Assessing the Environmental Capacity of Local Residential Streets

November 15, 2012

(Word Count: 6579 + 5 figures/tables)

Glen Koorey, PhD, MIPENZ
Senior Lecturer in Transportation Engineering
Dept of Civil & Natural Resources Engineering, University of Canterbury
Private Bag 4800, Christchurch, New Zealand
Tel: +64-3-364 2951, Fax: +64-3-364 2758
Email: Glen.Koorey@canterbury.ac.nz

Andrew Leckie, MET
Graduate Engineer, Fulton Hogan Ltd
Christchurch, New Zealand

Rhys Chesterman, MET
Director, Novo Group Ltd
Christchurch, New Zealand

ABSTRACT

The inherent conflict between the residential amenity and traffic access functions of roads causes debate on what constitutes a true "local" street. The concept of 'environmental capacity' was developed to identify a suitable maximum traffic volume on such local streets. In separate research in the 1960s–1970s, both Buchanan and Appleyard settled on broad-brush traffic thresholds of 2,000-3,000 vehicles/day. Since then, other research has relied heavily on these original findings; this paper investigates that presumption in the present day.

A residents' survey was applied to four conventional "local" streets with varying traffic volumes in Christchurch, New Zealand. Residents living on those streets with higher volumes felt that their streets were busier, noisier and less safe. There was also an increasing trend for residents along higher volume streets to have their houses turned away from the street and they tended to have less personal involvement and/or knowledge of their neighbors. A more appropriate environmental capacity appeared to be around 1,500-2,000 vehicles/day.

A subsequent study looked at further Christchurch streets, this time with treatments such as street calming and tree plantings, aiming to see whether the street treatments affected the perceived environmental capacity. As well as reinforcing the previous conclusions, a higher environmental capacity of around 2,000 vehicles/day was found for the surveyed streets. This suggests that appropriate street treatments can increase the environmental capacity, which has implications for local councils who want to maintain road traffic carrying capabilities without having unsatisfied residents.

INTRODUCTION

There appears to be an increasing trend for non-residential activities (such as education and health facilities) to establish along local residential streets, which some people would argue are to the detriment of residential amenity. Additionally, many local streets become attractive for through-traffic to other destinations. Often these non-residential activities develop in a piecemeal fashion and in a manner that appears to disregard actual or potential cumulative effects that might result from increasing traffic. While it is generally true that the geometric capacity of these streets can cater for these additional traffic volumes, the actual and potential effects on residential amenity are frequently concluded to have effects that are "less than minor". This often appears to be determined without any real justification – whether quantitatively or qualitatively.

While it is accepted that residential amenity effects are rather qualitative and subjective (as one person's perception and opinion often differs from another), there is likely to be some correlation between increasing traffic volumes and the degradation of residential amenity. This suggests that it might be possible to take an existing street and, after examination of some key elements, to define the volume and character of the traffic permissible in the street so that it is consistent with good environmental conditions. Buchanan, in his seminal thesis *Traffic in Towns* (*1*), first introduced the concept of "environmental capacity," which is likely to be much lower than the theoretical numbers of automobiles that the street could cater for physically. Since then, there has been debate on environmental capacity, particularly in reference to the acceptable upper limits of tolerable traffic on local streets. These differences are probably explained by many varying factors – perhaps volumes themselves, street widths, speeds, building setbacks, etc. These issues may also be perceived differently from one resident to another. In any instance, the answer is still not clear.

A widely used rule of thumb in the traffic planning and engineering profession is that a local residential street has an environmental capacity of 2,000-3,000 vehicles/day. This paper sheds some light on this presumption; it is based on research undertaken in the New Zealand city of Christchurch (*2, 3*). The overall objective of this research was to determine the environmental capacity of selected local residential streets in a Christchurch context, although this method is likely to provide a useful contribution to the international discussion of this topic. A secondary objective of this research was to see whether or not street treatments, such as traffic calming and plantings, could increase the environmental capacity of local streets, by altering residents' perceptions of their livability.

BACKGROUND LITERATURE

The idea of increasing residential amenity and livability along local residential streets is not new; it goes back over 100 years when the "garden city" concept was first introduced in the United Kingdom (*4*). This has since led to a continual desire to balance amenity needs and traffic effects – especially with increasing traffic volumes. The garden city idea was particularly influential in the United States, where a number of settlements were planned during the early 20th century using this format, as well as in many other countries (*5*).

As the motor car became more widespread and traffic volumes grew, the inherent conflict between the amenity and access functions of roads created the debate on what constitutes a true "local" street and what functions should take precedence. Such issues also found their way into discussion about urban planning and redevelopment (*6*).

The Buchanan Report

This concept of environmental capacity appears to have been first raised by Colin Buchanan (an architect, civil engineer and planner) in *Traffic in Towns* (*1*). This was an influential and popular report on urban and transport planning policy for the United Kingdom in the 1960s. Although Buchanan never intended to write about environmental capacity, it was an issue that arose and he consequently made an attempt to define some possible methods of calculating it.

Buchanan firstly recognized that traffic on residential streets affects the environment in many ways, including noise, fumes, vibration and the danger for people wishing to cross the street. He then explored the possibility that the environmental capacity could be assessed, for practical purposes, by the ease in which the street can be crossed by pedestrians; if this critical condition could be satisfied, then it is likely that needs relating to noise, fumes, etc would also be satisfied.

Buchanan suggested that the level of risk might be measured by the delay a pedestrian is subjected to when waiting to cross the road. The average delay for pedestrians will depend upon the volume of traffic and the width of the road. Buchanan assumed an average delay of two seconds as a rough guide to the borderline between acceptable and unacceptable conditions. Any greater delay would imply that most people have to adapt their movements to give way to automobiles, a situation not compatible with the idea of an "environmental area".

Buchanan further refined his method to consider the proportion of "vulnerable" pedestrians (children, elderly, parents with prams, etc) and the level of "protection" afforded by the street (i.e. parked cars, vehicle speeds, footpath continuity, etc). In order to explore the practical effect of these variables, Buchanan studied ~50 examples of residential streets with traffic flows ranging from 10 to 1500 vehicles per hour. From this, Buchanan derived a series of graphs that enabled the environmental capacity to be determined for any carriageway width and for any levels of 'vulnerability' and 'protection.' Figure 1 shows an example of one such graph, for streets with a high level of pedestrian protection ("Type A").

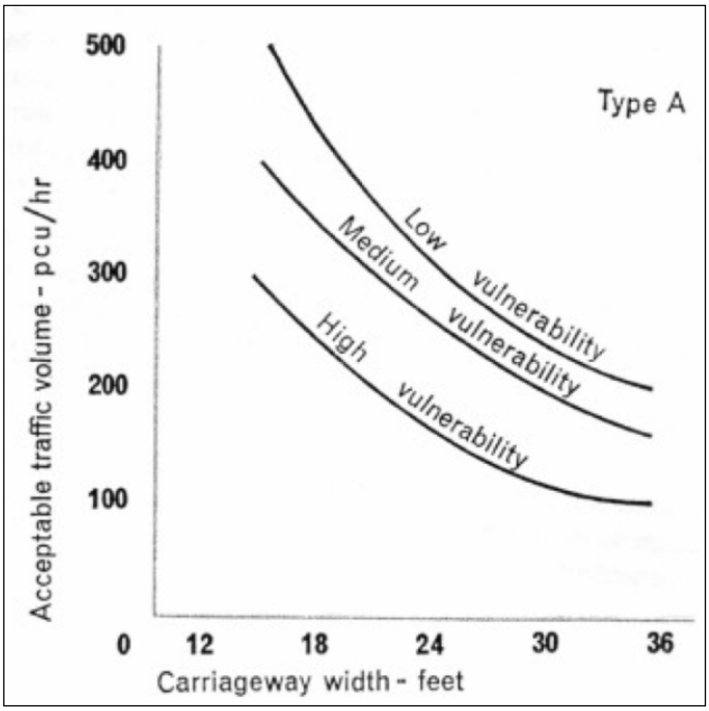

FIGURE 1 Example of Maximum Acceptable Traffic Volumes (Buchanan 1963)

In the New Zealand context, where residential streets are typically at least 10 m (33 ft) wide, Buchanan's work suggests that maximum daily traffic volumes of 2,000-3,000 vehicles/day are acceptable, although that figure will be less where there are low levels of pedestrian protection or high proportions of vulnerable pedestrians.

Appleyard's Livable Streets

In the late 1960s and 1970s, Donald Appleyard (a Professor of Urban Design at UC Berkeley) conducted a renowned study on residents' perceptions of their streets, comparing three residential streets in San Francisco that (on the surface) did not differ in much but their levels of traffic. This was documented in the widely acknowledged publication *Livable Streets* (*7*), although the original research had been undertaken somewhat earlier (*8*). One of these streets carried 2,000 vehicles/day (which he termed as a "Light Street"), one carried 8,000 vehicles/day (a "Medium Street"), and the final street carried 16,000 vehicles/day (a "Heavy Street"). In simple terms, Appleyard's research showed that residents on the Light Street had three more friends and twice as many acquaintances living on the street than the people on the Heavy Street. Further, as traffic volume increased, the space people considered to be their "territory" shrank.

Appleyard suggested that the Light Street was a "closely knit community." For example, front steps of the houses were used for sitting and chatting, sidewalks were used by children to play and the carriageway was even used to play more active games like football. Moreover, the street was seen as a whole and no part was out of bounds. The Heavy Street, on the other hand, had little or no sidewalk activity and was used solely as a corridor between the sanctuary of individual homes and the outside world. Residents kept very much to themselves, and there was virtually no feeling of community. The difference in the perceptions and experience of children and the elderly across the two streets was especially striking.

Appleyard clearly identified the connection between residential amenity and traffic volume. Although he settled on a maximum reasonable environmental capacity for a residential street of around 3,000 vehicles/day, he made the point that the 2,000 vehicles/day level was a threshold above which increasing numbers of residents would become concerned about traffic levels on their street. There was however no real rationale as to why he reduced the 'desirable' threshold from 3,000 to 2,000, although it was interesting to note that his lower level aligned with Buchanan's research. Thus, any street with peak flows greater than 200-300 vehicles per hour (or 2,000-3,000/day) was seen as an indicator of exceeding environmental capacity.

Appleyard's work, despite being based on perceptions that could be construed as being location-specific and somewhat subjective, appeared to be simple, yet credible and logical at the same time. Appleyard's study method was subsequently repeated in other research in New York (*9*) and Bristol, United Kingdom (*10*), and similar relationships were found between traffic volumes and neighborhood interaction.

The Effects of Street Treatments

From a network planning perspective it might be relatively difficult to counter growing volumes of traffic on some local streets, thus leading to a risk of greater resident dissatisfaction. An alternative management technique might be to introduce various attractive features to the streetscape so that the improved environment somewhat "cancels out" any increase in traffic volumes.

In a similar study to Appleyard's, conducted in New York and California, Bosselmann *et al* (*11*) found that high-volume (24,000-44,000 vehicles/day) "boulevards", where local access side lanes are separated from the main carriageways by landscaped medians, were rated as more livable than neighboring, conventionally designed streets with medium traffic volumes (4,000-14,000 vehicles/day). This suggests that appropriate street treatments can raise the acceptable environmental capacity of a local street.

Traffic calming (i.e. treatments to slow down automobile speeds) also has the potential to improve the perceived street environment. According to Litman (*12*), potential benefits of traffic calming include road safety, increased comfort and mobility for non-motorized travel, reduced environmental impacts, increased neighborhood interaction, and increased property values. Traffic calming can thus help create more livable communities, tending to provide the greatest benefits to pedestrians, bicyclists and local residents. Buchanan's earlier work (see Figure 1) also supports the theory that street narrowing work allows more traffic to be tolerated.

As well as making a street look more attractive, streets trees can also provide numerous benefits to residents. Drivers typically travel more slowly on streets with trees, due to their calming effect, and drivers seem at least subconsciously aware that, where there are trees, there are often pedestrians and children playing. Wide streets where the buildings are small and set back can feel primarily like a transportation corridor, not a place where people live, unless this effect is mitigated by lining the street with trees. Jacobs (*13*) cites research showing that, for many people, trees are the most important single characteristic of a "good street". Trees alongside streets also reduce the amount of engine noise by slowing down drivers and absorbing a lot of noise before it reaches private yards and homes.

Other Environmental Capacity Methods

A variety of other techniques have been identified, particularly in North America and Australia, for determining the relative effect of new developments on existing local streets:

1. RTA's *Guide to Traffic Generating Developments* (*14*), commonly used by traffic planners and engineers in Australasia, sets out a desirable maximum peak volume (the "environmental goal") of 200 vehicles/hour and an absolute maximum of 300 vehicles/hour for local 40 km/h (25 mph) streets. RTA suggests that there may be situations where alterations to these levels might be appropriate, e.g. if a street has a central median.
2. The "Traffic Infusion on Residential Environment" (TIRE) index (*15*), used in a number of North American cities, is an alternative approach to evaluating impacts on local streets to evaluate the change in average vehicles/day along a street segment. The TIRE index provides a numerical representation of residents' perceptions of the effect of traffic on residential activities and has values that range from 0.0 to 5.0. A change of 0.1 or more indicates that traffic would be noticeable to residents in an affected neighborhood, equating to approximately a 25% increase in traffic volumes. The TIRE Index however doesn't define a threshold at which a volume change should be considered unacceptable or a significant impact.
3. The Australian Model Code for Residential Development (AMCORD, *16*) is a national resource document for integrated residential development and refers to four key performance areas for new developments: noise, air pollution, crossing delay, and pedestrian safety (the latter regarded as the most important criterion). AMCORD proposes different environmental capacity values for each criterion and, while they do not provide any definitive rule-of-thumb figures (as each situation and local area should be considered on its individual merits), reference is often made to 2,000 vehicles/day in many instances.
4. The City of Portland developed an "Impact Threshold Curve" (*17*), for determining whether the secondary or unintentional impacts of neighborhood traffic management projects are acceptable (typically in terms of increased traffic on local roads). The standard impact curve provides for an increase of between 150-400 vehicles/day on local streets, but with the resulting traffic volumes not to exceed 3,000 vehicles/day. Because of the error inherent in the collection of traffic volume data due to daily volume fluctuation, the curve is presented as a wide band of values rather than a single curve. The standard impact curve may also be modified to account for factors such as the proportion of non-local or re-routed traffic, peak hour volumes, and truck traffic.

Although some of the above methods have incorporated other research (e.g. *18*, *19*, *20*), most of it still has some basis in the work of Buchanan and/or Appleyard. Note that some other researchers have also used the term "environmental capacity" in different contexts, such as the traffic volume at which local pollution limits are not exceeded (e.g. *21*, *22*). This is quite different to the concept here of a qualitative measure of residents' satisfaction with traffic-related impacts on their streets.

In summary, the idea of environmental thresholds or capacity with regard to traffic volumes has been bandied around for some time, yet there appears to be little modern research on the topic. Both Buchanan (*1*) and Appleyard (*7*) settled on broad-brush traffic thresholds of 2,000-3,000 vehicles/day, which were based on their own observations, surveys, and assumptions. A literature review on environmental capacity reveals that all other research since then heavily relies on the original Buchanan and Appleyard findings and that there has been little questioning of the validity of the original information in the present day. Perhaps one reason lies with the fact that issues involving traffic volumes have traditionally fallen within the domain of traffic engineers and other environmental considerations (such as amenity) have been in the domain of town planners.

CASE STUDY 1 – CHRISTCHURCH 2008-09

To explore these issues further, a residents' survey (using similar techniques and questions to those used by Appleyard) was applied to some "local" streets with varying traffic volumes in the New Zealand city of Christchurch (*2*). Four Christchurch streets in the same suburb were selected because they were similar in appearance (relatively conventional or "untreated"), yet quite different in traffic volumes. Table 1 summarizes their key characteristics. The intention was to include streets with varying traffic between 500 and 3000 vehicles/day; these were labeled LIGHT, LOW, MEDIUM and HIGH accordingly.

TABLE 1 Christchurch streets surveyed – Case Study 1 (Untreated Streets)

	Murdoch Street	Jennifer Street	Aorangi Road (northeast)	Aorangi Road (southwest)
Daily Traffic Volume (veh/day)	560 (LIGHT)	1090 (LOW)	2120 (MEDIUM)	3530 (HIGH)
Length of street (m)	170	580	630	300
Number of households	14	67	99	42
Carriageway width, in meters (feet)	8.0 (26)	11.0 (36)	14.0 (46)	14.0 (46)
Mean / 85th %ile speeds, in km/h (mph)	37 / 42 (23 / 26)	46 / 53 (29 / 33)	50 / 56 (31 / 35)	51 / 57 (32 / 36)

Other characteristics worthy of mention include:

- All four streets are generally characterized by stand-alone suburban residential houses rather than commercial activity.
- All streets are classified as local roads in the City Plan, and provide through-access to other local streets (i.e. not culs-de-sac).
- All streets appear to share a similar socio-economic status by virtue of their proximity to each other and with similar housing stock characteristics.

- All street are within 500 m (1600ft) radius of each other, directly linking with a main arterial road providing access to and from the inner City.
- All streets have a posted speed limit of 50 km/h (31 mph).
- All streets have no dedicated bus routes running along them.
- All streets have sidewalks along both sides, with no pedestrian crossing facilities.
- Other than Murdoch St (LIGHT) all streets had grass berms and occasional small street trees.
- All streets display typical residential “tidal flow” characteristics during peak hour periods, which represent around 10% of the total daily volume.

It is acknowledged that there are some differences in street width and length, and this may be affecting traffic speeds and resulting survey outcomes.

The study generally drew on resident perceptions using a letterbox questionnaire, which asked several broad questions relating to residential amenity such as:

- whether they know their neighbors
- whether the road is noisy
- whether they are delayed in crossing the street
- whether they consider the volume of traffic as high
- whether they would let their children play on the street

Perception questions were generally posed with a three or five-point descriptive scale. Given that the traffic volumes of each street were known, the responses to each question could be compared to those volumes. This information could then be used to examine the impact of traffic on street life. Essentially it was a simple, yet structured way to analyze the variables that might contribute to the complicated interaction between traffic and residents’ livability.

The use of a reply-post questionnaire was governed by limited resources (i.e. time and costs), which ruled out formal interviewing and/or direct observation. A $50 lucky prize provided an incentive to respond and the overall response rate for all four streets was 37%. Attempts were also made to word the questionnaire in such a way that no particular answer would be favored over others, but no random ordering of questions or possible responses was employed. It is important to remember that a key aim was to mimic as much as possible the questions posed by Appleyard in his study.

Results

The number of survey responses for each street ranged from just five on the LIGHT street to 36 on the MEDIUM street (response rates between 34% - 43%). Admittedly, the limited number of respondents on some streets might be susceptible to random variation, although the resulting trends proved remarkably consistent (it should be remembered too that Appleyard’s seminal study only interviewed 12 residents per street). Over 90% of respondents owned their homes (i.e. not renting), which is high even by New Zealand standards and may reflect a response bias.

Table 2 summarizes results from the key survey questions. Note that some of the questions had multiple-choice options and only the proportion of answers in the "worst" one or two response options are presented. Almost consistently, there is a clear trend in responses from the LIGHT street through to the HIGH street.

TABLE 2 Survey Questionnaire Results – Case Study 1 (Untreated Streets)

Survey Question	Murdoch Street	Jennifer Street	Aorangi Road (northeast)	Aorangi Road (southwest)
Traffic Volume	(LIGHT)	(LOW)	(MEDIUM)	(HIGH)
Number of responses	5	23	36	18
Rear-section Property?	0%	9%	39%	53%
Main living area in your house generally faces away from the street?	0%	43%	61%	83%
Front sections: do you have a fence in the front yard that blocks street views? *Yes*	60%	65%	72%	89%
Would you feel comfortable with children playing unsupervised on or near the street? *No*	60%	70%	86%	89%
Do you know any of your neighbors personally? *No*	20%	32%	33%	58%
Do traffic volumes along this road create a barrier to social connection with neighbors?	0%	9%	11%	14%
How would you rate the amount of traffic on this street? *Heavy / Very Heavy*	0%	26%	48%	57%
Do you think that the overall speed of traffic on this street is: *A bit fast / Too fast*	80%	87%	72%	67%
Has traffic on this street got worse over past few years? *Yes*	0%	41%	61%	70%
Looking ahead five years from now, do you think traffic on this street will get worse? *Yes*	20%	39%	58%	68%
Do you consider this road to be: *Noisy / A little bit noisy*	40%	49%	60%	84%
Does traffic in your street bother you during some activities? *Yes*	20%	28%	33%	40%
Do you usually have to wait for traffic before crossing the street? *Yes*	20%	49%	67%	89%

The dominance of traffic as a problem on all street types is the most salient finding of this study. From the survey results, residents on the lighter and lower volume streets were the most contented; however, they were not without their traffic problems. More than half (60%) of the residents along the LIGHT street still have a fence in their front yard that blocks views to and from the street and they would not let their children play on or near the street. While more residents along the LIGHT street personally know their neighbors, 80% of them believe the overall speed is “a little bit fast”, yet the same proportion suggest they do not have to wait at all to cross the road. In addition, 40% believe it is “noisy” or a “little bit noisy.” This however is further confused by findings that only 20% of the residents are bothered by traffic during some activities. The conflicting and contrasting verbatim comments on these topics also confirm the subjective and variable nature of opinions in relation to traffic issues along their streets.

Overall, the perception held by residents living on the streets with higher traffic volumes is that their streets are busier, noisier and less safe. The outlook is also not positive with an increasing trend for residents along higher volume streets believing the traffic will continue to get worse. This is coupled with an increasing trend for the same houses to turn away from the street through the construction of high fences in their front yards. This in turn could be limiting passive surveillance and the exposure to passers-by, and might explain why residents along busier roads tend to have less personal involvement and/or knowledge of their neighbors.

One interesting item to emerge was that residents on streets with lower daily traffic volumes perceived traffic as being “a little bit fast.” Again, this could be a reflection of people on the higher volume streets becoming accustomed to the overall speeds. This may account for the slightly higher proportion of residents on the higher volumes streets suggesting that the overall traffic speed was “about right.”

Commonplace throughout the survey responses was the regular verbatim comments referring to the streets being used as a short-cut route. Appleyard also found this on his surveyed San Francisco streets back in the late 1960’s. The issue of extraneous traffic was also referred to heavily in Buchanan’s research; he suggested that areas containing only local streets should have all through-traffic removed. For the surveyed Christchurch streets, all were classified as local roads and therefore had a function of providing property access to residential properties. The traffic volumes on all four streets however carried well in excess of the expected traffic that would be generated solely by the houses located along them (estimated to be between 2-8 times more traffic than expected based on dwelling numbers).

This raises questions as to whether the road classification is correct, or whether the street layout and overall housing pattern is correct. This is highlighted by the fact that many classified “local” roads in Christchurch carry more than 2,000 vehicles/day (such as Aorangi Road), which is the upper limit cited by the local Infrastructure Design Standard (*23*). Roads that carry more than this appear to have a dual function of traffic distribution and property access. This runs counter to the deeply entrenched inverse relationship between movement and access functions for local and arterial roads. On all four surveyed streets there appears to be some overlapping functions (whether intended or not) and this clouds the issue further of what a true local road is.

Appleyard’s surveys included a street where the traffic volumes were around 2,000 vehicles/day; this traffic volume coincides with that of Aorangi Road (northeast). Given that the same questions were used for both studies it is useful to compare resident responses from the two streets. Note that both streets served stand-alone residential houses.

In nearly every single aspect the overall response rate for the San Francisco street was noticeably more positive than the equivalent Christchurch street. Nearly twice as many Christchurch residents suggested that the traffic would get worse in the future and, although the streets carried the same amount of traffic, nearly twice as many Christchurch residents had to wait longer to cross the road. A greater proportion of Christchurch residents also implied that the traffic along their street was heavier and faster than the San Francisco equivalent. All this suggests that the Christchurch residents express more dissatisfaction in terms of environmental components that contribute to the livability of their street. However, it is interesting to note that the San Francisco street had a greater proportion of residents affected by traffic when doing other tasks around their home (i.e. watching television, working in the house, eating). Ultimately, the differences between both sets of results emphasize the point that there are many factors that influence environmental quality, both in absolute terms and as perceived by different communities. Given the 40-year time difference between the two surveys, it is also highly possible that attitudes have changed over time with regard to technology, the environment, and traffic in general.

CASE STUDY 2 – CHRISTCHURCH 2011-12

The streets investigated in the first study (*2*) were very typical of older conventional streets. They were wide and straight, with no apparent level of street hierarchy associated with them. Of particular interest in this next study (*3*) was how much of an effect local street treatments, such as speed humps, narrowings and trees, have on residential amenity and environmental capacity. Based on the previous literature, it was hypothesized that residents on streets with such street treatments would be able to tolerate higher daily volumes of traffic.

The survey method was as similar as possible to that used in the first study; this meant that survey findings would be more comparable. Streets with varying levels of traffic flows were again required, ideally with similar volumes to the previous sites for comparison.

A major consideration when looking for streets to study was the significant earthquakes that had struck Christchurch since September 2010, particularly February 2011. In order to obtain results that could be compared with the previous research, the streets studied needed to be as undamaged and unaffected by the earthquakes as possible. This was difficult, given that many streets in Christchurch had been affected, although less so in the north west of the city where the original study took place. Traffic patterns post-quakes had also significantly altered across the city, although largely on the arterial road network. Ultimately, the main criterion was just that the streets were not physically damaged by the earthquakes.

A group of local streets with high levels of street treatment was found, approximately 1.5km (one mile) away from the original study. The area, known as the Papanui Cluster, was reconstructed between 2004-08 to reduce vehicle intrusion into the residential area. This was an emerging problem in the area, being situated near a busy arterial road and major suburban shopping centre. The area has a median income of NZ$25,000, not too dissimilar to the $23,200 median income in the original study area.

As part of the street reconstruction works, the Papanui Cluster incorporated street narrowing, intersection platforms and realignments, re-opening and development of a previously piped stream, landscaping and swales, and art features. Streets were typically reduced to 9m (30ft) wide carriageways, with further narrowings mid-block and at intersections typically about

6m (20 ft) wide. An adjacent conventional street with large overhanging trees was also investigated to assess the effect of the vegetation canopy on residents' perceptions.

To improve survey response rates, face-to-face contact was made with residents where possible, with a post-back survey provided as an alternative. Together with another lucky prize incentive, this resulted in a very good response rate (>70%). Conducting interviews in person had the advantage of being able to avoid confusion and misinterpretations of questions, and to provide more opportunity for residents to describe their thoughts and give more comments. However, there was also the risk of biasing the respondents when asking the question, so careful work was done to develop a suitably neutral interviewing process.

Results

Nine "treated" street sections were surveyed and the resulting data grouped into four categories roughly corresponding to the average traffic volumes on each street. Table 3 summarizes the survey sites and results, by traffic category.

Again, the results show some general consistency in trends as traffic volumes increase. However, there is a lot more variation amongst the LIGHT – MEDIUM streets, with the HEAVY streets demonstrating consistently higher levels of concern than these groups. It may be that the street treatments are helping to make most sites feel like truly "local" streets to the residents, and only as traffic volumes get sufficiently high is this effect is being strongly negated.

One notable difference with some of the streets investigated in this study was the level of on-street parking. The proximity to a suburban shopping centre meant that some streets nearest to the retail district had high levels of all-day parking. From discussion with some residents, they had strong concerns about this parking. There was a risk that the parking issue could overshadow what the study was actually about. Therefore, it was important to separate the residents' negativity stemming from parking concerns, from their perceptions of the traffic levels on their street and how it was affecting them. This is where the face-to-face interview method was invaluable in getting residents to focus on the through-traffic, and generally there was little correlation between parking concerns and other traffic-related concerns. However, the streets used in this study were probably too close to the busy main roads and shops for an easy comparison with the first study.

The second study further investigated the effect of demographic factors on responses. Investigation focused on the street with the largest response sample (Proctor St, 42 respondents) to control for other variables. The respondents' age was a key factor in how respondents answered certain questions. Younger people seemed more blasé about traffic and its effects. This was reflected in findings such as younger people (especially under 30) being more likely to be comfortable than older people with kids playing on the street, and being less likely to think their street was busy.

During the interviews it was also noted that men seemed more relaxed about traffic and the associated problems. This was also evident in some survey reuslts, for example, 33% of men surveyed on Proctor Street were comfortable with kids playing on the street, whereas only 21% of women surveyed said the same.

TABLE 3 Survey Questionnaire Results – Case Study 2 (Treated Streets)

Approx. Daily Traffic Volume – CATEGORY	500 (LIGHT)	1000 (LOW)	2000 (MEDIUM)	3000 (HIGH)
(Treated) Street names	Proctor St Loftus St	Grants Rd Frank St Wyndham St	Gambia St	Rayburn Ave Mary St (×2)
Number of households	80	70	21	56
Number of survey responses (%)	53 (66%)	48 (69%)	15 (71%)	46 (82%)
Rear-section Property?	23%	40%	33%	22%
Main living area in your house generally faces away from the street?	48%	54%	59%	66%
Front sections: do you have a fence in the front yard that blocks street views? *Yes*	48%	46%	34%	75%
Would you feel comfortable with children playing unsupervised on or near the street? *No*	69%	89%	71%	89%
Do you know any of your neighbors personally? *No*	12%	8%	5%	13%
Do traffic volumes along this road create a barrier to social connection with neighbors? *Yes*	12%	9%	5%	39%
How would you rate the amount of traffic on this street? *Heavy / Very Heavy*	31%	21%	21%	87%
Do you think that the overall speed of traffic on this street is: *A bit fast / Too fast*	31%	23%	40%	52%
Has traffic on this street got worse over past few years? *Yes*	35%	48%	40%	67%
Looking ahead five years from now, do you think traffic on this street will get worse? *Yes*	19%	38%	36%	54%
Do you consider this road to be: *Noisy / A little bit noisy*	15%	31%	20%	61%
Does traffic in your street bother you during some activities? *Yes*	0%	6%	7%	17%
Do you usually have to wait for traffic before crossing the street? *Yes*	43%	34%	25%	86%

Determining Environmental Capacity

The findings of the Appleyard study (*7*) and the Christchurch surveys clearly show that as traffic volumes increase there is a reduction in other ‘environmental’ values. Although the overall trend is clear, there is a difficulty in determining what the actual environmental capacity is.

In order to make a quantitative judgment on a qualitative issue, a simple scoring system was derived from the Christchurch survey information for each of the four street categories, based on responses to ten of the main survey questions. The overall scores allocated were based on the percentage of *positive* responses to these questions. This reflects the proportion of responses where residents were “satisfied” with the overall residential amenity of the area, e.g. the percentage who said “yes” when asked if they would be comfortable with their children playing unsupervised on/near the street. For this exercise, 50% was considered the threshold (or environmental capacity). This aligns with Buchanan’s rough theory that simply separates acceptable from unacceptable, i.e. the majority (>50%) of people will find it acceptable/unacceptable. Figure 2 shows the results of the scoring system in comparison with the street volumes.

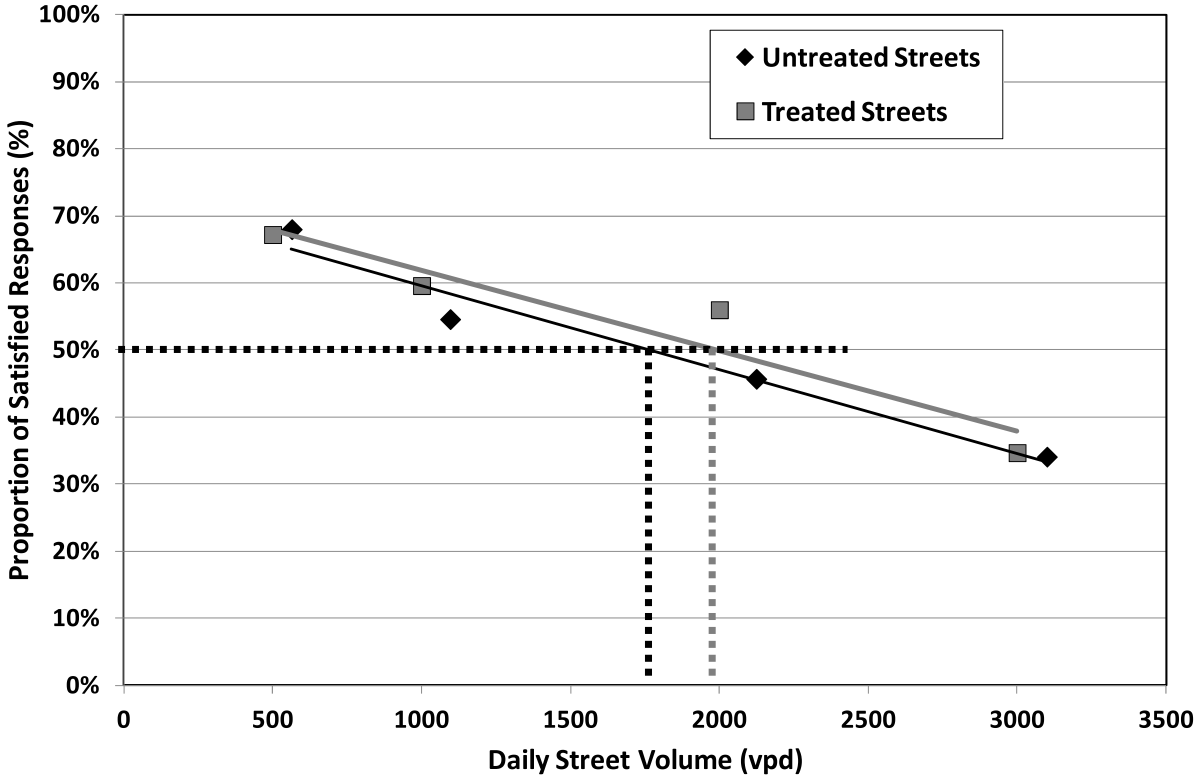

FIGURE 2 Environmental Capacity Trend-line for Christchurch Streets

A linear trend-line has been fitted to each dataset; while it is debatable whether this is actually the most appropriate relationship (particularly beyond the extents of this data) the r^2 values are >0.90 and it is considered sufficient for this exercise. Both sets of streets display similar decreasing relationships (in terms of “satisfied” responses) as traffic volumes increase.

While by no means an all-encompassing model for determining environmental capacity, it may provide some insights into the issue, especially in relation to the surveyed Christchurch streets.

If an environmental capacity/threshold limit is set at the “50% acceptable” mark, Figure 2 would imply that the environmental capacity for untreated streets is somewhere between 1,500-2,000 vehicles/day. This is clearly less than the 2,000-3,000 vehicles/day often quoted elsewhere. While this research is not suggesting that the environmental capacity of *all* residential streets is 1,500-2,000 vehicles/day, the surveys imply that typical environmental capacities are perhaps not as high as what previous literature has suggested.

Looking at the treated streets in Figure 2, it can be seen that around 2,000 vehicles/day is the traffic volume where half of the responses would be positive. This suggests it is possible that street treatments, such as those provided in the Papanui Cluster, can increase the environmental capacity of local streets. It is notable that this threshold value is still at the low end of the previously cited 2,000-3,000 vehicles/day figure.

CONCLUSIONS

A review of literature on environmental capacity reveals that the concept was first introduced by Buchanan in his London-based research, followed by Appleyard in San Francisco. Both authors settled on broad-brush traffic thresholds of 2,000-3,000 vehicles/day. Further literature review however reveals that other subsequent research heavily relies on the original Buchanan and Appleyard findings and there have been few questions on the validity of the original information. This is not a criticism of the original findings, which occurred 40 years ago when resident perceptions in relation to environmental and amenity values may have been different. Changes in the way we live, technological improvements and a greater (or lesser) acceptance of the automobile maybe partly responsible for any changes.

There are clear trends showing that residential amenity decreases as traffic volumes increase. Although it is accepted that the issue is highly subjective and varies between districts, the traditional rule of thumb that a residential local road could acceptably carry 2,000-3,000 vehicles/day is perhaps set too high. In the Christchurch context, an initial survey of four local streets suggest that a more appropriate environmental capacity would appear to be 1,500-2,000 vehicles/day. This has implications for local town planning and street network design guidance if true “local” roads are to be achieved.

A subsequent study investigated nine further streets in Christchurch using the same techniques. These streets contained more traffic calming and street trees than the original four sites. A threshold value of around 2,000 vehicles/day was determined as an acceptable traffic level in these “treated” local streets. This suggests that appropriate street treatments can increase the environmental capacity, which has implications for local councils who want to maintain road traffic carrying capabilities without having unsatisfied residents.

Recommended Further Research

The Christchurch surveys in this research included only a small number of streets. These of course do not represent all Christchurch streets and caution should be applied if using this information with other local areas. In addition, although the response rates to the questionnaires were reasonably good, the sample sizes were not particularly high on some streets (ranging from 5-42 responses). The trends however between low and high volume streets were obvious. Further research using the same questionnaire for a number of other streets would be beneficial and might reinforce the current conclusions further.

The streets studied also had some differences in road attributes such as carriageway width and traffic speeds. The original study focused on the relative effects of traffic volume alone but, like Buchanan's previous work, it is acknowledged that other road features may allow base environmental capacity values to be adjusted. While the second study enabled some assessment of the effects on residential amenity of road width, traffic calming, and landscaping, it has been difficult to identify the specific effects of certain features. For example, it may be that street trees have a far greater effect than speed humps on how well residents tolerate higher traffic volumes. Further investigation of the relative effects of these features is needed; ultimately this may provide some useful guidance on physical measures to improve the environmental capacity of existing local streets.

The proximity to a busy arterial road and shopping area appeared to influence residents' opinions, not least due to the level of on-street parking. Future research may want to either investigate streets further away from busy commercial areas, or examine this effect separately.

REFERENCES

1. Buchanan, C. (1963). *Traffic in Towns: A Study of the Long Term Problems of Traffic in Urban Areas*. HMSO, London, England.
2. Chesterman, R. (2009) Traffic Volumes and Residential Amenity: Is the Environmental Capacity of a Local Residential Street Really 2,000-3,000 Vehicles Per Day? *Master of Engineering in Transportation (MET) Research Report*, University of Canterbury, Christchurch, New Zealand.
3. Leckie, A. (2012) Environmental Capacity of Local Streets with Street Treatments. *Master of Engineering in Transportation (MET) Research Report*, University of Canterbury, Christchurch, New Zealand.
4. Howard, E. (1902). *Garden Cities of To-Morrow*, S. Sonnenschein & Co. Ltd, London.
5. Hardy, D. (1999) *Tomorrow and Tomorrow: The TCPA's First Hundred Years and the Next…* Town & Country Planning Association, London, England.
6. Jacobs, J. (1961). *The Death and Life of Great American Cities*. Random House, New York, USA.
7. Appleyard D., Gerson M.S., Lintell M. (1981) *Livable Streets*. University of California Press, Berkeley, USA.
8. Appleyard, D. & Lintell, M. (1972). The environmental quality of city streets: The residents' viewpoint. *Journal of the American Institute of Planners*, Vol. 38, No. 2, pp.84-101.
9. Transportation Alternatives (2006). *Traffic's Human Toll: A Study of the Impacts of Vehicular Traffic on New York City Residents*. Transportation Alternatives, New York.

10. Hart. J. & Parkhurst, G. (2011). Driven To Excess: Impacts of Motor Vehicles on the Quality of Life of Residents of Three Streets in Bristol UK, *World Transport Policy and Practice*, Vol. 17 No. 2, June 2011, pp.12-30.

11. Bosselmann, P., Macdonald, E. & Kronemeyer, T. (1999). Livable Streets Revisited, *Journal of the American Planning Association*, Vol. 65 No. 2, pp.168-180.

12. Litman, T. (1999). *Traffic Calming Benefits, Costs and Equity Impacts*, Victoria Transport Policy Institute, Victoria, BC, Canada.

13. Jacobs, A.B. (1995). *Great Streets*, MIT Press, Cambridge, MA.

14. Roads and Traffic Authority (RTA) (2002). *Guide to Traffic Generating Developments*. RTA, NSW, Australia.

15. City of Palo Alto (2002). *Transportation Significance Thresholds - Study Session and New Interim Standards*, Staff Report to the Planning & Transport Commission, Sep 2002.

16. Commonwealth of Australia (1997). *Australian Model Code for Residential Development (AMCORD)*, Local Government & Planning Ministers' Council.

17. City of Portland (2008). *Impact Threshold Curve*. Office of Transportation, Portland, OR.

18. Sharpe, C.P., Maxman, R.J., Voorhees, A.M. (1972). A Methodology for the Compilation of the Environmental Capacity of Roadway Networks. *Highway Research Record*, No. 394, Highway Research Board, US, pp.33-40.

19. Holdsworth, J & Singleton, D.J. (1997). Environmental Traffic Capacity of Roads, *Fifth Australasian Transport Research Forum*, Sydney, pp.219-238.

20. Song, L, Black, J A. & Dunne, M. (1993). Environmental Capacity Based on Pedestrian Delay and Accident Risk. *Road and Transport Research Journal*, Vol. 2, No.3. pp.40-49, Australia.

21. Bell, M. (2011). How can traffic engineers help manage our environment? *Traffic Engineering and Control*, Vol.52, No.2, Feb 2011, pp.51-57.

22. Li, T., Lin, J., Wu, M., & Wang, X. (2009). Concept and Spatial Analysis Method of Urban Environmental Traffic Capacity, *Journal of Transportation Engineering*, American Society of Civil Engineers. Vol. 135, pp.873-879.

23. Christchurch City Council (2007). *Infrastructure Design Standard*, Christchurch, New Zealand.