Working paper

A Microeconomic Framework for Evaluating Parking Requirements

New Zealand Association of Economists Annual Conference 2015

Stuart Donovan and Peter Nunns
MRCagney Pty Ltd

19 June 2015

MRCagney

Document Information

Project Name	**A microeconomic framework for analysing parking requirements**
Document Name	Working Paper
Client	New Zealand Association of Economists Conference 2015
Prepared by	MRCagney Pty Ltd Brisbane

Quality Assurance Register

Issue	Description	Prepared by	Reviewed by	Authorised by	Date
1	Working draft	SD	PN	JV	150619

Acknowledgements

The authors wish to acknowledge people who have motivated the development of this paper, especially Donald Shoup, Todd Litman, and Julie-Anne Genter.

Abstract

This paper sets out a microeconomic framework for analysing the impacts of minimum parking requirements (MPRs). MPRs are a relatively ubiquitous policy in New Zealand and overseas; they require developments to provide a certain minimum number of off-street car-parks. MPRs are often a binding constraint on development and a growing body of empirical research suggests MPRs have negative impacts on land use and transport efficiency. This paper seeks to place these findings within a general economic framework. The framework considers the economic impacts of MPRs in several related land use and transport markets. MPRs are found to have direct impacts on land use efficiency MPRs, as well as indirect impacts for several related secondary markets, such as the demand for vehicle travel, public transport, and walking/cycling. Evidence of imperfect market functioning is presented for all of these secondary markets. The relatively tractable nature of the microeconomic framework enables us to estimate of the magnitude of economic impacts of MPRs for a medium sized city. With some simple extensions the model could be used to evaluate land use and transport policies more generally. To finish, the paper discusses implications for policy and opportunities for further research.

Contents

1 Introduction

1.1 What are minimum parking requirements, and why should we care?

"Minimum parking requirements" (MPRs) are planning regulations that require new developments to supply a specified minimum amount of parking. MPRs can be understood as a regulatory intervention (i.e. public policy) that seeks to increase the supply of parking above what would normally be provided by market participants (specifically developers) were they free to choose themselves.

Economic theory suggests that in, a straightforward market setting, the "optimal" supply of parking will be given by the intersection of consumers' willingness-to-pay and the marginal costs of provision. The supply of parking above this optimal point, as is required by MPRs, can be expected to create economic costs. Economic theory also suggests that an increase in the supply of parking above what is optimal would cause the price of parking to be lower than what it would be otherwise. Hence, from an economic perspective MPRs create more parking at a lower price than what would otherwise occur.

In doing so they use up space which would otherwise be used for floor space, and other activities. The primary market affected by MPRs is land use. MPRs cause the supply curve for floor space in a location to shift up. This reduces the supply of floor space at equilibrium and, by extension, seems likely to reduce total employment.

The economic effects of MPRs, however, are not limited to the primary market. By distorting the market for parking, MPRs are found to have indirect impacts in several related and/or secondary transport markets. By increasing the quantity of parking and reducing employment the price of parking reduced. This brings a number of imperfectly functioning transport markets into play, most obviously:

- *Vehicle travel*, which is characterised by congestion externalities;
- *Public transport*, which is characterised by scale economies; and
- *Walking/cycling*, which is characterised by health externalities.

The primary losers from MPRs are those who produce and consume floor space. On the other hand, drivers are the primary beneficiaries of MPRs; they gain access to more parking at a lower price. However, drivers also experience congestion externalities associated with the increased demand for vehicle travel, which means their net position is unclear. Users of public transport, and those who would otherwise walk/cycle are also worse off from the application of MPRs.

The policy rationale usually advanced in support of MPRs is that, in their absence, developments would provide less parking, such that the excess demand "spilled-over" into surrounding areas. This spill-over demand could increase parking search and management costs, i.e. the time that people spend looking for a carpark. From a policy perspective the supposed benefits of MPRs have, as far as we know, never been quantified. Research suggests that alternative ways to manage spill-over parking are developing rapidly.

Why should we care about MPRs? Well, evidence suggests MPRs have the potential to introduce large distortionary impacts on the aforementioned markets. For example, MPRs are commonly set in the order of 1 car-park per $20m^2$ GFA. Given one car-park requires approximately $30m^2$ of space (NB: This includes space for access and vehicle manoeuvring), then they result situations where developments dedicate more space to parking than they do to GFA. This suggests the distortionary impacts of MPRs could be quite large.

From a land use and transport perspective MPRs are problematic. They reduce the supply of floor space, reduce employment, increase the demand for vehicle travel, and suppress demand for non-car modes. In our experience these impacts are contrary to the strategic planning objectives in most jurisdictions.

Our focus in this paper is to develop a microeconomic framework to understand the relative economic impacts of MPRs. The next section provides some context to the origins and application of MPRs.

1.2 The history and application of MPRs

This section provides a brief history of MPRs. Research by Shoup (2005) found that minimums first emerged in Los Angeles in the 1950s, where their adoption was motivated by the rapidly growing demand for vehicle travel.

In New Zealand, the history of MPRs varies between locations. Here we focus on Auckland, as the largest urban area in New Zealand and the one with which we are most familiar. We also trace the history of MPRs as they apply to residential dwellings, although it is expected that this history parallels the application of MPRs to commercial developments (NB: This paper focuses on the latter).

MRCagney (2014) suggests the first formally-promulgated District Scheme of 1961 required one off-street car parking space per dwelling. While MPRs may have been required earlier than this, it is somewhat difficult to tell because the 1961 scheme was predated by a succession of more informal guidelines, draft schemes, and by-laws. In 1993 the enlarged Auckland City Council (ACC) adopted quite high MPRs, including the oft-cited requirement of two off-street parking spaces per residential dwelling unit.

In New Zealand MPRs are now stipulated in district plans. The former-Auckland City Council's Isthmus district plan, for example, motivated the adoption of MPRs via the following objectives and policies.

Figure 1: Objectives and policies of the ACC Isthmus District Plan relating to MPRs

12.7.1 OBJECTIVE & POLICIES

Objective

To ensure that the impact of activities on the capacity and safety of the road system is adequately catered for, so as to avoid adverse impacts on the environment.

Policies

- By requiring activities to provide adequate off-street parking and loading facilities.
- By providing opportunities to alleviate parking deficiencies within existing commercial centres.

Here the objective of MPRs is to ensure that "the impact of activities on the capacity and safety of the road system is adequately catered for, so as to avoid adverse impacts on the environment." The policy section proposes to achieve this objective primarily by "requiring activities to provide adequate off-street parking and loading facilities."

Subsequent sections define adverse impacts as:

- "Overspill of parking onto the adjacent roadside", i.e. localised increase in parking demands;
- "Adversely affecting the "efficient use and capacity of a road", i.e. localised congestion; and
- "Adversely affecting the "amenity of an area in terms of aural privacy and visual appearance."

The District Plan then provides a list of MPRs for various land use activities, which has been truncated below.

Figure 2: Examples of minimum parking requirements - District Plan Isthmus Section (Source: MRCagney (2015))

ACTIVITY	PARKING SPACES REQUIRED
Boarding house/hostel	One for every non-residential employee plus one for every 3 residents the boarding house/hostel is designed to accommodate; plus 2 for any manager's unit.
Bulk store	One for every 100m² of GFA plus one for every 100m² of outdoor storage.
Buildings used for recreation	One for every 4 people the facility (including grandstands) is designed to accommodate.
Building improvement and hire centres	One for every 20m² of gross floor area of building and one for every 100m² of outside area used for display purposes.

More recently the direction of parking policy in Auckland appears to have turned again. Circa 1996 MPRs were removed in the city centre. In the years since MPRs have also been removed or reduced in Newmarket, New Lynn, and some of the more intensive residential and mixed use zones. This change in direction is likely to reflect a growing awareness of the potential for MPRs to have negative impacts.

The proposed Auckland Unitary Plan (pAUP) continues this policy direction by proposing to remove MPRs from higher density zones. This position has been opposed by some submitters, who consider that the benefits of MPRs outweigh their costs. In this context, a more formal microeconomic framework, such as that which we present here, would seem to be useful for informing policy.

1.3 Outline of this paper

This paper is structured as follows:

- Section 2 provides some empirical background to MPRs. It characterises their costs and benefits, identifies impact on land uses, and reviews alternative approaches to parking management.
- Section 3 then builds from this empirical background by sketching out the theoretical underpinnings of our microeconomic analysis, specifically the analysis of primary and secondary markets.
- Sections 4 and 5 then introduces microeconomic models of the primary land uses market, and on four related/secondary transport markets. We model the effects of MPRs and calculate potential impacts in a hypothetical medium-sized city (population ~100,000).
- Section 6 summarises our findings and discusses opportunities for further research.

1.4 About the authors

Stuart Donovan and Peter Nuns are employed by MRCagney. Both authors would like to acknowledge the support of our colleagues in undertaking this research. Stuart Donovan is also affiliated with the Tinbergen Institute, where he is studying towards a PhD in Economics. Financial and intellectual support for further research in these areas would be most appreciated. Please direct all correspondence and generous offers of research funding to sdonovan@mrcagney.com.

Finally, we note that this is a working paper which reflects the authors' opinions at the time of writing. It does not necessarily reflect the views of our colleagues nor our clients. All errors are our own.

2 Background to MPRs

2.1 The intended and unintended consequences of MPRs

MPRs have a simple objective: To provide a free parking space for customers, employees, or residents who travel by car to a particular development. MPRs are normally set as a percentile of the peak demand.

MPRs are usually applied by setting a minimum amount of parking that should be supplied with a new development. MPRs are usually calculated by considering parking demands to be a linear function of development size for specific types of activities.[1]

The regression equations used to derive MPRs therefore assume the following form:

$$Parking\ demand = f(Size) = \beta * Size$$

Here, parking demands are predicted to be a function of the size of the development.

Donovan (2015) identifies several methodological flaws with the specification and application of the regression models that are used to estimate parking rates. In short, they 1) omit a number of causal variables, such as adjacent land uses and transport infrastructure; 2) ignore the possibility of simultaneous causality between parking supply and parking demand (which can be expected via normal price mechanisms); 3) are based on biased data; and 4) do not adequately account for substantial dispersion within the data.

The consequence of these methodological issues is that MPRs are likely to 1) over-state the relationship development size and parking demand (coefficient β above) and 2) provide an inaccurate estimate of parking demands for many developments. By extension, the application of MPRs seems likely to result in the over-supply of parking for many developments.

Where MPRs bind on the decisions that developers make about how much parking to supply, then MPRs can be considered to shift the floor space supply curve up and the parking supply curve down. What are the potential economic effects of such a shift? Based on our review of the literature, notably MRCagney (2015), we have identified a range of potential costs and benefits from MPRs, which are summarised in Table 1.

Table 1: Primary economic impacts of parking provisions

Type	Impact	Affected party
Benefits	Reduced parking spill-over	Adjacent businesses and residents
	Improved ease of finding car-park / reduced parking prices	Drivers
	Reduced need for parking management	Local government
Costs	Reduced value of development	Developers (costs ultimately passed on to users)
	Increased compliance costs	Developers (passed on to users)
	Increased traffic congestion	Drivers
	Reduced public transport use leading to increased subsidy requirements	Local government / transport agencies
	Reduced walking and cycling leading to worsened health outcomes	Public health providers

[1] Where "Demand" denotes the demand for vehicle trips and/or car parking that is associated with an individual development; "Size" denotes the physical size of the development (often measured by the gross floor area, or "GFA"); and β denotes the regression coefficient that is estimated from survey data. "Size" is hypothesized to have a positive causal impact on demand (i.e. $H_0: \beta > 0$).

We find that MPRs may benefit local governments and existing property owners, who have less need to manage parking spill-over onto public and private parking. MPRs are also expected to benefit drivers, who have access to cheaper parking.

However, MPRs also have a number of costs. In terms of land use, they tend to operate as a tax on floor space, which results in an increase in price and a reduction in supply. MPRs can also be expected to reduce the value or viability of new developments, by requiring developers to provide more parking than is optimal. Alternatively, they may increase compliance costs by requiring developments to endure a more extensive consent process.

Furthermore, MPRs seem likely to impose additional costs. Abundant, low cost parking can induce changes in transport and land use behaviour. Specifically, it increases traffic congestion, reduces PT use, and suppresses walking and cycling. From an economic policy perspective the impacts of MPRs on transport markets are of interest because they are characterised by a number of externalities.

2.2 MPRs have significant impacts on land use

MPRs require developers to set aside large amounts of land for parking. By way of illustration, Table 3 compares MPRs for offices and retail premises in the legacy Auckland Isthmus and North Shore City district plans and the operative Christchurch district plan[2]. Based on the assumption that a single parking space consumes 30m^2 of space, including room for manoeuvring (Rawlinsons, 2013), we find that:

- Offices are required to provide parking area equivalent to 75-86% of their floor area
- Retailers are required to provide parking area equivalent to 136-176% of their floor area.

In other words, MPRs are large relative to the size of new developments. While many developers would choose to provide parking even in the absence of regulations, some may prefer a more flexible approach to parking provision. This is especially likely to be true in areas where land is expensive.

Table 2: A comparison of some MPRs in operative plans in Auckland and Christchurch (Source: Nunns, 2015)

Activity	Operative Auckland Isthmus district plan	Operative North Shore City district plan	Operative Christchurch district plan - outside city centre
Offices	One for every 40m2 of GFA[3]	One for every 20m2 of GFA in public service areas, and one for every 35m2 of GFA in all other areas	One for every 40m2 of GFA, plus an additional 5% for visitors – implying a total rate of one for every 38m2 of GFA
Approximate ratio of parking space to floor space	*0.75*	*0.86*	*0.79*
General retail premises	One for every 17m2 of GFA, plus one for every 17m2 of outdoor retail, one for every 40m2 of GFA specifically set aside and used exclusively for staff amenity activites, and one for every 40m2 of ancillary office or storage space	One for every 20m2 of GFA in most zones; one for every 35m2 of GFA in Takapuna	One for every 22m2 of GLFA[4] (different rates apply for retailers with more than 750m2 GFA)
Approximate ratio of parking space to floor space	*1.76*	*1.5* *(0.86 in Takapuna)*	*1.36*

[2] The Auckland and Christchurch plans are both currently under review by Independent Hearings Panels. In both cases, Councils are proposing to remove MPRs from a number of business zones.

[3] Gross floor area

[4] Gross leasable floor area

MPRs may also distort land use decisions as a result of the fact that different rates are often applied for different types of activities. This may prevent some businesses from establishing in their preferred location, as they are unable to afford enough land for parking, or give some types of businesses an advantage over others.

By way of illustration, Table 3 summarises some MPRs from Houston, Texas – which, in contrast to its reputation, has an extensive and highly detailed parking code. We note several ways in which Houston's MPRs may distort development decisions:

- MPRs are proportionately larger for one-bedroom apartments than two-bedroom apartments, which means that there may be a disincentive to provide larger, more expensive apartments.
- More parking spaces are required for one-bedroom apartments than small single-family dwellings, although single-family dwellings are likely to be larger.
- A substantially lower parking ratio is applied to small restaurants than to larger restaurants, which may discourage the supply of larger restaurants.
- Most bewilderingly, a higher parking ratio is applied to bars than to restaurants. Given the negative impacts of drink-driving, it is difficult to understand the public policy rationale for such a requirement.

Table 3: Examples of MPRs in Houston (Source: City of Houston, 2013)

Use classification	Required number of carparks
Residential	
One-bedroom apartment	1.333 parking spaces for each unit
Two-bedroom apartment	1.666 parking spaces for each unit
Single-family residential home	2.0 parking spaces for each dwelling unit, except that a secondary dwelling unit not larger than 900 square feet of GFA shall provide 1.0 parking space
Hospitality	
Small restaurant (under 3,000 square feet)	8.0 parking spaces for every 1,000 square feet of GFA and outdoor decks, patio and seating areas in excess of 15% of GFA[5]
Neighbourhood restaurant (3,000 to 4,500 sq ft)	9.0 parking spaces for every 1,000 square feet of GFA and outdoor decks, patio and seating areas in excess of 15% of GFA
Restaurant (over 4,500 square feet)	10.0 parking spaces for every 1,000 square feet of GFA and outdoor decks, patio and seating areas in excess of 15% of GFA
Tavern or pub (under 2,500 square feet)	10.0 parking spaces for every 1,000 square feet of GFA and outdoor decks, patio and seating areas in excess of 15% of GFA
Small bar (2,500 to 4,000 sq ft)	12.0 parking spaces for every 1,000 square feet of GFA and outdoor decks, patio and seating areas in excess of 15% of GFA

2.3 Empirical evidence of the impacts of MPRs

A range of empirical evidence suggests MPRs have their intended effect, i.e. an increase in the parking supply.

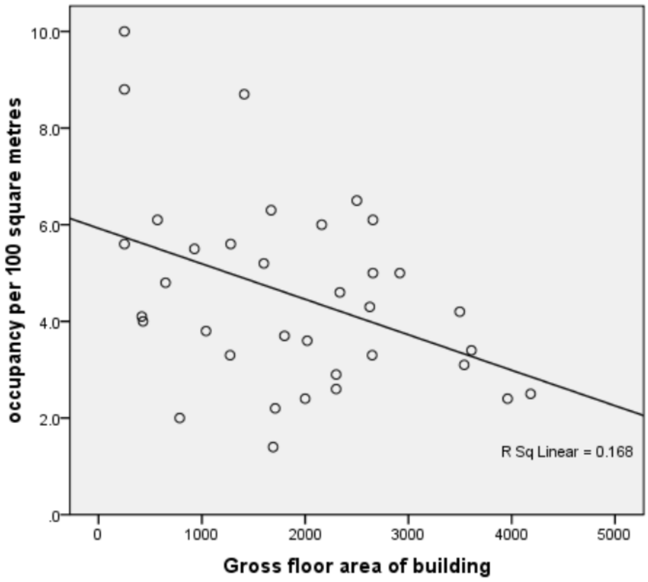
First, studies of peak parking demands and vehicle trip generation rates show that MPRs often exceed the requirements of individual businesses. Data from Douglass and Abley (2011) on vehicle trip generation rates for 32 shopping centres and supermarkets in New Zealand shows that it is common for vehicle trip generation rates to be above or below the average by 30-70%.

Similarly, Hulme-Moir (2010) presents an analysis of parking occupancy at retail sites in Porirua. He finds GFA explains only 17% of the variation in parking demand. An MPR that is based on average parking demands, let

[5] As 1,000 sq ft converts to 93m^2, this means that small restaurants are required to devote 2.6 times as much space to parking as to floor space. Other hospitality establishments must provide even more parking.

alone the 80-90th percentile of demand, is therefore almost certain to require many new developments to over-supply parking, leading to additional economic costs.

Figure 3: Relationship between GFA and peak parking occupancy at retail facilities (Hulme-Moir, 2010)



Evidence of parking over-supply has been found in contexts as diverse as suburban retail centres in Takapuna, Onehunga, and Dominion Rd (MRCagney 2014) and London (Guo and Ren, 2013). In their recent study, Weinberger and Karlin-Resnick (2015)[6] find consistent evidence of an oversupply of parking in 27 mixed-use districts in a range of US cities.

2.4 Potential alternatives to MPRs

Are MPRs the only way to manage parking, or do alternatives exist? And what are the relative benefits and costs of these alternatives when compared to MPRs?

We note that because parking is both rivalrous and excludable, it is what economists consider to be a private good. The implication is that it would be possible for property owners to respond to parking spill-over by managing access to their parking. Examples of potential parking management measures include:

- *Controlling access*, such as:
  - Restricting access and contracting enforcement[7].
  - Installing an access identification, e.g. parking permits.
  - Physical access restrictions, e.g. by installing boom gates
- *Pricing demand*, e.g. installing parking meters and hiring monitoring and enforcement staff;

Recent decades have seen significant innovation in parking management. Online trading platforms, such as TradeMe, have for several years supported the trading of parking spaces between those have it and those who need it. Technological improvements have reduced the costs of managing, monitoring, and pricing parking. Variable pricing has been trialled extensively in San Francisco and more recently inn Auckland. The results of these schemes appear to have been positive. This suggests alternatives to MPRs exist more so than in the past.

[6] These studies applied different methodologies to determine whether parking was oversupplied. MRCagney (2013) used a hedonic analysis of commercial property transactions to establish that while more floor space was associated with higher sale prices, more surface parking was not. Hulme-Moir (2010) used data collected in Porirua City Council's annual comprehensive survey of parking supply and demand to determine what share of on-street and off-street parking was occupied at peak times. Guo and Ren (2013) studied outcomes for on-site parking supply with new developments both before and after London's parking reform. Weinberger and Karlin-Resnick (2015) used data from a large number of parking supply and demand surveys.

[7] Under New Zealand law, users of off-street carparks enter into an implicit contract with property owners. If signs are posted specifying that parking is for the use of customers, employees, or residents only, property owners may have unauthorised cars towed or clamped. This results in few direct costs for businesses, as enforcement companies will seek to recoup costs from the owners of those cars.

3 Principles for Analysing Costs and Benefits in Primary and Secondary Markets

Here, we briefly discuss the microeconomic theory which underpins our approach to analysing the costs and benefits of MPRs. We draw upon three main sources of guidance in developing these principles: 1) Boardman et al.'s (2011) Cost Benefit Analysis: Concepts and Practice; 2) The Australian Transport Council's (2006) National Guidelines for Transport System Management; and 3) The New Zealand Treasury's (2013) Regulatory Impact Analysis Handbook. Based on these sources, we identify the following four principles:

Principle 1: Policies can have effects across multiple markets, including a primary market that is most directly affected and secondary markets[8] for complementary or supplementary goods

MPRs affect multiple markets. They most directly affect the land use market, especially new developments. However, they also affect the parking market, as they increase the supply of on-site parking within areas. By virtue of this they impact on the wider transport market, as parking is a complement to driving and a substitute for public transport, walking and cycling. All else being equal, we would expect an increase in the supply of parking (or a decrease in the price of parking) to result in an increase in complements (driving) and a decrease in use of substitutes (public transport, walking, and cycling).

Principle 2: In the absence of market imperfections[9], all benefits and costs can be valued based on people's willingness to pay to obtain or avoid them.

This has important implications for how we value benefits and costs in the land use market. Because we assume that the land use market is efficient, we can assess the gross costs of MPRs based on the change in consumer and producer surplus, including any deadweight losses arising from reduced activity. Likewise, it means that we can assess the gross benefits of MPRs for parking users (which is a transfer from the land use market) based on the change in consumer and producer surplus in this market, as this market is also assumed to be efficient.

Principle 3: Any changes to consumer and producer surplus in perfectly functioning secondary markets are already accounted for in an analysis of costs and benefits in the primary market[10]

This has important implications for valuing benefits and costs in secondary markets. For example, if a 10% reduction in the price of parking encourages a 3% increase in driving (as opposed to using other transport modes or staying at home), we cannot account for the added monetary costs of car use as an additional cost. Any user costs incurred as a result of these behaviour changes are already fully accounted for in the primary market. The practical significance of this is that it is not necessary to separately account for changes to user costs of transport in the driving, public transport, and walking and cycling markets.

Principle 4: The presence of imperfections in secondary markets may result in additional costs or benefits which should be considered in our analysis.

Market imperfections can result in additional costs or benefits over and above changes to consumer and producer surplus. These include everything from unpriced externalities to economies of scale in production (which can arise from large fixed costs in production). Because transport markets tend to be imperfectly functioning, there are likely to be additional costs and benefit attributable to MPRs. It is necessary to estimate these impacts to ascertain their significance. In order to do so, we must model changes in demand in these markets and make estimates of the resulting changes in the size of the external costs/benefits.

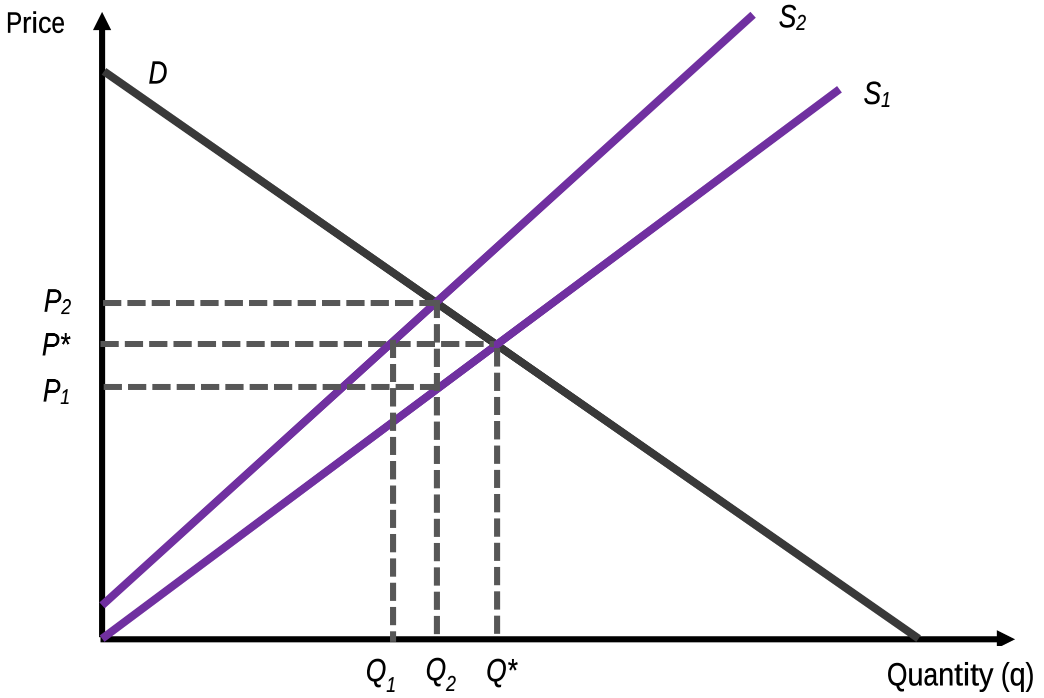
[8] Also called "related markets" or "parallel infrastructure".

[9] Such as unpriced externalities, information problems, monopolies/monopsonies, or public goods.

[10] Provided that we are using a primary market demand schedule that does not assume that prices in the secondary markets stay constant.

4 The Primary Market: Land use

MPRs affect the long run supply of floor space. They do this by shifting the supply curve upwards, bringing about an increase in price of floor space and a reduction in the quantity of floor space demanded at equilibrium. This is in some respects similar to a tax, with the difference that it generates no revenue. The upwards shift in the supply of floor space caused by MPRs is illustrated in the figure below.



As noted above MPRs are distinct from a tax in one respect: They do not generate revenue. Hence the impacts of MPRs on economic efficiency are not restricted to the dead-weight losses, but also include reductions in consumer and producer surplus (NB: This loss is partly an economic transfer from consumers/producers to private vehicle users, which is discussed in more detail in section 5.1).

Let us define linear demand and supply curves as follows:

$$D(q) = D_R + m_D * q$$

$$S_1(q) = S_R + m_s * q \text{ and } S_2(q) = (1+t) * S_1(q)$$

Where:

- $D(q)$ is the demand curve, which defined by the maximum reservation price D_R and elasticity of demand m_D;
- $S_1(q)$ is in the initial supply curve, which is defined by the minimum supply price of S_R and the elasticity of supply m_S; and
- $S_2(q)$ is the supply curve defined by $S_1(q)$ shifted up to account for the tax effect of MPRs t.

In this context the economic costs of MPRs in the primary land use market can be calculated as the sum of the deadweight loss and the reduction in consumer and producer surplus, i.e.

$$Deadweight\ loss_{Floor\ space} = {}^1\!/_2\,(Q^* - Q_2)(P_2 - P_1)$$

$$Consumer\ surplus_{Floor\ space} = Q_2(P_2 - P^*)$$

$$Producer\ surplus_{Floor\ space} = Q_2(P^* - S_R) - \frac{1}{2} Q_1(P^* - (1+t)S_R) - \frac{1}{2} Q_2(P_1 - S_R)$$

To estimate the magnitude of these costs, we now turn to empirical data. Research suggests MPRs can be expected to result in a 40% excess of in the level of parking supplied with developments (Guo and Ren, 2013; Weinberger and Karlin-Resnick, 2015). If the MPR is set at 1 car-park per 30m^2, then this implies that in the absence of MPRs the market would supply parking at 1 car-park per 50m^2.

We draw on construction cost data to estimate the costs of providing commercial floor space and car-parking at approximately $1,500 and $500 per m2 respectively (Rawlinsons, 2013). This implies that in the presence of MPRs, the cost per square metre of floor space would be $2,000 (i.e. 1m^2 of floor space plus 1m^2 of parking) whereas without MPRs this would reduce to $1,800 per square metre (i.e. 1m^2 of floor space plus 0.6m^2 of parking). From this we can deduce that MPRs are equivalent to an 11% tax. This is therefore our estimate for the tax effect of MPRs denoted by t.

Let us also assume the demand and supply curves in our market are characterised by the following parameters:

- $D_R = \$10{,}000$ and $m_D = -0.03$
- $S_R = \$500$ and $m_S = 0.02$

Under these assumptions, the market equilibrium without MPRs is defined by $Q^* = 190{,}000m^2$ of floor space and $P^* = \$4{,}300$. The imposition of MPRs is found to shift the market clearing point to $Q_2 = 180{,}851m^2$ of floor space and $P_2 = \$4{,}574$.

Assuming 20m^2 of floor space per employee, then the imposition of MPRs effectively reduces total employment from 9,500 without MPRs to 9,043 with MPRs. This highlights an interesting impact of MPRs which has not received much attention in the literature which considers their impacts: They have the effect of reducing total employment within the centre.

Using the aforementioned formulas, then the application of MPRs can be expected to cost $95.6 million. This is comprised of $49.6 million in reduced consumer surplus, $44.7 million in reduced producer surplus, and $1.3 million in deadweight losses.

5 The Related Markets: Transport

The previous section discussed the economic impacts of MPRs in the primary land use market. In this section we now consider a range of related markets in which MPRs can be considered to have an impact. The following sub-sections discuss the economic impacts of the following related markets:

- Parking
- Vehicle travel
- Walking/cycling
- Public transport

We also discuss imperfect market functioning, where relevant.

5.1 Parking

The first related market we consider is the market for parking. We note that the parking market is not characterised by imperfect market functioning.

The application of MPRs, however, is a transfer from consumers of floor space to drivers. It is reasonable, however, to suggest the consumers of floor space would subsequently internalise most of the benefits that this parking confers to drivers. For example, retail activities which provide additional parking will likely benefit from some increase in visitation, while office activities will be able to offer parking to their employees.

This benefit to drivers is assumed to subsequently benefit the consumers of the floor space who are providing parking. Hence, we need to estimate the value of the benefit which MPRs confer to drivers and subtract this benefit from our analysis, lest we risk over-estimating the costs of MPRs to consumers of floor space.

Supply and demand in the parking market is illustrated in the figure below. This shows the impacts of MPRs is to reduce the price of parking faced by people who consume parking, i.e. those who drive vehicles. Note that in this case we measure price per day per vehicle; the importance of these units will be discussed in more detail below.

Let us again assume linear demand and supply curves defined by the following parameters:

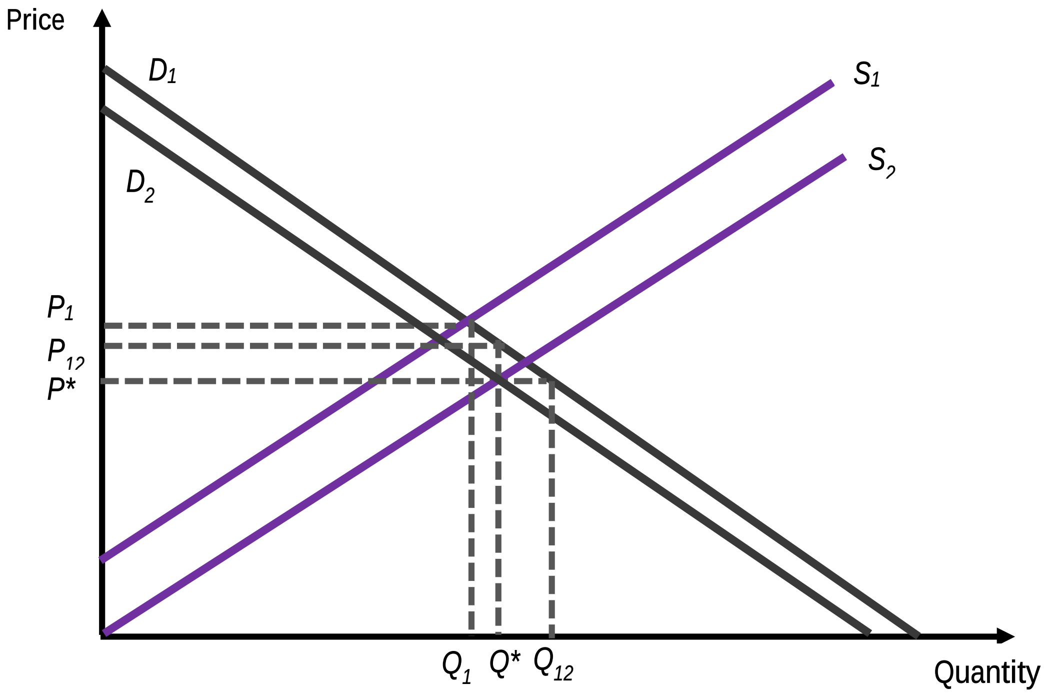
$$D_1(q) = D_{PR} + m_{PD} * q \text{ and } D_2(q) = D_1(q + \Delta Emp)$$

$$S_1(q) = S_{PR} + m_{PS} * q \text{ and } S_2(q) = S_1(q) + \delta$$

Where:

- $D_1(q)$ is the original demand curve, which defined by the maximum reservation price D_{PR} and elasticity of demand m_{PD};
- $D_2(q)$ is the new demand curve associated with the application of minimums, which is defined by $D_1(q)$ shifted by the change in demand associated with the change in employment quantified in section 4.
- $S_1(q)$ is in the initial supply curve, which is defined by the minimum supply price of S_{PR} and the elasticity of supply m_{PS}; and
- $S_2(q)$ is the supply curve defined by $S_1(q)$ shifted down to account for the increased supply associated with MPRs

In terms of estimating ΔEmp, we note that the application of minimums caused a reduction in employment, specifically 9,500 - 9,043 = 457 employees. How much of an impact on parking demands can we expect this to have? Well, if we assume a vehicle mode share of 80%, then this implies 0.8 x 457 = 366 fewer vehicle trips. We use this as our estimate for the downwards shift in the parking supply curve due to the employment effect of MPRs. This demand and supply curves are illustrated in the following figure.



Benefits to drivers can then be estimated as follows:

$$Benefits_{Existing\ drivers} = Q_1(P_1 - P^*)$$

$$Benefits_{New\ drivers} = {}^1/_2\,(Q_{12} - Q_1)(P_1 - P^*) - {}^1/_2\,(Q_{12} - Q^*)(P_{12} - P^*)$$

To estimate these benefits we need to characterise our demand and supply curves. Let us assume the following values for these parameters:

- D_{PR} and S_{PR} are equal to \$20 and \$3 per vehicle per day respectively; and
- m_{PD} and m_{PR} are equal to -0.0015 and 0.0010 respectively

We also set $\delta = S_{PPR}$, i.e. \$3 per vehicle per day. This means the effect of MPRs is to result in free or almost free parking at low levels of demand, which tends to align with experience.

Under these assumptions the equilibrium in the presence of MPRs is defined by $Q^* = 7{,}020$ vehicles and $P^* = \$8.92$ per vehicle per day. In this scenario, the total benefits which MPRs confer to drivers is estimated as \$6,129 per day. To place this figure on a comparable basis we need to scale it in two steps:

- First, we annualise it by multiplying it by 250 days per day. This represents an estimate of the number of days per year which we assume drivers benefit from MPRs.
- Second, we then need to calculate the total net-present value of this benefit. We use a simple discounted cashflow model with a lifetime of 10 years and a discount rate of 10%). This results in a total benefit of **\$10.9 million**. We use these parameters because the benefit is accruing to the private sector. Later sections apply different parameters for the public sector.

It is useful to contrast the \$10.9 million benefit which MPRs confer to drivers with the costs they impose on the consumers of floor space. Analysis of the market for floor space estimated the reduction in surplus for consumers at \$49.6 million. Hence, our analysis suggests approximately 20% of the cost that MPRs impose on consumers of floor space is offset by the benefits MPRs subsequently provide deliver to drivers. This effectively represents a transfer from consumers of floor space to people who need parking.

It is important to note that the reduction in consumer surplus (in this case \$49.6 million) represents an upper bound on the value of the economic benefits to drivers. More formally:

$$Benefits_{Drivers} \leq -Consumer\ surplus_{Floor\ space}$$

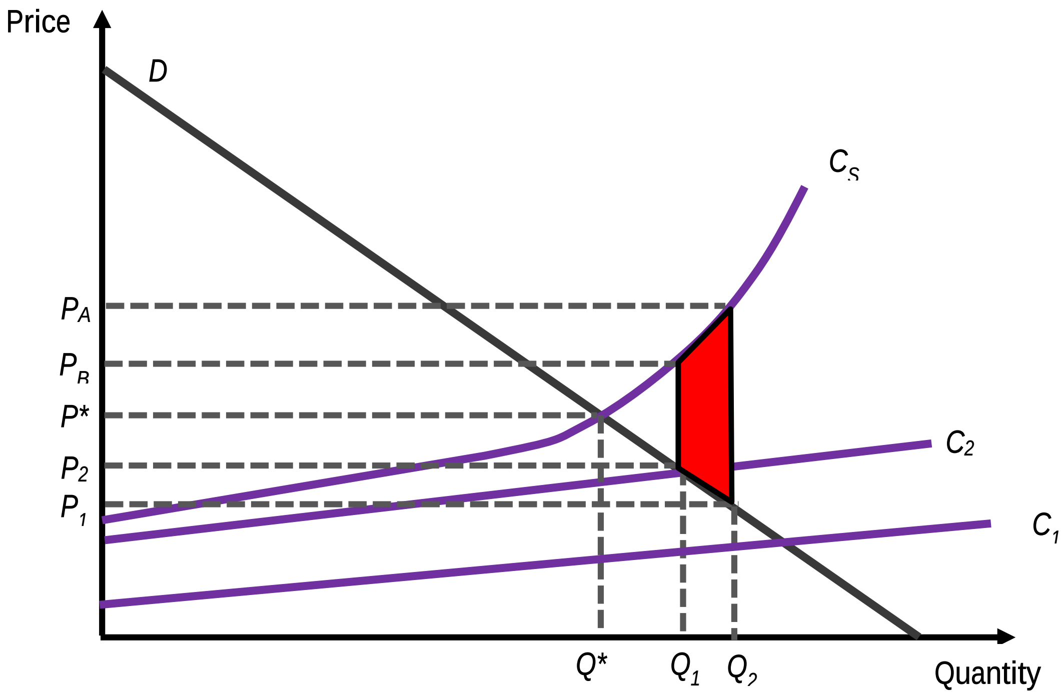
This result follows logically from the structure of the markets and our aforementioned principles. Specifically, if the costs which MPRs impose on the consumers of floor space are effectively a transfer which benefits drivers, then the value of the benefit arising in the related market for parking cannot exceed the costs MPRs impose in the primary market for floor space. Indeed, if the benefits to drivers were to exceed the costs to the consumers of floor space, then we might expect the latter to willingly provide more parking.

5.2 Vehicle travel

By increasing the supply of parking and reducing its price, MPRs are also likely to have an impact on the market for vehicle travel. More specifically, MPRs reduce the price of parking and thereby can be expected to increase the demand for vehicle travel, which is a complementary good.

The following figure presents an economic framework of the market for vehicle travel. The social cost curve for vehicle travel is depicted by C_S, which increases non-linearly due to the presence of 1) increasing marginal costs of supply and 2) non-linear external costs, such as congestion and air/noise pollution.

The private cost curve faced by vehicle users is depicted by C_1. This is lower than the social cost curve due to the presence of parking subsidies and unpriced externalities. C_2 shows an alternative private cost curve, where parking subsidises are not present but the unpriced externalities remain.



The red area is the additional congestion costs resulting from the presence of parking subsidies. To quantify the red area, let us first characterise our demand and supply curves as follows:

$$D(q) = D_{DR} + m_{DD}.q$$

$$C_1(q) = S_{DR} + m_{PS}.q$$

$$C_2(q) = S_1(q) + \delta_P$$

$$C_A(q) = S_2(q) + \tau(q)$$

Where:

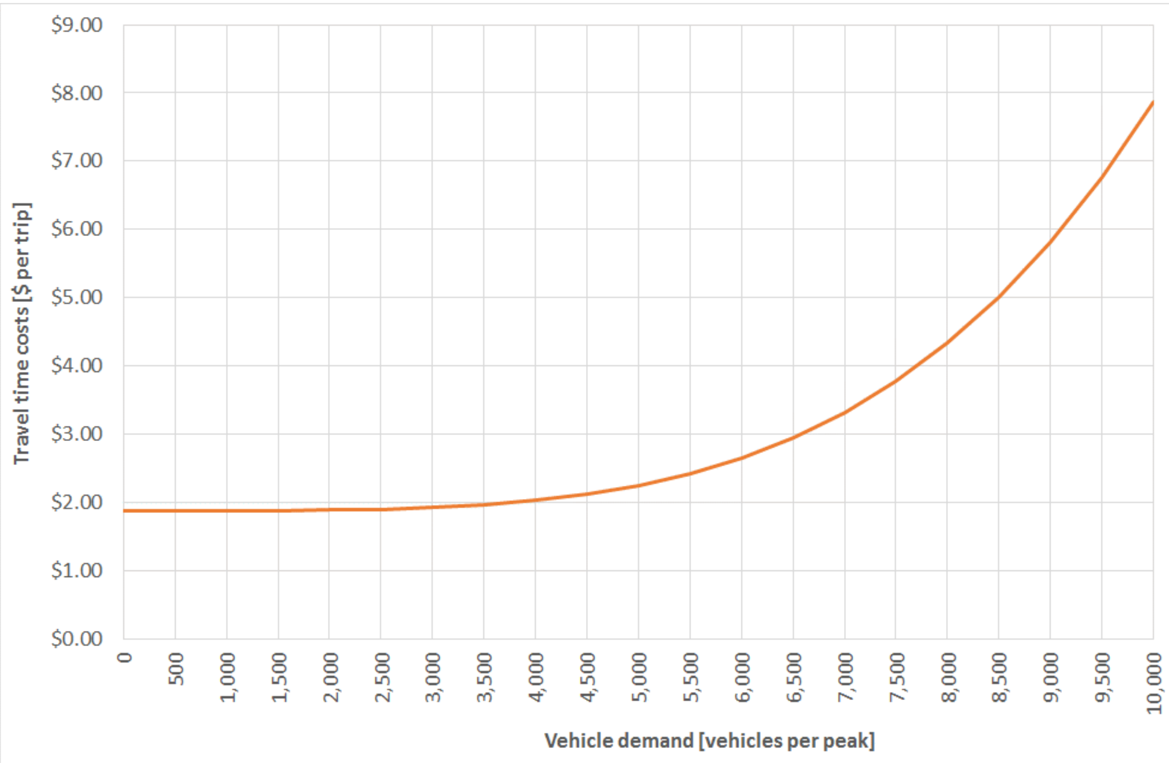
- $D(q)$ is the demand for vehicle travel, which defined by the maximum reservation price D_{DR} and elasticity of demand m_{DD};
- $C_1(q)$ is the private cost curve in the presence of parking subsidies and unpriced negative externalities, which is defined by the minimum supply price of S_{DR} and the elasticity of supply m_{PS}; and
- $C_2(q)$ is the private cost curve defined by $S_1(q)$, but shifted up by δ_P to account for additional parking costs that would occur in a situation where MPRs were not applied. We note that δ_P is the change in parking costs caused by MPRs, which for the scenario analysed in the previous section was estimated to be \$9.80 - \$8.92 = \$0.88
- $C_A(q)$ is the social cost curve defined by $C_2(q)$, but shifted up by $\tau(q)$ to account for externalities.

We further define $\tau(q)$ using the (non-linear) BPR speed-flow function:

$$\tau(q) = t_{ff}\left(1 + \beta\left(\frac{q}{\kappa}\right)^{\rho}\right)$$

Where $\tau(q)$ is measured in minutes per kilometre, where t_{ff} is the free-flow time, q is demand and β, κ and ρ are constants. We follow Wallis and Lupton (2013) and define β=0.2, and ρ=4. However, we choose a value of $\kappa = 5{,}000$ because we are modelling delays across the wider road network, rather than delays on a single road link (as is normally the case). Moreover, we define $t_{ff} = 1.5$, which is equivalent to an average free-flow speed of 40km per hour. To monetize the value of travel-time, we multiply the function by a value of time of \$10 per hour, or \$1.67 per minute. To finish, we assume an average vehicle trip distance of 7.5km, which is indicative of average vehicle trip distances in cities of approximately 100,000.

Under these settings, the BPR cost function takes the following form.



Analysis presented in the discussion of the parking market showed that in the absence of MPRs $Q_1 = 6{,}800$ while in the presence of MPRs $Q_2 = 7020$ vehicles. We now define $P_1 = 0$ and $P_2 = \delta_P = \$0.88$. P_A and P_B then follow directly from our monetized version of $\tau(q)$, i.e. $P_A = P_2 + \tau(6{,}800) = \$0.88 + \$3.16 = \$4.04$ and $P_B = P_2 + \tau(7{,}020) = \$0.88 + \$3.33 = \$4.21$.

In this way, we can define the value of the points bounding the red area in our figure. By extension, if we assume the BPR function is linear in the interval between Q_1 and Q_2, then the area can be readily calculated as the area of a simple trapezoid, or $847 per day. This represents the congestion costs incurred in one peak period. If we multiply this result by two for both peak periods, and then 220 to annualise, then we find total congestion costs of $373,000 p.a.[11] Incorporating this into a discounted cashflow model (period = 30 years; discount rate of 6%) returns total congestion costs of **$4.4 million**.

This finding is interesting for two reasons. First, the magnitude of congestion costs is significantly less than the $95.1 million in costs calculated for the floor space market. This corroborates previous empirical analysis undertaken by MRCagney (2013) for Auckland Council using a different metholodology. It is also approximately half of the $10.9 million in benefits which we estimate accrues to drivers. So while MPRs benefit drivers once they reach their destination, a reasonably large proportion of these benefits seem to be eroded by the additional congestion experienced travelling to and from their destination.

Second, because we have approached the problem by defining the market for parking first and the market for vehicle travel second, then the costs of congestion cost are able to be calculated independently of the demand curve for driving. There are, however, likely to be some advantages from integrating our analysis of these two related markets within a more general economic framework. This would ensure consistency between the assumptions which were made in each market. Such frameworks are discussed in more detail in the Appendix.

5.3 Public transport

By increasing the relative attractiveness of driving, MPRs are also likely to have an impact on the market for public transport, which is a substitute good. More specifically, MPRs reduce the aggregate price of driving and thereby can be expected to reduce the demand for public transport.

The following figure presents an economic framework of the market for public transport. The social cost curve for public transport is depicted by cost curve C_S, which tends to *decrease* non-linearly with increasing ridership due to 1) the presence of large fixed costs in the provision of public transport networks, such as fixed infrastructure, e.g. bus depots and rights-of-way[12], and 2) the presence of economies of density in public transport service provision. This means that the variable costs per trip decline as ridership increases[13].

The private cost curve faced by public transport users is depicted by cost curve C_1. At relatively low levels of demand the private cost curve is lower than the social cost curve, indicating that fare revenues do not cover all costs of system operation. However, at higher levels of demand the private cost curve may *exceed* the social cost curve, indicating that fares are covering all of the costs of system operation and delivering a profit to the operator. This is observed on some PT routes in New Zealand cities, such as the Devonport and Waiheke ferries, airport buses in Auckland and Wellington, and Northern Busway services in Auckland[14].

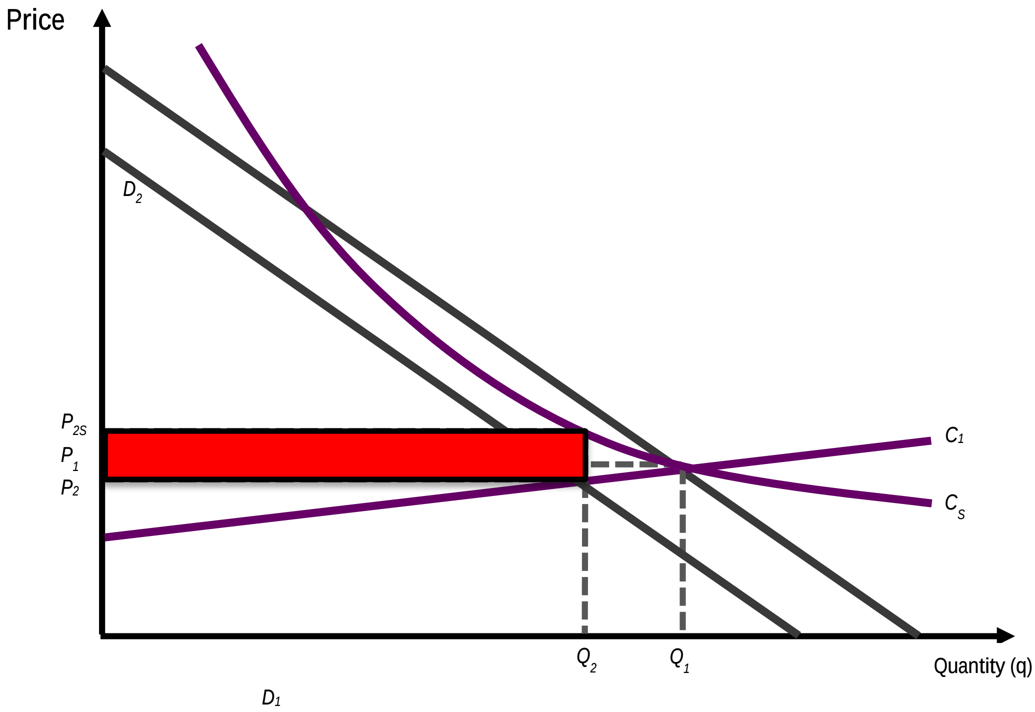
Finally, rather than changing the private cost of public transport, as they did for driving, we expect MPRs to change the *demand* for public transport. This is shown as a downward shift in demand from D_1 to D_2.

[11] We use a lower annualisation figure of 200 for congestion due to the presence of holidays and other times when travel demands, and hence congestion, will be lower.

[12] For rapid transit systems, fixed costs can be large relative to variable costs. ATC (2006) presents some data on US railways showing that fixed costs and costs associated with tracks and right of ways account for 43% of total costs.

[13] Holding other factors, such as network service-kilometres and infrastructure, constant. This concept therefore differs from economies of scale, which arise when per-unit costs *decline* as overall network size and service outputs increase. See Wikibooks (2014) for a succinct description of the difference.

[14] These ferries and airport buses are more likely to have "captive markets" and as a result have more ability to set prices to maximise their profits.



If we assume a simple case in which private costs are equal to social costs at the initial level of demand (i.e. fares cover all variable costs of operation), then the red area describes the additional public transport fare subsidy required as a result of parking subsidies. To quantify the red area, let us first characterise our demand and supply curves as follows:

$$D_1(q) = D_{TR} + m_{TD} * q$$

$$D_2(q) = D_{TR} + m_{TD} * (q - r_T)$$

$$C_1(q) = S_{TR} + m_{TS} * q$$

$$C_S(q) = C_1(q) + \gamma$$

Where:

- $D_1(q)$ is the demand for public transport in the absence of MPRs, which defined by the maximum reservation price D_{TR} and elasticity of demand m_{TD};
- $D_2(q)$ is the demand for public transport in the presence of MPRs, which defined by the maximum reservation price D_{TR} and elasticity of demand m_{TD}, with demand shifted down by a parameter r_T that reflects the shift away from public transport towards driving;
- $C_1(q)$ is the private cost curve for public transport, which is defined by the minimum supply price of S_{TR} and the elasticity of supply m_{TS}; and
- $C_S(q)$ is the social cost curve defined by $C_1(q)$, plus a parameter γ that accounts for the difference between fares collected from passengers and the variable costs per trip. γ can take on positive or negative values.

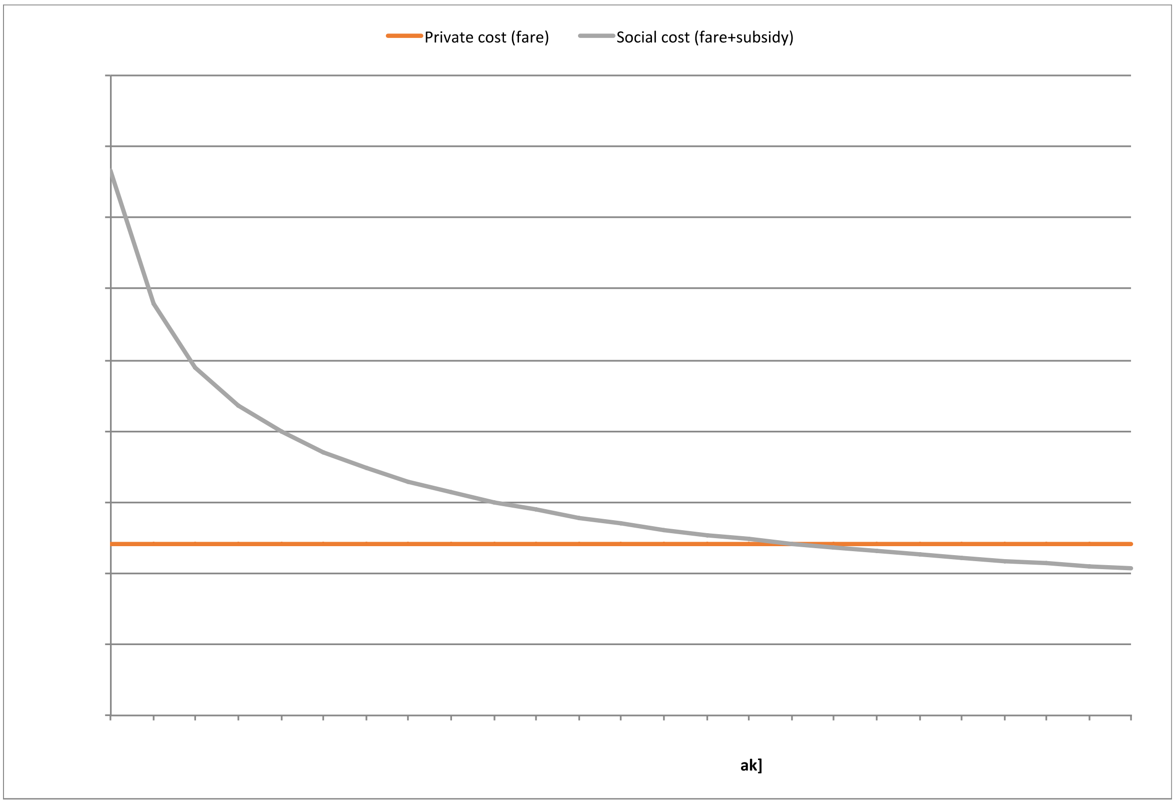
Rather than formally defining γ, we begin by identifying the degree to which public transport is characterised by economies of density. Formally speaking, economies of density exist when the elasticity of short-run variable costs with respect to ridership, ε_q^C, is less than 1 (Savage, 1997). This indicates that a 1% increase in ridership (q) is associated with a less than 1% increase in per-unit costs (C_S), holding system size constant:

$$\varepsilon_q^C = \frac{\partial C_S}{\partial q} * \frac{q}{C_S} < 1$$

The reason that this tends to reduce the fare subsidy required for public transport is that new public transport users tend to pay the same fare as existing users[15]. The combination of declining per-user costs and flat per-user revenues leads to increasing cost recovery (or profitability).

A number of empirical studies have studied the existence and magnitude of economies of scale and economies of density in public transport provision (Oum and Zhang, 1997; Savage, 1997; Graham et al, 2003). While most of this evidence is drawn from urban rapid transit systems, such as light and heavy rail, it is also likely to be broadly relevant for a bus system with fixed costs in depots and infrastructure (e.g. bus lanes or busways) as the variable costs of both types of system are broadly similar – vehicles, fuel, labour, etc.

Savage (1997) provides the most relevant estimates for our purposes. He estimates that the elasticity of short run variable costs (i.e. excluding the costs of fixed infrastructure) with respect to load factor is approximately 0.592[16]. We use this as an estimate of ε_q^C. It indicates that a 10% increase in ridership is associated with a 5.92% increase in operating costs. Under this assumption, the public transport cost functions take on the following form:



Analysis presented in the earlier section on the functioning of the parking market showed that in the absence of MPRs, a total of 9,500 people would work in the centre, and 7,480 of them would drive (assuming 6,800 vehicles at 1.1 people per vehicle. If we assume that public transport captures 75% of the remaining trips (as suggested by MRCagney, 2014), then $Q_1 = 1{,}515$ public transport users per day in the absence of MPRs. However, if MPRs are applied employment in the centre would fall to 9,043, and driving would increase to 7,722. This means that $Q_2 = 992$ public transport users.

[15] However, other user costs, such as travel time and time spent waiting for services, may still increase as demand increases. This could be interpreted, for example, as new public transport users living further from their destinations than existing users. Consequently, we have assumed that overall private costs, $C_1(q)$, tend to increase with increasing demand.

[16] Graham et al (2003) measure output as passenger journeys per annum and model the relationship between output and fixed and variable inputs. Their estimate of returns to density is equivalent to an elasticity of approximately 0.745. We prefer Savage's estimate as it accounts for a greater range of variable costs.

We assume that public transport fares for adults are equal to $2.40, after discounts for use of pre-paid cards[17], and that fares cover approximately 80% of total operating costs in the absence of MPRs[18]. We assume that fares do not change in the presence of MPRs. Hence we have $P_1 = P_2 = \$2.40$ and $P_{1S} = \$3.00$. Now, we can calculate the expected total operating costs that would be expected to occur in the presence of MPRs using the following logarithmic function:

$$(P_{2S} * Q_2) = (P_{1S} * Q_1) * \left(\frac{Q_2}{Q_1}\right)^{\varepsilon_q^C} = (\$3.00 * 1{,}515) * \left(\frac{992}{1{,}515}\right)^{0.592} = \$3{,}535$$

In other words, the total cost of operating the public transport system is expected to fall from $4,545 ($3*1,515) trips) to $3,535 in the absence of MPRs. However, as fares have fallen by a *larger* amount, the overall subsidy per trip rises from $3.00 to $3.57 ($P_{2S}$). This indicates that in the presence of MPRs, we would expect public transport cost recovery to fall from 80% to around 67%. In other words, MPRs can have a large impact on the financial viability of public transport networks. This may be a relevant consideration to PT fare policy.

We can calculate the overall change in the daily subsidy required for public transport trips to the centre as follows:

$$\Delta Subsidy = Q_2(P_{2S} - P_2) - Q_1(P_{1S} - P_1) = \$248$$

If we multiply this result by two for both peak periods, and then 250 to annualise, then we find that the total annual subsidy required increases by $124,000. If we apply an additional fiscal externality of 1.2, to account for the efficiency losses associated with raising tax revenues, then this amounts to approximately $149,000. Incorporating this into a discounted cashflow model (period = 30 years; discount rate of 6%) returns total public transport subsidy costs of **$1.8 million**.

This suggests that the costs of decreasing economies of density in the public transport market are approximately one third the costs of congestion from increased demand for driving. This suggests that it is generally appropriate to place a greater focus on quantifying congestion costs arising from MPRs rather than costs to the public transport system, as done by MRCagney (2014). However, in saying that, we note that increasing the required subsidy by $149,000 per annum is likely to be significant within the context of a mid-sized city's public transport operating budget. We also note that this figure is likely to be on the low side because we have estimated impacts on public transport only for journey-to-work trips. Where the increase in parking associated with MPRs results in mode shift to driving for other trips, e.g. retail travel, then the costs in the PT market are likely to increase from what has been estimated here.

5.4 Walking and cycling

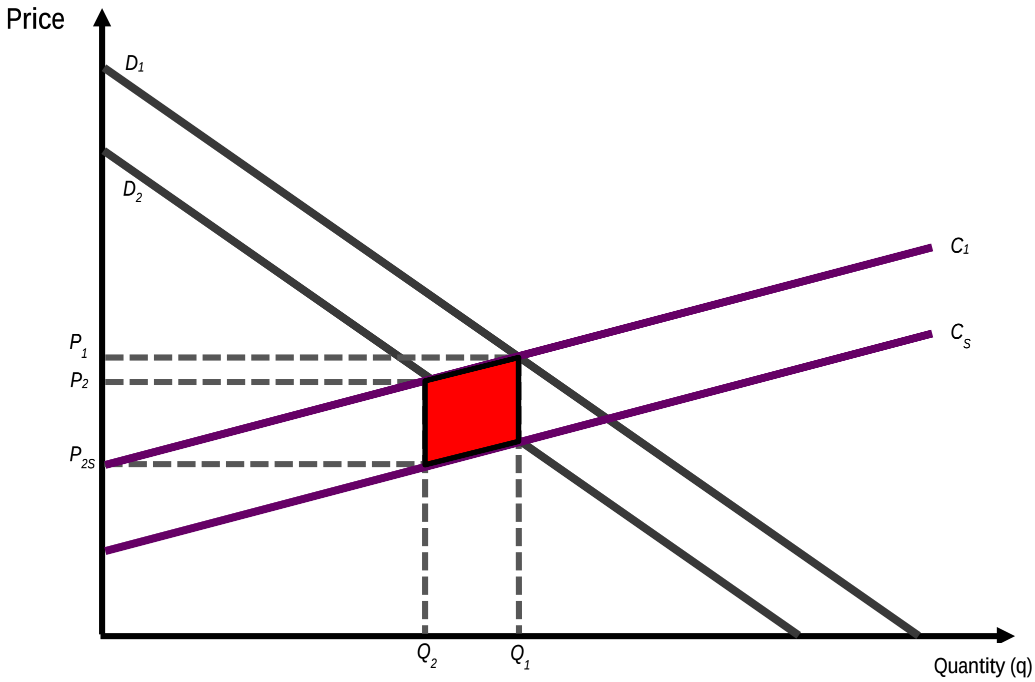
In a similar vein, MPRs are also likely to reduce the demand for walking and cycling commutes, as these are a substitute good.

The following figure presents an economic framework of the market for walking and cycling. The private cost curve faced by walking and cycling users is depicted by cost curve C_1. However, because there is a positive externality associated with increased walking and cycling, in the form of long-term reductions in public health costs, the social cost curve C_S is actually *below* the private cost curve.

[17] These figures are based on fares from Hamilton, NZ. See http://www.busit.co.nz/hamilton-city-fares/. Fares in other mid-sized New Zealand cities are generally similar.

[18] This figure assumes that public transport would attract a small public subsidy to reflect the fact that there is an unpriced congestion externality related to car trips. This type of "second best" strategy is frequently employed in transport pricing. Furthermore, we note that this level of subsidy is at the lower end of farebox recovery figures observed on city centre-based routes in large New Zealand cities where MPRs are not applied in the city centre.

As above, we expect MPRs to change the demand for walking and cycling rather than change the cost of walking and cycling[19]. This is shown as a downward shift in demand from D_1 to D_2.



The red area describes the magnitude of the positive health externalities that are foregone as a result of parking subsidies. To quantify the red area, let us first characterise our demand and supply curves as follows:

$$D_1(q) = D_{AR} + m_{AD} * q$$

$$D_2(q) = D_{AR} + m_{AD} * (q - r_A)$$

$$C_1(q) = S_{AR} + m_{AS} * q$$

$$C_S(q) = C_1(q) - \beta$$

Where:

- $D_1(q)$ is the demand for walking and cycling in the absence of MPRs, which defined by the maximum reservation price D_{AR} and elasticity of demand m_{AD};
- $D_2(q)$ is the demand for walking and cycling in the presence of MPRs, which defined by the maximum reservation price D_{AR} and elasticity of demand m_{AD}, with demand shifted down by a parameter r_A that reflects the shift away from walking and cycling towards driving;
- $C_1(q)$ is the private cost curve for walking and cycling, which is defined by the minimum supply price of S_{AR} and the elasticity of supply m_{AS}; and
- $C_S(q)$ is the social cost curve defined by $C_1(q)$, minus the positive health externality β that arises from walking and cycling activity.

Following NZTA (2013), we assume that the positive health externality β is a linear function of distance travelled per trip. We follow NZTA (2013) in using a figure of \$1.30 and \$2.60 per kilometre for the health and environmental benefits of cycling and walking respectively. We assume that half of these health benefits are

[19] In doing this, we note that MPRs do tend to raise the cost of walking and cycling. Requiring large amount of land to be set aside for parking typically increases walking and cycling distances, as buildings may be set back large distances from the street. It may also reduce the perceived safety of walking and cycling, due to an increase in vehicle accessways and manuevring space.

internalised by users, and that the average cycle and walk commute distance is 5.1 and 1.2 kilometres respectively[20]. If we assume that new active mode users are split 50:50 between walking and cycling, then the average positive externality per additional trip is calculated to be:

$$\beta = \$1.82 * 0.5 * 2.03 = \$2.78$$

Analysis presented in the earlier section on the functioning of the parking market showed that in the absence of MPRs, a total of 9,500 people would work in the centre, and 7,480 of them would drive. If we assume that walking and cycling captures 25% of the remaining trips (as suggested by MRCagney, 2014), then $Q_1 = 505$ walking and cycling users per day in the absence of MPRs. However, if MPRs are applied employment in the centre would fall to 9,043, and driving would increase to 7,722. This means that $Q_2 = 330$ walking and cycling users.

Consequently, we can calculate the reduction in the positive health externality as follows:

$$\Delta Health\ externality = (Q_1 - Q_2) * \beta = \$486$$

If we multiply this result by two for both peak periods, and then 250 to annualise, then we find that there is a total annual reduction in positive health externalities of $243,000. Incorporating this into a discounted cashflow model (period = 30 years; discount rate of 6%) returns total health costs of $2.9 million. This suggests that the costs of foregone positive health externalities in the walking and cycling market are the same general order of magnitude as costs in the public transport market.

[20] This figure was sourced from 2011-2014 Household Travel Survey data for journeys to work, available online at: http://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE7432.

6 Summary and Next Steps

6.1 Findings

6.1.1 Literature

An existing body of literature documents the land use and transport effects of MPRs. Most of these studies find that MPRs have negative impacts on land use markets, with subsequent negative impacts on transport markets. Productivity Commission (2015) recommends the removal of MPRs from district plans and a greater focus on parking demand management. Based on our review of the literature, we agree with this recommendation.

6.1.2 Analysis

In this study we present a microeconomic framework which helps us to analyse the impacts of MPRs in the primary land use market and several related and/or secondary transport markets, specifically parking, vehicle travel, public transport, and walking/cycling. Our simulation of the impacts of MPRs in a medium sized city (population ~100,000) estimated the following economic impacts.

Table 4: Summary of economic impacts

Market	Economic impacts
Land use	-$95.6 million
Parking	+$10.9 million
Vehicle travel	-$4.4 million
Public transport	-$1.8 million
Walking/cycling	-$2.9 million
Total benefits/(cost)	*-$93.7 million*

To place these impacts in context, we note that in the absence of MPRs our microeconomic framework predicted a total of 9,500 employees would be accommodated in this city centre. From this we find the negative economic impacts equate to approximately $10,000 per employee. This is a sizable reduction in economic efficiency.

6.2 Further research

6.2.1 Demand and Supply Parameters

Our analysis has assumed values for demand and supply parameters. Further research could seek to refine these parameters to align with actual market settings. This would also help to ground our findings with regards to economic impacts more solidly in empirical data.

6.2.2 Productivity impacts

Our analysis of the land use market found that the application of MPRs reduced employment in the city centre from 9,500 to 9,043. This represents a reduction in employment density of approximately 5%.

Research by Mare & Graham (2009) find an elasticity of productivity with respect to density of 0.690 for New Zealand businesses. If we assume GDP per employee of $65,000 p.a. in a scenario without minimums, then this implies productivity per worker will decline to $62,844 p.a. due to the application of MPRs. Factoring aggregate employment by productivity per work yields a reduction in productivity of $49.4 million p.a.

We note that this is a gross productivity impact. Some of the reduction in aggregate employment found in the centre is likely to see an increase in employment elsewhere. This may in turn raise productivity levels elsewhere in response to MPRs. Hence, once employment transfer effects are considered we would expect this figure to reduce substantially. Indeed, even a net productivity impact of $10 million p.a. would have a net present value of a similar order of magnitude to the land use effects we quantify above.

Nonetheless, further research in this area would seem to be warranted. This could seek to draw on the excellent work into the nature of congestion, agglomeration, and the structure of cities presented in Brinkman (2013).

6.2.3 Management and search costs

One market we do not analyse in detail is the market for parking management and search costs. Proponents of MPRs often point to these as the primary benefits of applying MPRs. While these benefits remain unquantified, they could be estimated within our framework. This would likely build from the analysis of the parking market, and consider how changes there might interact with parking management and search costs.

We note that – contrary to what proponents of MPRs assert – it is possible that search and management costs increase following the application of MPRs. Research by the likes of Shoup (2005) and Litman (2008) suggest MPRs cause a fragmentation in the parking supply, i.e. a larger number of smaller car-park areas across a wider area. Providing parking may therefore reduce efficiency, because variations in the aggregate demand curve over time are not able to be realised to the degree that they would be with a more centralised parking supply. Drivers may also have less information on where parking is available, and therefore have to circulate for longer to find a park. Shoup (2005) presents empirical data to suggest search costs are high even in the presence of MPRs.

More recent research in San Francisco has found parking management measures, such as those discussed in section 2.4, may actually reduce search costs compared to the status quo (SFpark, 2014). Hence, it is not immediately apparent whether parking search and management costs will be smaller or larger under the application of MPRs, especially when the latter is accompanied by better parking management.

Further research could consider the change in costs with and without MPRs in these areas.

6.2.4 Restrictions on parking supply

If externalities in the transport markets are sufficiently large, and have a strong enough association with parking supply, then there exists a prima facie case for considering limits on the supply of parking. The economic impacts of such a policy could be analysed using the microeconomic framework developed in this paper.

We note, however, the transport externalities estimated here are an order of magnitude less than the land use efficiency impacts associated with MPRs. This would suggest relatively greater benefits may follow from removing and/or reducing MPRs compared to formulating and applying restrictions on parking. Addressing issues with MPRs first would also reduce the magnitude of the distortions in these secondary transport markets, and thereby reduce the potential benefits of applying restrictions to parking supply.

Finally, restrictions on parking supply are a second-best policy with the potential for unintended consequences in other secondary markets that we may not consider. The issue of parking maximums has attracted considerable policy attention, but is not well-supported by research; Guo and Ren (2013) being the notable exception.

6.2.5 Distributional impacts

Lastly, our research thus far has principally considered the economic efficiency of MPRs. Our microeconomic framework and associated comparative statics provides preliminary support to other research, i.e. MPRs seem likely to lead to large reductions in well-being. We have not, however, considered distributional impacts.

The potential exists for MPRs to have significant distributional or equity impacts on businesses and households. In Section 2.2, we argued that applying different parking ratios to different types of activities or different sizes of businesses may unfairly subsidise some businesses and penalise others. In Section 2.3, we presented some empirical evidence showing that parking demand varies significantly between similarly-sized retail facilities, which means that the costs of MPRs are not likely to be distributed evenly between businesses.

In a similar vein, household car ownership and car use can vary significantly, meaning that the benefits and costs of MPRs may be unevenly distributed across the population. MPRs raise the prospect of a “double budgetary whammy” on households with limited access to private vehicles. First, these households will be required to acquire dwellings with more carparks than they require, increasing the cost of housing (Litman, 2014). Second, because MPRs require retailers to provide abundant, low-priced parking, parking costs are typically bundled into the price of all groceries and goods, rather than charged directly to drivers.

While low-income households bear the costs of MPRs, they seem less likely to realise the associated benefits. For example, consider the case of Auckland. Only 7.6% of households own no cars – a small but not insignificant number. However, as Table 5 shows, non-car-owning households are heavily concentrated in the lowest income categories. Overall, roughly two-thirds of households without cars earn less than $50,000 per annum, and almost all are below the Auckland median household income of $76,500.

Table 5: 2013 Census data on household car ownership in Auckland (Source: Statistics NZ, 2013)

Household income category	Number of households	Households with no cars	Share of households with no cars
$20,000 or less	39,135	11,061	29.5%
$20,001 - $30,000	33,291	6,372	19.5%
$30,001 - $50,000	57,177	4,878	8.7%
$50,001 - $70,000	51,522	2,337	4.6%
$70,001 - $100,000	69,201	1,533	2.2%
$100,001 or more	141,819	999	0.7%
Total households	**469,500**	**33,468**	**7.6%**

In short, further research could consider the distributional impacts of MPRs for both households and businesses. This could include further empirical research into variations in parking demands and transport behaviours within and between different types of households and businesses – an area flagged by Donovan (2015) as a weaknesses in the traffic engineering profession.

It could also entail further elaboration of the microeconomic model sketched out in this paper. For example, it may be possible to develop a partial equilibrium or general equilibrium model that allows for variations in parking demand between similar land uses, or allows for different MPRs to be applied to some land uses.

6.2.6 General Equilibrium

In Appendix B we present some preliminary work which has been undertaken towards developing a general equilibrium model of parking policies. Further work could seek to:

- Identify appropriate and complete equilibrium conditions
- Solve for the general equilibrium using the approach sketched out in Coleman and Scobie (2009); and
- Extend the partial equilibrium analysis in the previous section to fully and consistently parameterise the model in way that give clear linkages to policy.

If the approach sketched out here does not prove feasible, an alternative would be to pursue a numeric, rather than analytical, solution for the general equilibrium. This approach would entail extending the partial equilibrium analysis, which explicitly specified a functional form for the supply and demand equations, using mathematical modelling software (e.g. Matlab, Mathematica).

References

Australian Transport Council. (2006). National Guidelines for Transport System Management in Australia: Volume 5, Background Material.

Boardman, A., Greenberg, D., Vining, A., & Weimer, D. (2011). Cost-Benefit Analysis: Concepts and Practice, Fourth Edition. Boston: Pearson Education.

Brinkman, J. (2013). Congestion, agglomeration, and the structure of cities. Federal Reserve Bank of Philadelphia working paper 13/25.

Donovan, S. (2015). Do our aspirations match our abilities? Systematic challenges facing the traffic and transport profession. Paper presented at the 2015 Institute of Professional Engineers New Zealand – Transportation Group conference.

Douglass, M. and Abley, S. (2011), “Trips and Parking Related to Land Use”, NZ Transport Agency Research Report 453.

Graham, D., Couto, A. Adenay, W. and Glaister, S. (2003), “Economies of scale and density in urban rail transport: effects on productivity”, Transportation Research Part E, vol 39.

Guo, Z. and Ren, S. (2013), “From Minimum to Maximum: Impact of London Parking Reform on Residential Parking Supply from 2004 to 2010”, Urban Studies 50(6).

City of Houston (2013). Amendment to Article VIII of Chapter 26 of the Code or Ordinances. City of Houston, Texas Ordinance 2013-208. Available online at” http://www.houstontx.gov/planning/DevelopRegs/offstreet/docs_pdfs/Chapter26_Ordinance_march_2013.pdf

Hulme-Moir, A. (2010), Making Way for the Car: Minimum Parking Requirements and Porirua City Centre, thesis submitted to Victoria University of Wellington as partial fulfilment of requirements for the degree of Master of Environmental Studies. Available online at http://sustainablecities.org.nz/wp-content/uploads/Angus-Hulme-Moir.pdf.

SFpark (2014). Pilot Project Evaluation. Available online at: http://direct.sfpark.org/wp-content/uploads/eval/SFpark_Pilot_Project_Evaluation.pdf

Litman, T. (2008). Parking management best practices. Chicago: Planners Press.

Litman, T. (2014). Parking Requirement Impacts on Housing Affordability. Victoria Transport Policy Institute.

Mare, D. and D. Graham (2009). Agglomeration elasticites in New Zealand. NZTA Research report 376. Available online at http://nzta.govt.nz/resources/research/reports/376/docs/376.pdf

MRCagney (2014a), “The Economic Impacts of Parking Requirements in Auckland”, a report to Auckland Council. Available online at http://www.aucklandcouncil.govt.nz/EN/planspoliciesprojects/plansstrategies/unitaryplan/Documents/Section32report/Appendices/Appendix%203.9.11.pdf.

MRCagney (2014b), ACT Transport Pricing Study, ACT Government.

Nunns, P. (2015). Statement of evidence before the Christchurch Replacement District Plan Independent Hearings Panel in the matter of the Transport Proposal (Part). On behalf of Christchurch City Council. Available online at http://www.chchplan.ihp.govt.nz/hearing/hearings/.

NZTA (2013). Economic Evaluation Manual (EEM). Available online at: http://nzta.govt.nz/resources/economic-evaluation-manual/economic-evaluation-manual/docs/eem-manual.pdf

Oum, T. H., & Zhang, Y. (1997). A note on scale economies in transport. Journal of Transport Economics and Policy, 309-315.

Productivity Commission (2015). Using Land for Housing. Draft report. Available online at:

http://www.productivity.govt.nz/sites/default/files/using-land-draft-report.pdf

Rawlinsons New Zealand. (2013). Rawlinsons New Zealand Construction Cost Handbook 2013/14, 28th Edition. Auckland: Rawlinsons Publications.

Savage, I. (1997). Scale economies in United States rail transit systems. Transportation Research Part A: Policy and Practice, 31(6), 459-473.

Shoup, D. C. (2005). The high cost of free parking. Chicago: Planners Press.

Statistics New Zealand. (2013). Number of motor vehicles by total household income (grouped), for households in occupied private dwellings, 2013 Census. Available online at http://nzdotstat.stats.govt.nz/wbos/Index.aspx?DataSetCode=TABLECODE8188.

Treasury (2013). Regulatory Impact Analysis Handbook. Available online at

http://www.treasury.govt.nz/publications/guidance/regulatory/impactanalysis

Wallis, I and D. Lupton (2013). The costs of congestion reappraised. NZTA Research report 489. Available online at: http://www.nzta.govt.nz/resources/research/reports/489/docs/489.pdf

Weinberger, R. and Karlin-Resnick, J. (2015). “Parking in US mixed-use districts: Oversupplied no matter how you slice the pie”. Paper presented at the 2015 Transportation Research Board Annual Meeting (US).

Wikibooks. (2014). Transportation Economics/Costs. Available online at https://en.wikibooks.org/wiki/Transportation_Economics/Costs.

Appendix A – General Equilibrium

In this section, we consider how to extend the partial equilibrium analysis of the previous section to a general equilibrium model of parking policies. We draw upon the approach developed by Coleman and Scobie (2009) to analyse the impact of housing policies on prices, quantities, and home ownership.

Coleman and Scobie (2009) model supply and demand in two related markets – rental housing and owner-occupied housing. They begin by specifying supply and demand equations for each market as a function of rents, house prices, and several exogenous variables such as taxes, interest rates, and construction costs. Second, they specify two market-clearing conditions that require (a) the supply of rental housing to equal demand for rental units and (b) the total supply of housing to equal total demand. Third, taking the market clearing equations as a system of linear equations, they differentiate them to identify the responsiveness of price and quantity in both markets to changes in the exogenous variables. Finally, they establish parameters for the model and test policy scenarios.

This approach has several advantages. The first is its simplicity – it can be implemented analytically using basic linear algebra and calculus. In addition, it is flexible – it does not require us to explicitly define a functional form for supply and demand curves. However, there are also some challenges in applying it to more than two markets, as markets may not necessarily converge to a single equilibrium.

Here, we begin to specify a general equilibrium model for studying parking policies, but do not attempt to solve it. Unlike the previous section, we now restrict our analysis to four related markets, excluding walking and cycling for the sake of tractability[21]:

- CBD offices
- CBD parking
- Driving access to the CBD
- Public transport access to the CBD

As before, we assume that there are no market imperfections in the supply or demand for CBD offices or CBD parking spaces. However, there are market imperfections in the transport markets that lead to differences between private costs and the social costs: a congestion externality associated with driving, and increasing returns to density in public transport provision.

Supply and demand in the CBD office market

We begin by specifying functions for supply and demand in the CBD office market. Rather than identifying a specific functional form, as we did in the previous section, we instead identify the general shape of the equations by making assumptions about the sign of key elasticities and cross-elasticities. For example, we assume that demand for CBD office space:

- decreases as office rents increase, and
- decreases as transport costs to the CBD increase.

As before, we model MPRs as a "parking tax" on office supply and an equivalent "parking subsidy" for parking supply.

[21] Including a third transport mode would require us to define a specific functional forms for supply and demand in transport markets. Without doing this, it would be possible for all users to choose one mode of travel regardless of parking policies.

Table 6: Supply and demand equations for CBD office space

Variable	Functional form	Key assumptions
CBD office demand	$Q^o = D^o(P^o, P^t)$	$\partial Q^o / \partial P^o < 0$: as office rents increase, office demand decreases $\partial Q^o / \partial P^t < 0$: as transport costs increase, office demand decreases
CBD office supply	$Q^{os} = S^o(P^o, C^o, T^p)$	$\partial Q^o / \partial P^o > 0$: as office rents increase, office supply increases $\partial Q^o / \partial C^o < 0$: as office development costs increase, office supply decreases $\partial Q^o / \partial T^p < 0$: as the regulatory "parking tax" increases, office supply decreases

To make modelling simpler, we could choose units such that one unit of office space (Q^o) is equal to the space required for a single worker, and P^o is equal to the annual cost of renting one unit of office space.

Supply and demand for CBD parking

Next, we specify functions for supply and demand in the CBD parking market. These equations are fairly similar to the CBD office market equations, except for one crucial difference: as the "parking tax/subsidy" T^p increases, the supply of parking increases. For the purposes of this model, we are somewhat vague about whether parking is provided on-site or off-site.

Table 7: Supply and demand equations for CBD parking

Variable	Functional form	Key assumptions
CBD parking demand	$Q^p = D^p(P^p, P^d)$	$\partial Q^p / \partial P^p < 0$: as parking prices increase, parking demand decreases $\partial Q^p / \partial P^d < 0$: as other driving costs increase, parking demand decreases
CBD parking supply	$Q^{ps} = S^p(P^p, C^p, T^p)$	$\partial Q^o / \partial P^p > 0$: as parking prices increase, parking supply increases $\partial Q^o / \partial C^p < 0$: as parking development costs increase, parking supply decreases $\partial Q^p / \partial T^p > 0$: as the regulatory "parking tax/subsidy" increases, parking supply increases [this is because office developers are required to subsidise parking]

Once again, we choose units such that one unit of parking (Q^p) is equal to the space required for a single car commuter, and P^p is equal to the annual cost of renting one parking space.

Supply and demand equations for car access to the CBD

We now specify functions for supply and demand in the driving market. As driving is a complement to parking, we model a negative relationship between parking costs and driving demand: as parking costs rise, driving decreases.

We also begin to introduce market imperfections to the model. In order to do so in a tractable way, we have introduced a separate function for the congestion externality. As congestion is unpriced in our model, individual drivers do not directly bear the full costs of their activities[22]. Consequently, we propose to first model the general

[22] The distinction between individual and social costs is a slightly artificial one in this case. While individual drivers externalise costs onto others, in the form of added delays and unreliability of travel time, they in turn have similar costs externalised onto them by other drivers.

equilibrium based on the *private* cost of driving, and then use the equilibrium quantity of drivers to estimate the magnitude of congestion costs.

We argue that the magnitude of the congestion externality is strictly positive and that it increases with increased quantity of drivers – probably at an exponential rate.

Table 8: Supply and demand equations for driving

Variable	Functional form	Key assumptions
Driving demand	$Q^d = D^d(P^d, P^p, P^r)$	$\partial Q^p/\partial P^d < 0$: as the cost of driving increases, driving demand decreases $\partial Q^p/\partial P^p < 0$: as parking prices increase, driving demand decreases $\partial Q^p/\partial P^r > 0$: as the cost of public transport increases, driving demand increases
Private supply of driving	$Q^{ds} = S^d(P^d)$	$\partial Q^{ds}/\partial P^d > 0$: as the private cost of driving increases, the quantity of driving increases
Congestion externality	$E^d = f(Q^d)$	The congestion externality is a nonlinear function of total quantity of drivers. Total social cost of driving is equal to Pd+Ed. $E^d > 0$: The congestion externality is always positive $\partial E^d/\partial Q^d > 0$: as the quantity of driving increases, the magnitude of the congestion externality increases

For simplicity in modelling, we choose units such that one unit of Qd is equal to a single worker / car, and P^d is equal to the annual cost of commuting by car. A similar convention is applied for public transport.

Supply and demand for public transport

We follow a similar approach in modelling supply and demand in public transport. As public transport is a substitute for driving, we model a positive relationship between the cost of parking and driving and public transport demand: higher costs for alternative modes increase demand for a substitute.

In modelling PT, we have assumed that it is operating in separated lanes and hence not subject to (or contributing to) vehicular congestion. This may include anything from on-street bus lanes and signal priority to metro rail systems. And, as we did with driving, we have introduced a separate function for a market imperfection that can be estimated after modelling the general equilibrium based on the *private* cost of PT.

The form of this equation is different in several important ways, as market imperfections in public transport provision take on a different form. The empirical literature suggests that PT is characterised by economies of density due to the presence of significant fixed costs in infrastructure provision and network management (Oum and Zhang, 1997; Savage, 1997; Graham et al, 2003). Consequently, the average cost per trip tends to decrease, not increase, as demand increases.

We have assumed that PT users tend to pay the marginal cost of their trip, and modelled the difference between marginal cost and average cost in PT provision as a farebox subsidy. The farebox subsidy may in some cases be negative, which would imply that PT is covering all of its costs and making a profit.

Table 9: Supply and demand equations for public transport

Variable	Functional form	Key assumptions
Public transport demand	$Q^r = D^r(P^d, P^p, P^r)$	$\partial Q^r/\partial P^d > 0$: as the cost of driving increases, public transport demand increases $\partial Q^r/\partial P^p > 0$: as parking prices increase, public transport demand increases $\partial Q^r/\partial P^r < 0$: as the cost of public transport increases, PT demand decreases
Private supply of PT	$Q^{rs} = S^r(P^r)$	$\partial Q^{rs}/\partial P^r > 0$: as the private cost of PT increases, the quantity of PT increases
Fare subsidy per passenger	$E^r = f(Q^r)$	The fare subsidy (i.e. external cost of PT) is a nonlinear function of total quantity of PT demand. Total social cost of PT is equal to Pr+Er. Er may be either positive or negative – i.e. it's possible for the system to be profitable at sufficiently high levels of demand. $\partial E^r/\partial Q^r < 0$: as PT use increases, the magnitude of the fare subsidy decreases

Market-clearing conditions

After characterising these related markets, it is necessary to specify market clearing conditions. As we have eight endogenous variables to solve for – price and quantity in each of the four markets – we require four market clearing conditions. We tentatively propose the following conditions.

First, observing that the total number of people commuting into the CBD must be equal to the total demand for office space, we set a market clearing condition for offices:

$$F_1(P^o, P^p, P^d, P^r, T^p, C^o) = S^o(P^o, C^o, T^p) - D^d(P^d, P^p, P^r) - D^r(P^d, P^p, P^r) = 0$$

Second, observing that the total number of people driving into the CBD must be equal to the total demand for parking, we set a market clearing condition for parking. However, we note that it may be inappropriate to argue that parking markets "clear" even in the presence of a large MPR, given the empirical evidence on parking oversupply.

$$F_2(P^p, P^d, P^r, T^p, C^p) = D^d(P^d, P^p, P^r) - S^p(P^p, C^p, T^p) = 0$$

Third, we set a simple market clearing condition for driving:

$$F_3(P^p, P^d, P^r, C^p) = D^d(P^d, P^p, P^r) - S^d(P^d) = 0$$

Similarly, we set a market clearing condition for PT:

$$F_4(P^p, P^d, P^r, C^p) = D^r(P^d, P^p, P^r) - S^r(P^r) = 0$$

Finally, I note that there is one additional condition for equilibrium: that there is no potential for arbitrage in transport pricing. Or, in other words, the user cost of public transport must be equivalent to the cost of driving and parking.

$$P^d + P^p = P^r$$