing current parking provision to better meet future needs in the City?
4. In your opinion, how might the City of Worcester and its landowners best make use of this excess parking space in the future?
5. How might the City and County councils incentivise / motivate business and landowners to make changes to how they manage their parking space?
6. What sort of information would be the most helpful for Transport planners to better facilitate the evolution of parking and transport policy in the future?