

## **ARE WE STILL PAVING PARADISE? NEW TECHNIQUES IN PARKING MANAGEMENT**

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### **ABSTRACT**

Parking is an integral component of the transportation system. The way that parking is managed has a variety of economic, social and environmental consequences. Effective parking management has the opportunity to create more attractive communities, and reduce congestion and pollution, whilst also preserving greenspace. It is essential to recognise that cars are only one part of the transportation system and the way parking is managed can encourage moving away from automobile dependency to more sustainable modes of transport.

The old parking paradigm focuses on a 'predict and provide' approach, where motorists should always be able to find convenient parking. This results in an abundant supply of parking and contributes to an automobile dependent society, which is not a sustainable society. The new parking paradigm (parking management), armed with innovative planning mechanisms and the use of technology aims to manage parking more efficiently and provide optimal parking supply, restrictions, and price. This paper looks at the success of the practical application of parking management across New Zealand. Parking management policies and programs investigated include:

- Demand responsive pricing, and
- Parking maximums.

Deployment of technology is identified as an effective management tool for parking management as it provides a flexible and responsive platform for regulation and enforcement. This paper also investigates how parking management policies are being implemented in New Zealand with the use of technology. Challenges and learnings from implementing new parking management strategies and moving away from the old parking paradigm are examined so we can strive towards a more sustainable transport system.

## 1. INTRODUCTION

### 1.1 Overview

The overall aim of this research is to investigate the benefits, weaknesses and lessons learned from implementing parking management policies in New Zealand, specifically demand responsive pricing and maximum parking requirements in District Plans. In addition, the study also investigates the use of technology to manage parking and how it can be applied to manage parking more efficiently and effectively.

### 1.2 The Parking Problem

Parking is an integral component of the transportation system and requires careful management. Parking is a land use that supports a wide range of activities that people participate in. The issue of managing parking is convoluted and often contentious, as there are different competing interests and views involved. Managing off street and on street parking resources is a resource management issue for local authorities that requires careful consideration. Challenges around managing parking include:

- Little guidance for those tasked with parking management (e.g. planners, operators, landowners etc.), and
- Lack of research on quantifying how many parking spaces to supply.

It is recognised by several authors that parking is the inadequately studied link between transportation and land use (Manville and Shoup 2005, Shoup 1997, Marsden 2006). There is often the perception of not enough parking spaces when drivers are forced to search for a car park, however, in reality it is the way that the parking resource is managed as opposed to lack of supply (Litman, 2006). Parking management has typically been reactive, where a policy is implemented when there is an agreed area where parking needs to be managed (Rye, 2010). Parking policies originally emerged from concerns about safety and hindrance of traffic flow on roads (Marsden 2006). Previous policy makers have viewed that car parking spaces should always be available and free (Litman, 2006). Additionally, the traditional 'predict and provide' approach contributes to an automobile dependent society and contributes to an "asphalt wasteland that compels people to drive" Shoup 2015, p29).

When parking is not managed effectively there are several detrimental effects that may arise. Cars circling for car parking spaces create vehicle emissions and safety concerns due to distracted drivers. A copious amount of parking supports vehicle use and contributes to urban sprawl, which ultimately leads to an automobile dependent society. The problems with an automobile dependent society are numerous and multi-faceted, and include loss of street life and community in neighbourhoods; congestion costs, oil vulnerability and road safety concerns (Schiller et al., 2010).

Land use patterns associated with automobile dependence comprise wide roads that promote higher speeds and large car parks that make walking impractical and cycling dangerous. Oversupply of car parking spaces reduces development density, this increases developer costs and reduces the ability to provide for alternative modes of transport thus facilitating further vehicle use. New Zealand has one of the highest rates of personal car ownership in the world (Perrau 2007). Newman and Kenworthy (1996) assert that in car-dependent societies, the car drains the city centre of its life and disperses it. Effective parking management policies are integral in moving away from car dependence and helping to create a more sustainable transport system.

### 1.3 Parking management policies

What is referred to as a 'new paradigm' of parking policies, involves the introduction of parking management strategies to help manage parking more efficiently. These strategies focus on managing parking as an economic resource and directly link to wider transportation objectives and goals. Rye (2010) addresses that parking management is a strategic tool that can help achieve environmental, social, and economic objectives. Both parking design and management has an important influence on mode choice, therefore parking can contribute to wider policies of urban centres. The concept of parking management encompasses both strategies and policies that result in using parking as a more efficient resource (Litman 2016). Over two dozen parking management strategies have been developed worldwide and implemented that have resulted in wider community benefits. Parking facilities are considered well utilised if they are over 85% occupancy (Litman 2006). An example of some of the parking management strategies used around the world are listed below:

- Unbundle parking (parking is sold/ rented separately to the development),
- Shared parking (parking facilities are shared between multiple activities),
- Enhanced enforcement and control,
- Improved user information,
- Demand responsive parking;
- Parking maximums (capping the amount of parking that can be provided on private land).

Parking management can reduce the amount of supply required for future developments. This has wider benefits for the community including the ability to create more compact developments that support smart growth principles<sup>1</sup>. Parking management strategies help reduce land use consumption, providing more space for attractive urban space that facilitates social engagement and economic activity. More effective transport services can be provided in a compact area, and revenue generated from managing parking as an economic commodity can be put back into the community to provide infrastructure for alternative modes of transport (Litman 2006).

This research concentrates on two parking management strategies; parking maximums and demand responsive pricing.

Parking maximums set an upper limit on the amount of parking that can be supplied for a land use activity. Parking maximums help ensure that there is not an oversupply of parking and therefore poor utilisation of the parking resource.

Demand responsive pricing changes the cost of parking in response to demand, for example, the cost is reduced when occupancy is low and in times of high demand the cost of pricing is at its highest. Demand responsive pricing is implemented to varying degrees, where sometimes it is changed in direct response to parking sensors that obtain occupancy data, this is demand responsive pricing in 'real time'. In other instances, demand responsive pricing is changed at certain intervals after meter information or occupancy surveys are undertaken and analysis demonstrates that parking is under-utilised (for example, less than 85% occupancy) or in high demand (over 90% occupancy).

Technology is a useful tool to provide frequent and improved information to the public, including dynamic signage and mobile applications. In addition, technology helps parking management strategies become more effective and facilitates enforcement. Technology can improve customer experience and effectively communicate up to date information to transport users. Day to day operations and revenue gathering is enhanced when technology is employed. Technology is constantly improving and making transportation more convenient. Incorporating technology into policy and its associated implementation will help increase its effectiveness and transparency of information to the public.

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<sup>1</sup> Smart Growth principles include: walkable neighbourhoods, collaboration, mix land use, variety of transportation choices, compact urban design (Knapp and Talen, 2005)

## 1.4 Research gap

Shoup (1997) asserts that parking is inadequately studied area between transportation and land use. The scope of this research does not permit in-depth research of parking management but instead looks at two key policies that have been implemented in different contexts. Parking is context specific; the land use, geography, and political context need to be taken into consideration when considering parking policy. Policy needs to be informed by good research and up to date information, this ensures policy holds rigour and is both robust and effective in its intentions. Poorly informed policy can be detrimental and unproductive, well-informed policy is critical to implementing change and improvements.

Local authorities across New Zealand have implemented various parking management policies, this includes demand responsive pricing and parking maximums. These policies are the focus of this research as they are implemented in New Zealand and are progressive parking management strategies. The weaknesses, benefits and challenges from these parking management approaches are examined to gain a better understanding of how we can more effectively manage parking and inform policy.

The use of technology is an important tool that complements efficient parking management. This paper also looks at how technology is being used in parking management and opportunities to further incorporate technology. Local authorities can benefit from lessons learned and can incorporate the findings into their own parking management policies and strategies.

## 2. METHODOLOGY

To achieve the objectives of this research, a mixed methodology is employed in the study. This involves both qualitative interviews and quantitative surveys of practitioners. A literature review and analysis of relevant parking documents was undertaken. The mixed method approach is also known as triangulation. It provides stronger evidence than a singular approach due to strengths of both methods complementing each other (Johnson and Onwuegbuzie 2004). Clifton and Handy (2001) describe qualitative methodology as important in being able to capture the complexities of the transport system.

The initial research looked at the current parking management policies local authorities have employed to manage parking. In conjunction, a literature review examined the concept of parking management and the various planning mechanisms available that seek to manage parking more efficiently. The results from the literature review are not included in this report, however, key concepts and findings are presented that inform the premises of the research and to complement the findings.

Interviews were conducted with key informants from both Auckland Transport and Christchurch City Council. Key informants are experienced professionals within the parking and transportation profession. Their ideas, experiences, and knowledge are valuable in establishing themes and patterns to answer the research objectives. The interviews followed a semi-structured approach, consisting of a series of open-ended questions. Semi-structured interviews allow the interview to be shaped by the interviewee's knowledge so that new findings can emerge (Lewis-Beck et al., 2003). Reference to the interview findings are referred to as Key Informant 1 and Key Informant 2 denoting Auckland Transport and Christchurch City Council respectively.

A total of 58 practitioners completed an eleven question survey online through Survey Monkey. The survey yields both qualitative and quantitative information to inform the research findings. Written surveys can help eliminate any bias that may potentially arise in interviews through consistency, this is because all survey questions are the same. An online link to the survey was emailed to known parking practitioners across New Zealand and through the New Zealand Planning Institute email list, and a link shared through LinkedIn. The occupation of the

respondents includes resource management professionals, transport engineers and planners (Figure 1). Other occupations include operations officers, urban regeneration planners, and retired transportation professionals.

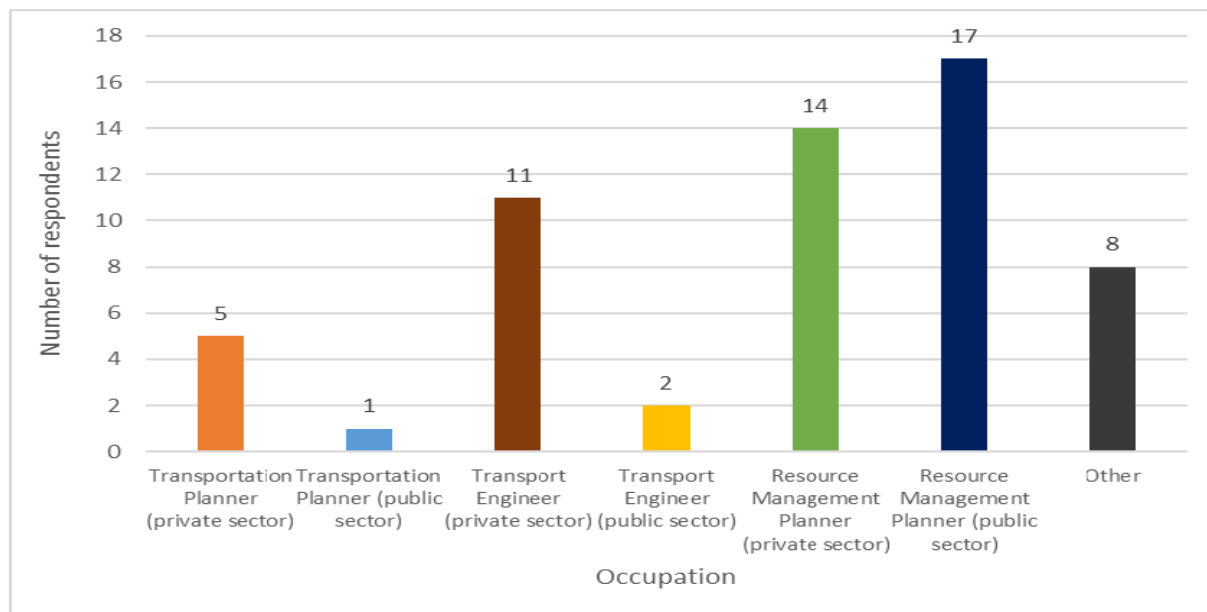


Figure 1 Survey respondents occupation (source: author).

### 3. PARKING MANAGEMENT IN NEW ZEALAND

Local authorities are tasked with the management of their off-street and on-street parking resources. Through both district plans and transportation strategies, local authorities manage public and private parking through a range of policy initiatives. The supply of parking on private land is managed through operative rules in the district plan. Some Second Generation District Plans include parking management strategies,<sup>2</sup> common strategies include parking maximums, cash in lieu, and parking reduction factors. Resource consents and plan changes are ways that Councils can impose parking management tools on private. For example, parking reduction factors can be applied in a resource consent application for a development.

Parking management strategies are often developed for localities to address the various pressures and objectives in a more holistic manner. A list of some of the parking management strategies are below:

- Auckland Transport Parking Strategy 2015,
- Christchurch City Council Parking Management Plan 2015,
- Whangarei District Council Parking Management Strategy 2011;
- Dunedin City Council Parking Strategy 2009.

Parking strategies often include objectives for managing on street and off street parking on public land. Key issues pertaining to parking in the locality are outlined with policies to address these. Policies include park and ride, demand responsive pricing, and pay by space. Parking strategy documents also include how monitoring and enforcement are going to be undertaken to ensure compliance. Local authorities also develop transport, or wider land use strategy documents. These strategies often include wider transport objectives for the city, district, or region. Parking policies are then developed in conjunction with these strategies.

<sup>2</sup> Second generation district plan is the second district plan that has been created for the district. The second generation district plan supersedes the original district plan when it is fully operative.

To investigate how the management of parking is perceived in New Zealand the survey asked respondents what are the current strengths and weaknesses of parking management policies and strategies in their respective localities. Respondents expressed the desire for improved parking management in conjunction with improving alternative modes of transport. Key points raised in the survey regarding parking management and how many respondents stated the point are listed below:

- *Not enough encouragement for alternative modes of transport (10)*
- *Not enough free car parks, must keep circling to find parks (7)*
- *No consistency in price of car parks (6)*
- *Conflict in priorities (regeneration vs reduction in automobile dependence) (6)*
- *Enforcement to varying degrees (5)*
- *Technology not used to assist parking management (5)*

As evident above, a range of issues with the current management of parking illustrate that the parking resources are not being managed as efficiently as they could be. The concerns raised from the survey respondents could be addressed through implementing parking management strategies. Circling to find car parks can be addressed through dynamic signage and mobile/online applications that communicate up to date information on where there are available car parking spaces. Demand responsive pricing that adjusts the price to demand will ensure costs are transparent to the price of parking. A suite of technology tools are available to assist in parking management, this is discussed further in **Section 2.4**. Furthermore, collectively applying parking management strategies can support alternative modes of transport.

The results from survey respondents when asked what parking management strategies they believe could be effective parking management strategies in New Zealand is illustrated in Figure 2. The most popular strategy suggested is shared parking with 22% of respondents selecting this strategy. Parking enforcement and improved user information through technology are the next most popular parking management strategies selected. Other strategies suggested include park and ride schemes and better provision for alternative transport modes such as public transport and cycling. Only 12% of survey respondents believed demand responsive pricing could be an effective parking strategy in New Zealand and 13% of people selected parking maximums as an effective parking management strategy. The benefits, weaknesses and lessons regarding demand responsive pricing and parking maximums are reviewed in further detail in the next two sections of this paper.

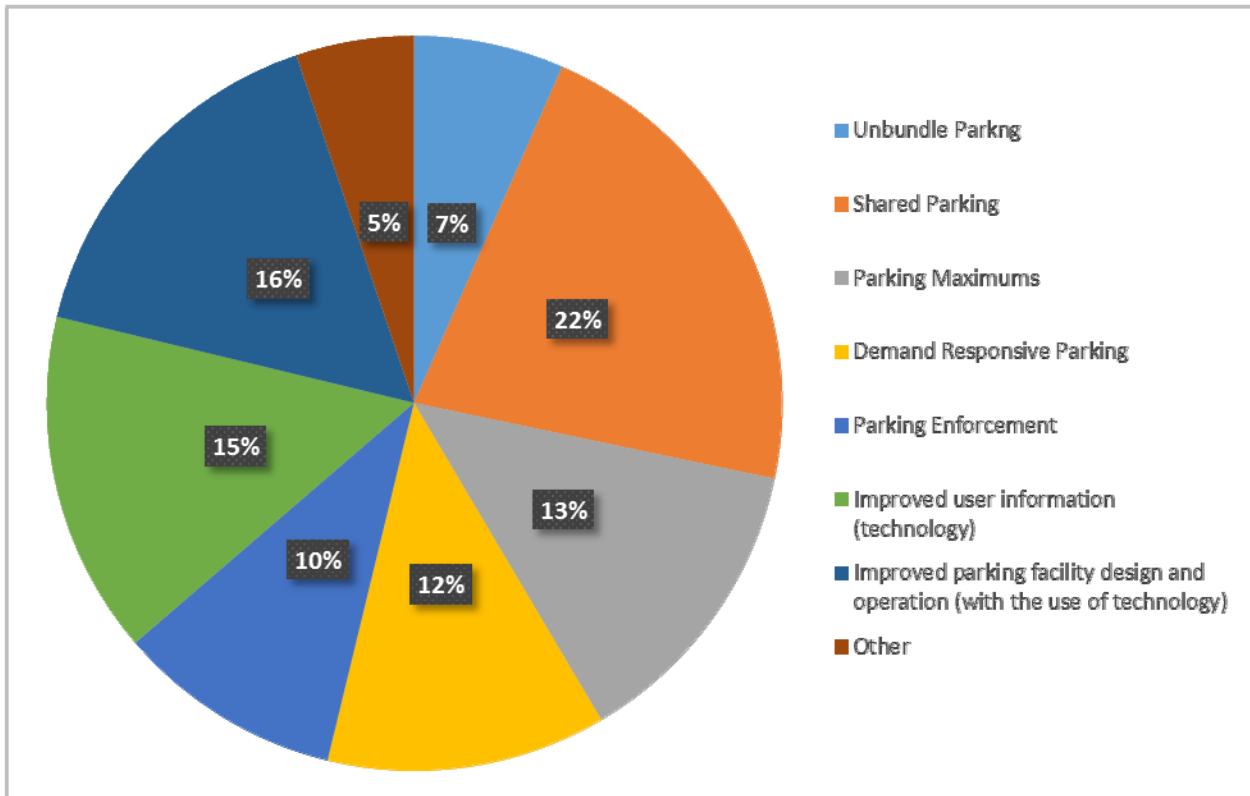


Figure 2 Parking management strategies that could be used as effective strategies to manage parking in New Zealand (source: author)

### 3.1 Demand Responsive Pricing

Shoup (1997) argues the problem with managing parking is not oversupply, but instead free parking. David Shoup in the paper *The High Cost of Free Parking (1997)* claims that when managing parking, the cost of on-street parking should be directly related to demand. This is because pricing parking in accordance with demand will manage parking more efficiently and lead to wider social, environmental, and economic benefits. As opposed to time limits which try to predict how long people want to spend in certain areas and creates further issues such as low occupancy, car dependency and excessive parking infringements. Cities around the world have trialed and adopted to various degrees demand responsive pricing as a parking management strategy. As evident in Figure 3 numerous cities in North America have adopted demand responsive pricing. Demand responsive pricing encourages people to think about whether to use their car and facilitates a higher turnover of cars in the areas of high demand.

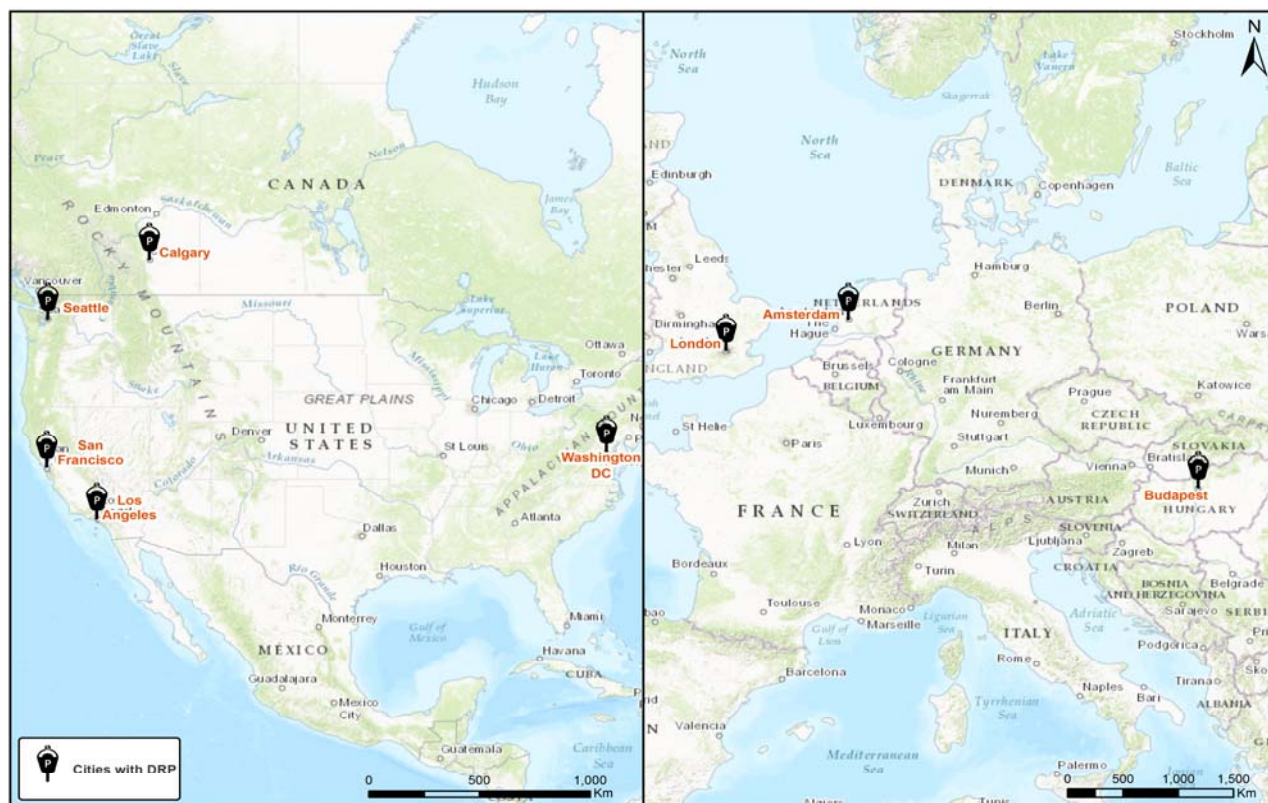


Figure 3: Cities with demand responsive pricing (source: author)

San Francisco is an important case study, as it is where the first large-scale trial of real time demand responsive pricing took place. Known as *SFpark*, the San Francisco Municipal Transportation Agency (SFMTA 2014) used parking occupancy data collected by in-ground sensors to adjust meter rates in response to demand. Demand responsive pricing is used to achieve a minimum level of availability so parking spaces can be found most of the time with a target occupancy rate of 60 – 80% (SFMTA 2014). *SFpark* involved deploying several emerging technologies such as smart parking meters, parking sensors, and an intelligent data management tool (SFMTA 2014). A large amount of data is captured that is analysed and applied to make smarter decisions without additional resources, increasing efficiency.

The main objective of *SFpark* was to make it easier to find a car park and improve the parking experience. The benefits of *SFpark* were numerous and multi-faceted; parking availability increased by 45 percent and utilisation by 31 percent (Demisch 2015). *SFpark* was successful in demonstrating a parking experience that is simple, consistent and easy to use. Parking tickets were reduced, and peak period congestion, traffic volume, and vehicle miles travelled decreased. *SFpark* is a great example of parking management strategies used in conjunction (both technology and demand responsive pricing) to have a high impact on efficient parking management. Technology employed in *SFpark* to aid its success is discussed further in **Section 2.3**

A presentation by David Shoup outlining how pricing parking as a function of demand should replace time restrictions inspired Auckland decision makers to remove time limits and apply demand responsive pricing (Key Informant 1).

The implementation process of demand responsive pricing in Auckland involved workshops and consultation with councillors, key stakeholders, and the public. It was found that there was a lot of opposition to the policy, specifically the removal of timed parking restrictions. However, once Auckland Transport engaged with those concerned and explained the intentions behind the policy and potential impact many people changed their minds and supported the policy. The benefits and disbenefits of demand responsive pricing are outlined in Section 3.2, Figure 5.



Central Auckland is currently the only area in New Zealand that has implemented demand responsive pricing. Auckland Transport undertook consultation with business owners, stakeholders and the community. The policy then gained support and achieved traction, and as a result the 2015 Auckland Parking Strategy embedded the policy of demand responsive pricing. The policy sets out how the price is set according to demand. Demand responsive pricing in Auckland is not in real-time, instead it involves undertaking hourly surveys over a couple of days, and the average of the four highest hours is taken. If parking occupancy is over 90% the price will increase, if between 70 – 90% the price will remain the same, and if below 70% then the price will be reduced. The policy has been successful in the reduction of parking infringements and achieving the desired 85% occupancy in the Central City (Key Informant 1). Auckland Transport is looking at extending demand responsive pricing to further areas of the City. Development and associated parking management need to be undertaken smartly to achieve strategic objectives, in particular, the goal of being “*the world’s most liveable City*” (Auckland City Council 2016).

The survey asked practitioners what is the biggest benefit associated with demand responsive pricing. As illustrated in Figure 4, the majority of practitioners (51%) believe there are numerous benefits of demand responsive pricing, that all are significant and no one benefit is significantly better than others. The survey results show that 24% of practitioners viewed the reduction in peak period congestion as the biggest benefit of demand responsive pricing. These results illustrate that the collective benefits of demand responsive pricing are considered significant.

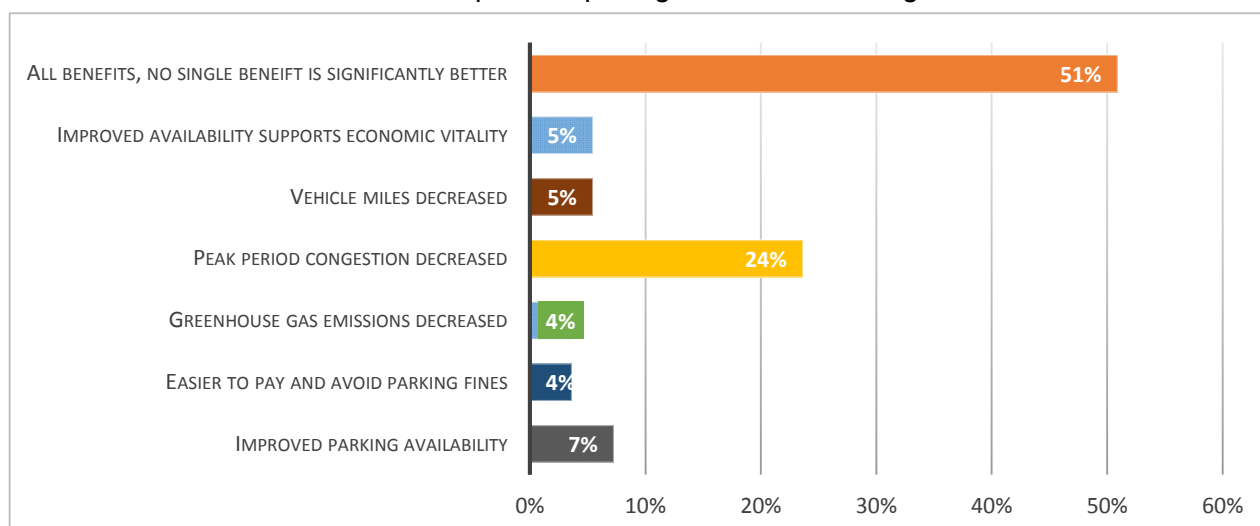


Figure 4 Main benefits from parking management strategies (source: author)

Key Informant 2 raised the issue of legibility as an issue surrounding implementing demand responsive pricing. When demand responsive pricing is applied in real time, users may read on mobile applications that the price is \$2 but then when the user arrives the cost is \$2.50 due to the current occupancy. Key Informant 2 states that this may add confusion to users and reduce the legibility of the parking costs. This may be the case if a real time strategy is implemented, however as users become familiar with the pricing and strategy this limitation may be reduced.

## 3.2 PARKING MAXIMUMS

Parking maximums refer to the parking policy in district plans that outline a maximum quantity of car parking spaces that can be provided based on the type of activity and its size. An example of parking maximums in the transport section of the Auckland Unitary Plan operative in parts (AUPOiP) is shown in Table 1: Parking maximums are seen in district plans either with no minimum parking requirements or in addition to minimum parking requirements. Parking maximums are important in starting the conversation about restricting parking supply and supporting alternative modes of transport. Results from the research found that there is strong support by practitioners to remove minimum parking requirements from district plans, as Donald

Shoup put it “*minimum parking requirements create an asphalt wasteland that blights the environment and compels people to drive:*” (Shoup 2015, p. 29).

A study in London in 2004 investigated the impact of removing parking minimums with and without parking maximums. The study found that the reduced car parking supply was 98% of the time due to the removal of parking minimums and two percent from imposing parking maximums. This study illustrated that removing the parking minimum is much more effective than imposing parking maximums (Shoup 2015).

Respondents from the survey suggested that maximums may not be effective when they are set at an inappropriate level. In addition, it is difficult to quantify what an effective parking maximum should be for each activity type. Numerous survey respondents stated that imposing parking maximums that are not very restrictive will have no impact on the supply of parking and may still result in an oversupply.

Activity			Applies to zones and locations specified in Standard E27.6.2(4)	
			Minimum rate	Maximum rate
(T22)	Emergency services		No minimum	1 car parking space per employee on site plus one per emergency service appliance based at the facility
(T23)	Care centres		No minimum	0.10 per child or other person (other than employees) plus 0.5 per FTE (full time equivalent) employee
(T24)	Education facilities	Primary and secondary	No minimum	0.5 per FTE employee plus 1 visitor space per classroom
(T25)		Tertiary	No minimum	0.5 per FTE employee plus 0.25 per EFT (equivalent full time) student the facility is designed to accommodate
(T26)	Medical facilities	Hospital	No minimum	1 per 40 m <sup>2</sup> GFA
(T27)		Healthcare facilities	No minimum	1 per 20 m <sup>2</sup> GFA

Table 1 E27.6.2.3 Parking rates -area 1 in the Auckland Unitary Plan Operative in Parts illustrating no minimum parking requirements and a maximum parking rate.

Survey respondents suggested that when attempting to restrict parking supply, business owners frequently believe that by not providing additional car parking this will hinder the success of their business. In addition, if businesses do not supply parking or supply a reduced amount they rely on the council to provide public car parking which is costly and may revert the impact of parking maximums. Even with the implementation of parking maximums, there is always the ability to provide for more car parking through the consent process, where councils may permit additional parking on a case by case basis. One benefit suggested by respondents is that parking maximums encourage a collaborative approach to parking management and facilitate shared

parking. The benefits and disbenefits of parking maximums found in the research are shown in Figure 5.

Key Informant 2 discussed that parking maximums in Christchurch Central City are not very restrictive, as there was a lot of debate around whether they should even be imposed. Tensions between development and regeneration are at the forefront of parking management in Christchurch. Parking maximums have been met with some resistance, as it is believed they would constrain development too much. Key Informant 2 stated “if Christchurch had a functional central city and didn’t have the issue of trying to encourage development back into the central city (following the earthquakes), then parking maximums could be stricter”. Moving from minimum parking requirements to maximum parking requirements is important in helping to facilitate more modal choice (Key Informant 2).

Having no parking minimums has had more of an impact than the implementation of parking maximums in Christchurch (Key Informant 2), this complements the findings from the literature. New developments are being built with no parking, with the anticipation that customers will use alternative modes or public parking facilities. The removal of minimum parking requirements and parking maximums is linked to wider transport strategy and policy for Christchurch such as the Central City Parking Strategy and the transport chapter of the Central City Recovery Plan titled ‘An Accessible City’. The intention of the policy is to consolidate parking in the central city and focus parking in strategically located areas. This is an incentive to developers, where instead of building parking for each development, “let’s work together and manage it better” (Key Informant 2). Applying a carrot and stick concept, removing parking can act as a ‘stick’ in terms of trying to move to other modes of transport and reduce traffic. Primarily, local government focuses on carrots where initiatives improve alternative modes, using both the carrot and the stick will both enhance parking management and encourage alternatives to the car.

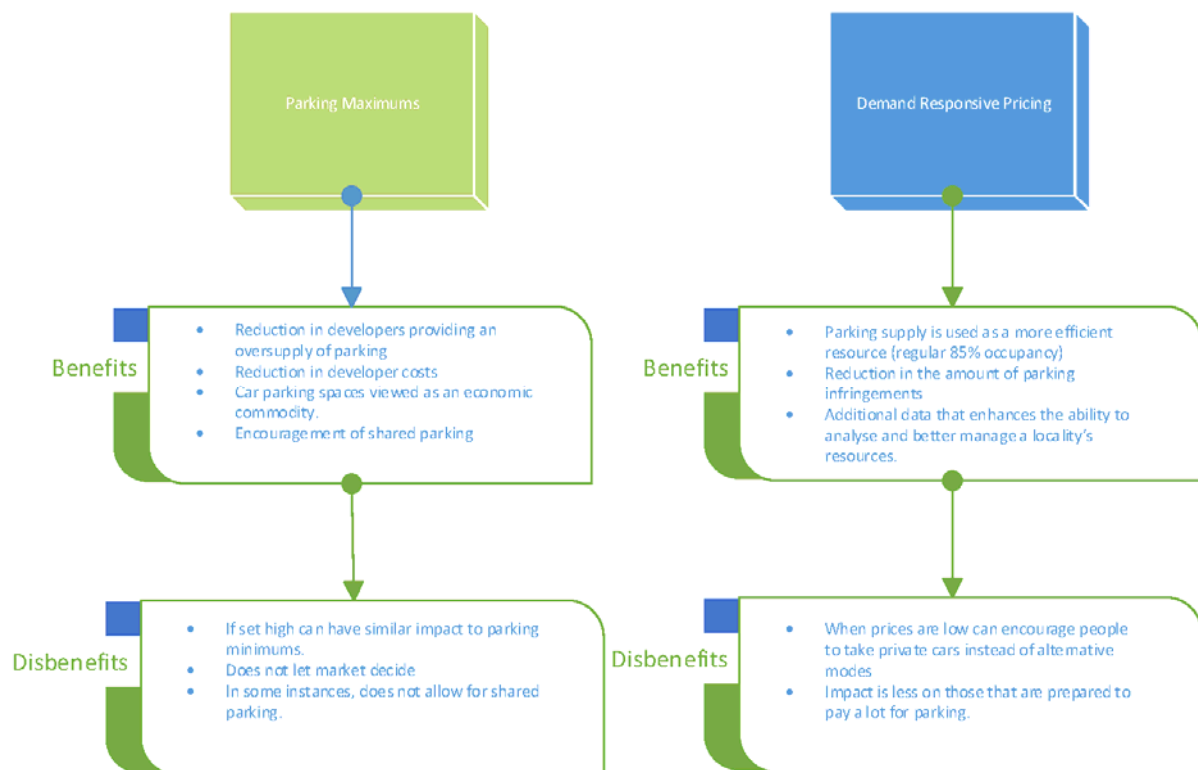


Figure 5: Benefits and disbenefits from parking maximums and demand responsive pricing (source: author)

### 3.3 TECHNOLOGY

Technology can be an effective tool in parking management and can be used in a variety of ways. Some examples of applying technology to parking management are provided in Table 2. These tools can be used to support other parking management strategies such as demand responsive pricing and improved user information. The benefits of technology lie in the enhanced user experience and making the communication of information, payment, and compliance more convenient.

<b>Use of technology</b>	<b>Benefit</b>
<b>Smart payment technology</b>	<ul style="list-style-type: none"> <li>• Convenient and easy to use</li> <li>• Increased compliance</li> </ul>
<b>Enforcement software</b>	<ul style="list-style-type: none"> <li>• Increased compliance</li> <li>• Reduced parking infringements</li> </ul>
<b>Dynamic signage</b>	<ul style="list-style-type: none"> <li>• Reduction in time taken to find a park</li> <li>• Safety benefits</li> <li>• Improved user experience</li> </ul>
<b>Mobile applications identifying parking availability</b>	<ul style="list-style-type: none"> <li>• Reduction in time taken to find a park</li> <li>• Improved user experience</li> </ul>
<b>Car park sensors</b>	<ul style="list-style-type: none"> <li>• Increased capture of data</li> <li>• Improved enforcement</li> <li>• Improved user experience</li> </ul>

Table 2 Various application of technology in parking management (source: author)

San Francisco’s SFpark demand responsive pricing project used a suite of technology tools including:

- Parking and road sensors,
- Smart parking meters,
- Real-time data and mobile applications;
- Data management and reporting tools.

The key application of the technology is the collection and analysing of data used to inform pricing and enforcement, and improved user experience through simplification and communicated information.

The research survey results found that practitioners acknowledge that technology is a powerful tool in communicating information. Somewhat surprisingly survey respondents did not mention the ability of technology to collect parking data. The ability of technology to collect parking data is a powerful resource along with the capability to analyse trends and patterns to better understand the transport network and subsequently inform policy. In addition, respondents did not suggest that technology can be used in support of and in cooperation with parking management strategies to make them more effective.

When posed the question of how important technology is in managing parking, several respondents dismissed the idea in favour of making alternative forms of transport more attractive. Survey results found a mixed response from practitioners regarding the part technology plays in managing parking. As one respondent answered “technology is only part of the answer”. The application of technology is another methodology that can be employed to encourage alternative transport modes. Survey respondents stated that alternative transport modes need to be provided for in the first instance, and the use of technology is secondary to enhancing alternative modes. Therefore, it is considered that some practitioners are unaware of how technology contributes to improving alternative modes of transport. Through communicating information regarding public transport routes and times, and the location cycle routes around the city, people are more likely to

use these modes as they are more accessible and convenient.

One of the uses of technology can be to provide better information. By providing better information, travellers can make informed choices and are aware of the transport options available to them. Technology is also a key tool that can be used to collect parking data. Technology can collect, analyse and display information that otherwise may be hard to communicate to the general public. Key Informant 1 describes that technology provides additional convenience to parking, by allowing contactless payment and through easily accessible information on mobile phones. Auckland Transport is looking at bringing in live availability into the current mobile application. In this way, customers can view the real time availability of parking before visiting an area to see which areas are full and what is available. Live availability can reduce congestion and help people make an informed choice of where to park. The benefits of smart parking machines (and demand responsive pricing) means that the user does not have to guess how long they are going to stay, instead paying for the duration of the stay afterwards, thereby improving the customer experience.

Key Informant 1 and 2 stressed the benefits of parking sensors and something both the Auckland and Christchurch authorities are looking to implement in the future. Parking sensors can detect vehicles entering and exiting a parking space, and can therefore obtain occupancy and duration of stay data. This data is powerful in being able to manage the existing parking supply and to determine how it is currently performing (low demand versus high demand). San Francisco provides a useful example of how sensors enhanced a parking management strategy.

Technology is also used to facilitate compliance and enforcement, as illustrated in San Francisco's *SFpark* project. The study showed that payment compliance can be increased through effective enforcement, which is where technology can play a part. Software called reENforce combined real-time occupancy data and payment data from the parking machines to identify the specific parking spaces that were occupied and not paid for (SFMTA 2014). Parking enforcement officers have mounted tablets with the software showing which parking spaces require enforcement. This application of technology provides a high level of enforcement and resulted in enhanced compliance (SFMTA 2014).

Interviews undertaken as part of this research found that some of the benefits of technology to assist with managing parking are still untapped. There are many reasons for this, including the cost of technology, construction and other planning priorities are significant factors. The findings from the research conclude that sensors and enforcement software are technologies that should be further investigated by local authorities in New Zealand.

## CONCLUSIONS

It is imperative that policy is informed by up to date research and sound information. This research paper looked at current parking management and the weaknesses, benefits and lessons from implementing parking maximums and demand responsive pricing. The use of technology in managing parking more efficiently was also investigated. Local authorities can use the findings of this research to help inform future parking management strategies

Although parking maximums are being applied in some New Zealand cities based on international research, the removal of parking minimums is found to have a greater impact on parking supply than implementing parking minimums. Parking maximums can encourage shared parking, which can reduce the total supply of parking required and manage the existing supply more efficiently. An intangible benefit of adopting a parking maximum policy is that it is an important step in communicating that providing excessive parking is harmful and to support the use of alternative modes of transport.

Demand responsive pricing has clear benefits. The parking supply is used more efficiently, it reduces the number of parking infringements and the customer experience is improved. In addition, demand responsive pricing provides additional data that adds to the ability to analyse and

better manage a locality's resources. Demand responsive pricing is an example of incorporating technology to enhance the use of the existing parking supply. As seen in both San Francisco and Auckland demand responsive pricing improves overall occupancy and peak period congestion decreases.

Challenges with the implementation of parking management policies include the ability to communicate the benefits of the policy before implementation. Getting users to adapt to new policies that may make parking more expensive for them is also a challenge. In addition, getting business owners to realise the wider benefits and encouraging alternative modes of transport is also a challenge to implementation. Parking maximums may be set at a level that is too high, where they do not have much of an impact on the provision of parking supply.

The ability of technology to manage parking has not been fully realised in New Zealand. Practitioners value technology in providing user information and making parking management a more efficient process. However, the ability for technology to collect and analyse data and to enable effective enforcement is not currently identified by practitioners. Findings suggest that parking sensors and enforcement technology could be further investigated to complement parking management in New Zealand.

Every locality has its own challenges, due to its unique context, geography, and political environment. Christchurch and Auckland are very different contexts but parking management is imperative to developing an effective transportation system and enhancing the quality of life in the urban realm. Improving parking management in New Zealand will have wider benefits for the transportation network and community.

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