Accelerating the uptake of electric vehicles in New Zealand

Rapid chargers for battery electric vehicles in New Zealand: current use, access and location preferences

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Executive Summary

Rapid chargers are now installed at many strategic positions to enable long-distance travel through much of New Zealand, even by short-range Battery Electric Vehicles (BEVs). However, our survey of 108 BEV owners found that they are required to wait an average of 10 minutes for their turn to charge in around 14% of visits to a rapid charger station. The chargers are not functioning on around 4% of the visits and blocked by an internal combustion vehicle on 2% of visits. Stability and predictability of rapid service is important for existing BEV owners, but also assures prospective purchasers of BEVs that they can undertake long trips away from home or the main population centres.

A choice experiment found that immediate availability of the rapid charging was the most important priority for rapid charger users. Proximity to a main route and high visibility to increase security was the second most important charger location factor, while charger proximity to shops and food, and proximity to a public toilet were also important. Proximity to recreational amenities was predicted to be the lowest priority by the choice model, but additional comments by participants suggested that provision of shelter from the weather was also important. Women gave relatively more emphasis to visibility and access to toilets, whereas men prioritised proximity to main routes and to shops and food. Immediate access to a rapid charger was on average 2.4 times more important than proximity to shops and food.

The rapid increase in the size of the national BEV fleet threatens to make congestion at rapid chargers worse, but the advent of more affordable, long-range BEV models and provision of super-fast chargers, may lessen this stress in the longer run. A lessening of the impact of charger congestion can also be expected as more alternative charging sites are made available in the vicinity of high need areas, whereas at the moment a delayed driver has little alternative but to wait their turn.

A multimedia education programme is required to prevent conventional vehicles from parking in EV charging spots, and for BEV owners to minimise the time they occupy the charger. This would reduce charger congestion. Another recommendation is for a local and municipal authorities to demonstrate a more active role in the electrification of their and the nation's vehicle fleet. This could be facilitated by Local Councils investing in chargers themselves or co-investing with businesses to capture efficiency and reduce costs. They might also facilitate the private investment in chargers by expediting planning and regulatory requirements.

Provision of multiple chargers at each site, and provision of a mix of medium and rapid chargers to meet different users' needs, would increase the probability that a charger is available when a user arrives. Many rapid chargers are currently free. Business investment in additional chargers in the vicinity would be accelerated and congestion would be lessened if a usage charge was instigated, because local BEV owners would charge at home in preference to using the at present free public chargers. More generally, rising congestion at existing rapid charger sites signals the looming need for a new strategy of investment promotion to increase the density of chargers in regions and districts that already have a rapid charger. There is still a need to extend the charging network to remote geographic areas, but consolidation of more varied charging infrastructure is the next challenge for accelerating BEV uptake in New Zealand.

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Introduction: the need for this research

Long range travel with Battery Electric Vehicles (BEVs)[1] is constrained by the availability of "rapid chargers" along the journey. The rapid chargers use direct current to recharge most BEVs in around 30 minutes[2]. Installation of these chargers is expensive and time consuming and the full return for investors will be delayed until New Zealand's BEV fleet grows significantly. A perception that there are insufficient chargers exacerbates "range anxiety"[3] of current owners and prospective purchasers of BEVs[4]. This chicken or the egg dilemma is particularly acute in New Zealand because of its small BEV market, sparse population, and long stretches of remote and mountainous terrain.

The aim of having at least one rapid charger per 75 km of main highway is now in sight for much of New Zealand[5], thanks largely to the efforts of ChargeNet and several electricity distribution companies[6] who have installed chargers either independently or in partnership, often with partial funding from the New Zealand Government provided by its Low Emission Vehicle Fund[7]. However, enabling BEV long-distance travel requires that the chargers need to be reliable and accessible. In addition, it is desirable that chargers are provided in a location were people feel safe and comfortable to wait while charging and services are near so owners can be entertained or shop while waiting to charge. Dunedin residents have been experiencing severe problems accessing rapid vehicle charging in the central city for the following reasons: congestion and competition for time at the station; charger malfunction; and the charging park being occupied by a conventional Internal Combustion engine Vehicle (ICV). This latter obstruction is particularly frustrating for BEV owners, and is colloquially known as "being ICEd". This study aimed to see how prevalent such problems are around New Zealand. It was conducted by *Flip the Fleet,* a nationwide citizen science coalition of BEV owners with a shared goal to advise on the constraints and opportunities for accelerating BEV uptake[8].

ChargeNet recently announced plans to install four rapid chargers in and around Dunedin to relieve congestion. This precipitated vigorous discussion amongst local BEV owners as to the best locations to install them. This debate highlighted the need to establish a hierarchy of location criteria that could then be applied to candidate sites in a systematic and transparent way. *Flip the Fleet* set out to survey BEV owners opinions by conducting a "choice experiment". Participants were asked to choose between hypothetical alternatives for notional chargers that had different combinations of desirable features. This choice modelling is a formal tool borrowed from economics where participants are forced to trade-off the competing criteria, rather like a virtual online auction. The relative "weight" that users put on competing criteria can then be applied to choose amongst competing local sites without individuals of particular business interests dominating the selection process.

This research linked a choice experiment and survey of use of rapid chargers to (a) assess present demand and user experience of rapid chargers, (b) assess the need for more chargers in the future, (c) identify the most important criteria for rapid charger placement for users, and (d) link owners' experiences of existing chargers over the last three months to where future chargers might be placed. We asked how often respondents used rapid chargers, how often they were prevented or delayed from using them, and how long they had to wait for access. These metrics provide a baseline against which future use and congestion can be monitored. Details about the gender, age and regional location[9] of the participants were also gathered so that the relative needs of all BEV users can be better understood and provisioned.

Methods

Structure of the choice experiment

The choice experiment was constructed using the 1000Minds platform[10]. It asked participants to weigh the relative importance ("utility") of the following criteria, and levels within each criterion, when choosing between two hypothetical rapid charging station locations:

1. **Proximity to main route**
   1.1 Low (5+ minute drive from arterial route)
   1.2 Medium (2-4 minute drive from arterial route)
   1.3 High (on or within 1 minute drive from arterial route)
2. **Visibility to increase personal security and discourage vandalism**
   2.1 Low
   2.2 High (on or within 1 minute drive from arterial route)[11]
3. **Immediate availability**
   3.1 Low (frequently have to wait my turn to charge)
   3.2 Medium (sometimes have to wait my turn to charge)
   3.3 High (hardly ever have to wait my turn to charge)
4. **Proximity to shops & food**
   4.1 Low (shops 5+ minute walk away)
   4.2 Medium (shops 2-4 minute walk away)
   4.3 High (shops 1 minute walk away)
5. **Proximity to public toilet**
   5.1 Low (toilet 5+ minute walk away)
   5.2 Medium (toilet 2-4 minute walk away)
   5.3 High (toilet 1 minute walk away)
6. **Proximity to recreational amenity (park, gardens, beach, playground, view)**
   5.1 Low (no recreational amenity within practical walking distance)
   5.2 High (recreational amenity within practical walking distance)

These criteria were chosen from the discussion observed in the EV community on Facebook. The levels within each criterion were scaled according to the researchers' own experiences of practical distances and times experienced in a variety of existing charging stations.

The experiment was performed by having the participant choose the left or the right combination of traits for the two notional rapid chargers displayed on their computer screen. An example is shown in Fig. 1 below. Respondents could also select 'They are equal' if they felt there was a tie between the left and right paired options. Once one choice had been made, the computer randomly assigned the next combination of traits to choose from, the cycle is repeated until the participant's preferences were measured. A transitivity assumption is used to speed the selection process i.e. only less extreme combinations than those already revealed by the participant's prior choices are tested, so the algorithm rapidly exhausts the remaining options to weigh all the different levels of each criterion.

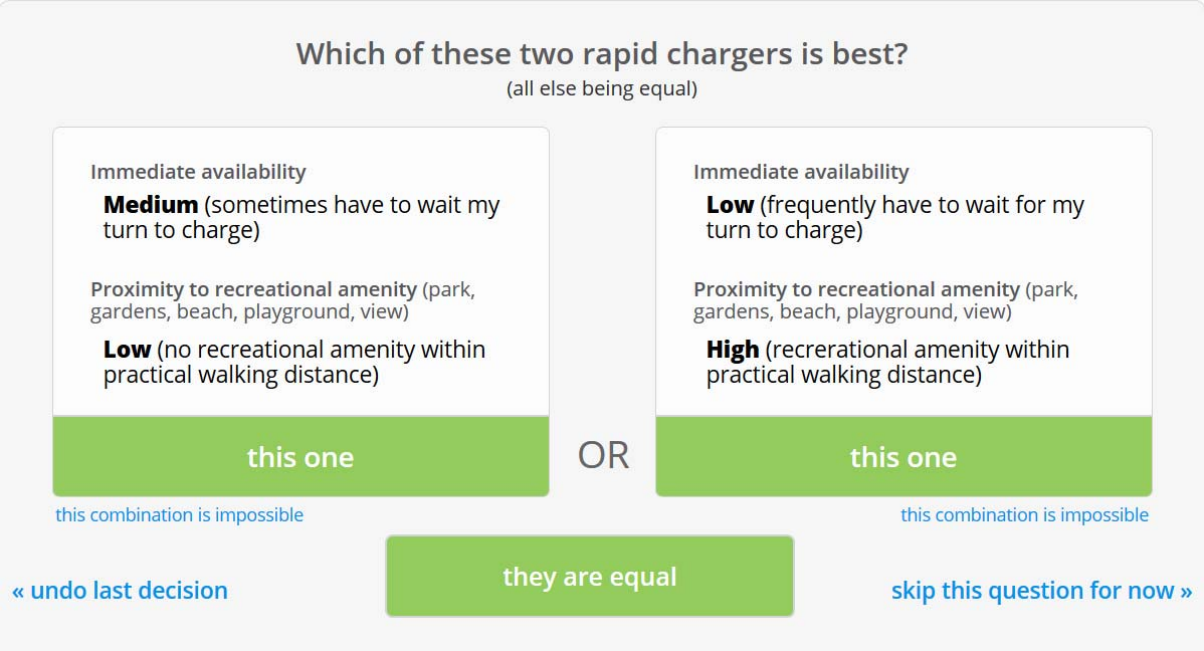

Figure 1: An example of one of around 30 choices that each participant made while conducting the choice experiment. The participants select either the right or left green buttons to show which situation they would prefer, or the green button in the middle if they think the left and right side are equal.

The method calculates a 'Utility' that signals the value the participant places on each level and criterion. Utility is an abstract measure scaled across all choices, scaled from 0% (no value) to 100% (all the value available). It can be thought of as a measure of the "weight" or "preference" or simply "relative importance" given to each option given that there is only a fixed amount of utility (100%) to be distributed amongst the options. For example, had all six criteria been equally valued by the participant, the final utility assigned to each would have been 100/6 = 16.6% at their 'highest' level.

Once the participant had made all the required choices, they are taken directly to a survey form constructed[12] in the Wufoo software package[13] so that their answers to the choice experiment can be linking to their own circumstances and identity.

Survey questions

The survey asked the following questions:

1. What is your gender?
2. What is your age?
3. How many times have you used (or tried to use) a rapid charger in the last three months?
4. On how many times of those visits (over the past 3 months) was the charger out of action?
5. On how many times of those visits (over the past 3 months) did you have to wait your turn to charge?
6. On how many times of those visits (over the past 3 months) did you have to wait or leave altogether because an ICE vehicle was occupying the rapid charger space?
7. How many minutes did you have to wait (on the last occasion when the charger was occupied?)
8. Regions where you have mostly used fast chargers (tick-boxes provided)?

9. The choice experiment asked you to weight the importance of security, availability, and proximity to routes, services and amenities. Are there any other features of rapid chargers that are important for you?
10. Are there sufficient rapid chargers in your region? (tick one)
    a. We need a lot more
    b. We need some more
    c. We need a few more
    d. We have enough already to meet current demand
    e. I don't know
11. Feedback please?! Was the choice experiment clear and easy enough to complete? Will the exercise be useful once the results from a lot of people have been combined? What other choice experiments should we conduct to help guide infrastructure development for EVs and PHEVs?

Deployment of the choice experiment and survey

We first invited members of the 'Otago EV Owners group'[14] to do the experiment and survey in December 2017 by clicking on a link in their Facebook page. The same invitation was extended in late December to EV members in other regions by posting (i) on the Facebook NZ EV Owners group[15], (ii) on *Flip the Fleet*'s discussion page, and (iii) an item in December's monthly update emailed to all *Flip the Fleet* members. The choice experiment and survey was closed in late January 2018 when no responses had been received in the previous week.

Statistical analysis

Linear Bayesian models[16] with priors to deal with multiple comparisons were fitted to the choice experiment weights, and log-normal models[17] and binomial models[18] were fitted to the survey data, using the brms package[19] in the R statistical environment[20]. The New Zealand-wide models included only an intercept, while the models investigating regional differences included an intercept and region predictor. The models output includes an uncertainty interval, which conveys how uncertain we are about the parameter of interest, and 95% of the time the parameter should be in the interval provided.

Results

Preferences revealed by the choice experiment

The choice experiment and survey were fully completed by 108 BEV owners[21], 83 were men and 25 women. The majority of BEV owner participants were aged between 35 and 64 years old (Fig. 2).

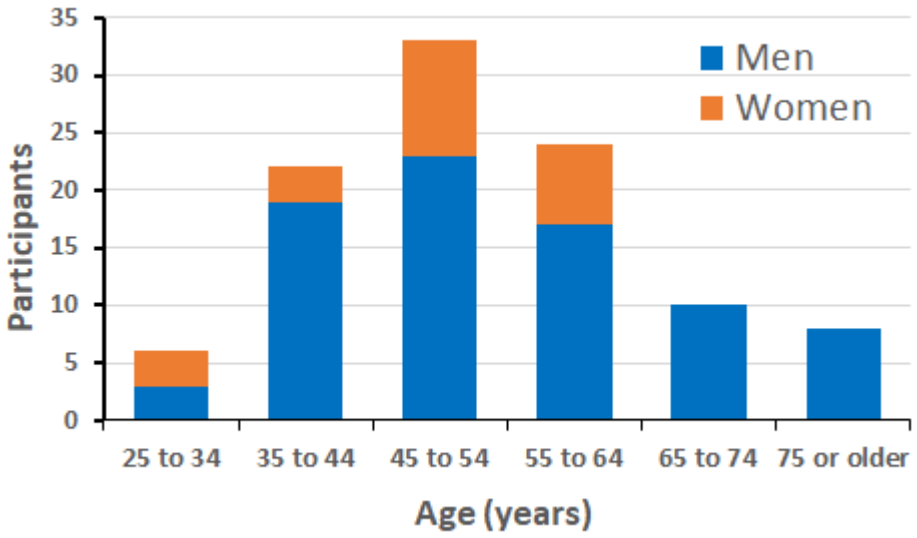

Figure 2. The number of men and women who participated in the choice experiment and survey about rapid chargers between December 2017 and January 2018[22].

By far the most important criterion for all users was immediate availability, followed by proximity to the main route (Fig. 3). Visibility and proximity to toilets were relatively more important for women than men, and proximity to the main route was prioritised more by men than by women. Proximity to recreational amenities was the lowest priority overall.

Even a medium level of availability was more important to the respondents than being close to toilets, shops & food, or recreational amenities (Fig. 4). This shows that users were reluctant to trade-off immediate availability of the charger against most of the other attributes, and 'high' availability was considered to be almost twice as important as medium availability.

The differences in the relative importance of the criteria have been expressed as ratios or multipliers (Table 1). The experiment suggests that New Zealand BEV owners judge immediate availability to the charger as 1.8 times more important than its proximity to the main route, and 2.8 times more important than proximity to recreational amenities. On average, being close to the main route is 1.4 times as important as being close to shops and food.

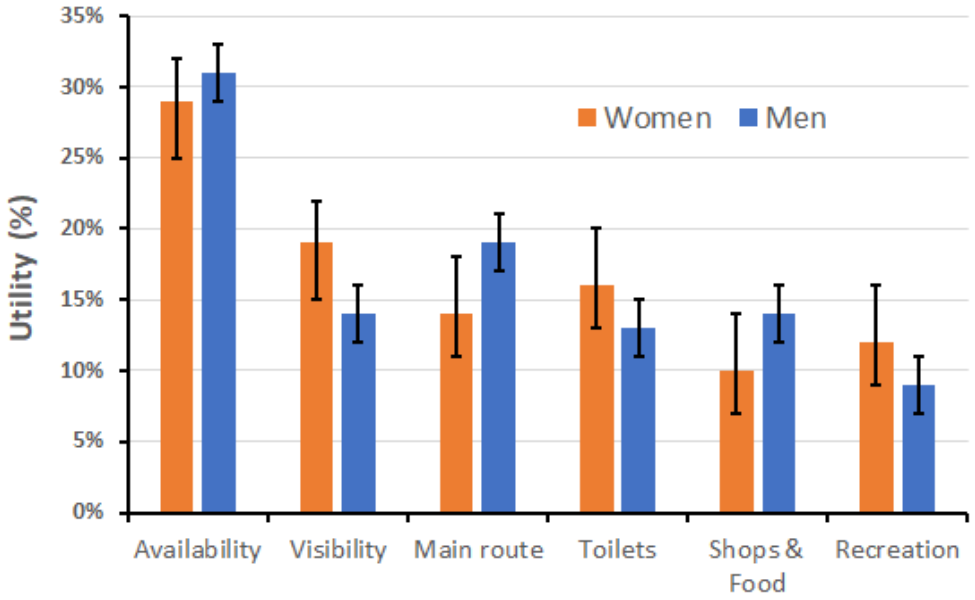

Figure 4. Preferences of men and women for different attributes of rapid charger locations in New Zealand. The error bars are 95% uncertainty limits.

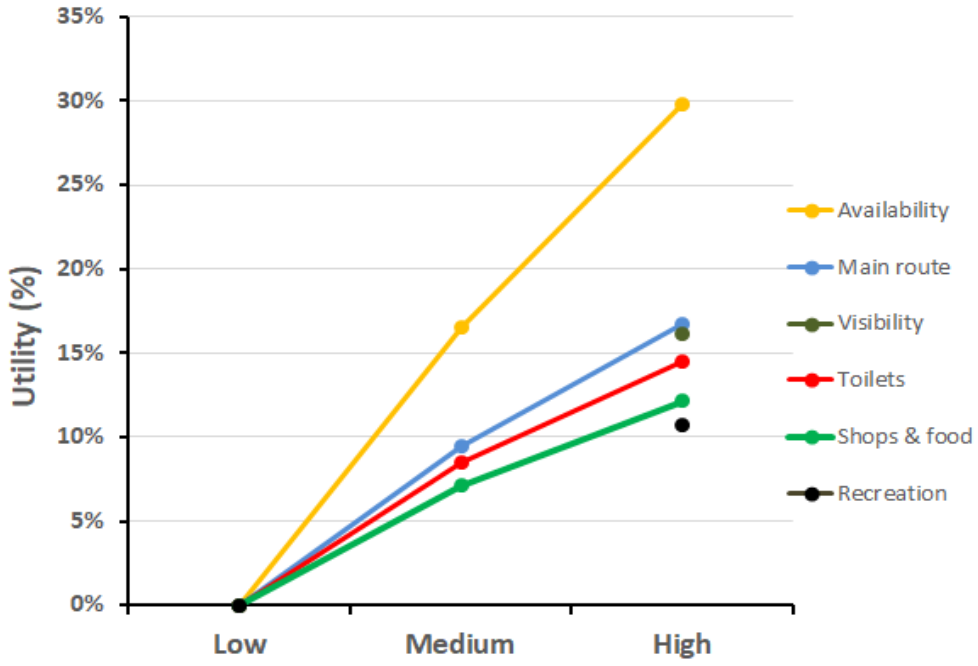

Figure 4. The relative importance of six criteria for positioning of rapid chargers, as predicted by the choice experiment results from 108 BEV drivers in New Zealand. The utilities have been calculated as the mid points between the scores for women and men so that their preferences are equally balanced.

Table 1: Relative importance of six criteria for placement of rapid chargers, as predicted by the choice experiment.

	Main route	Visibility	Toilet	Shops & food	Recreation
Availability	1.8	1.8	2.1	2.5	2.8
Main route		1.0	1.2	1.4	1.6
Visibility			1.1	1.3	1.5
Toilet				1.2	1.4
Shops & food					1.1

BEV owners within the age groups 45-54 and 55-64 were perhaps slightly more concerned about visibility than those in other age groups, but there was insufficient data to confirm this. In view of the influence of gender, and the concentration of women surveyed in these middle age groups (Fig. 2), part of this apparent effect may relate to gender preference rather than age itself.

The average utilities depicted in Figs. 4 & 5 and Table 1 do not reveal the large amount of variability between individual preferences, irrespective of age and gender. For example, utilities for the highest levels of immediate availability, proximity to main route, visibility, proximity to toilets, proximity to shops and proximity to recreation had a range of utilities of 8-52%, 2- 49%, 1-36%, 2-47%, 2-27% and 1-31% respectively.

Frequency of visits to rapid chargers

Around 90% of people who answered the survey had visited a rapid charger at least once in the past three months. The estimated number of visits over 3 months was 6 (95% uncertainty interval 5 to 8). But some people used fast changing extensively (two had made approximately 100 visits within the previous three months (Fig. 5). There was no evidence that the frequency of visits to a rapid charger varied between regions.

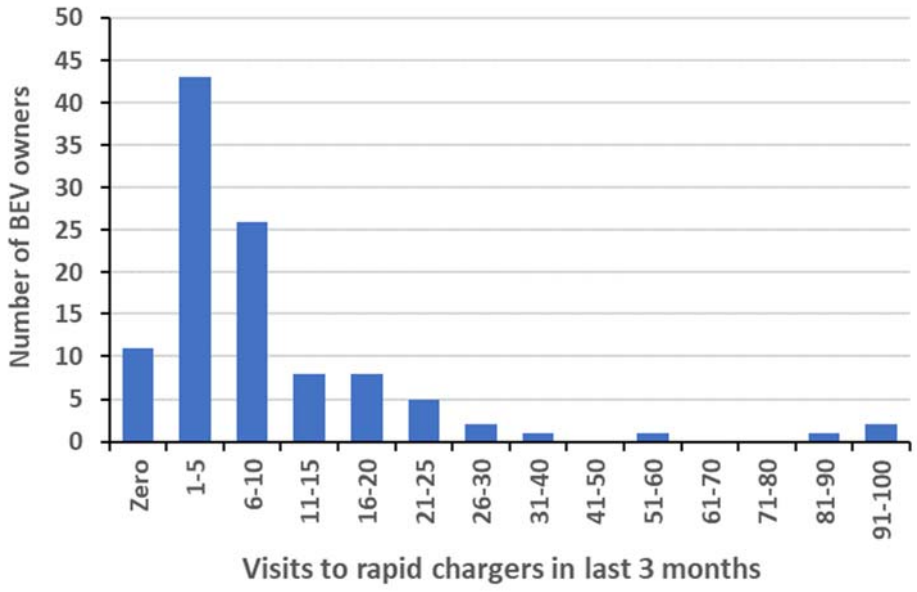

Figure 5. Number of times that the respondents had visited rapid chargers in the three months before the survey.

Experiences at rapid chargers

The charger was not working for around 3.6% of visits (95% uncertainty interval 2.7% to 4.8%) and occupied at the time of arrival on 14% of visits (95% uncertainty interval 12% to 16%; Fig. 6). An ICV occupied the space on 2.2% of the visits (95% uncertainty interval 1.5% - 3.2%), which equates to approximately 16% of the occasions where the charging space was not immediately available for the BEV driver. If they had to wait to access the charger, the average wait time was 10 minutes (95% uncertainty interval 9 to 12 minutes). One respondent had to wait 40 minutes to access that charger.

There was no evidence that proportion of times the charger was faulty or already occupied differed between regions. However, Otago had a much higher rate of being blocked by an ICV (10% of visits, 95% uncertainty interval 6% to 15%). This compares to the rest of NZ where the charging spot is blocked by an ICV on 1% of the visits (95% uncertainty 0.5% to 2%)[23].

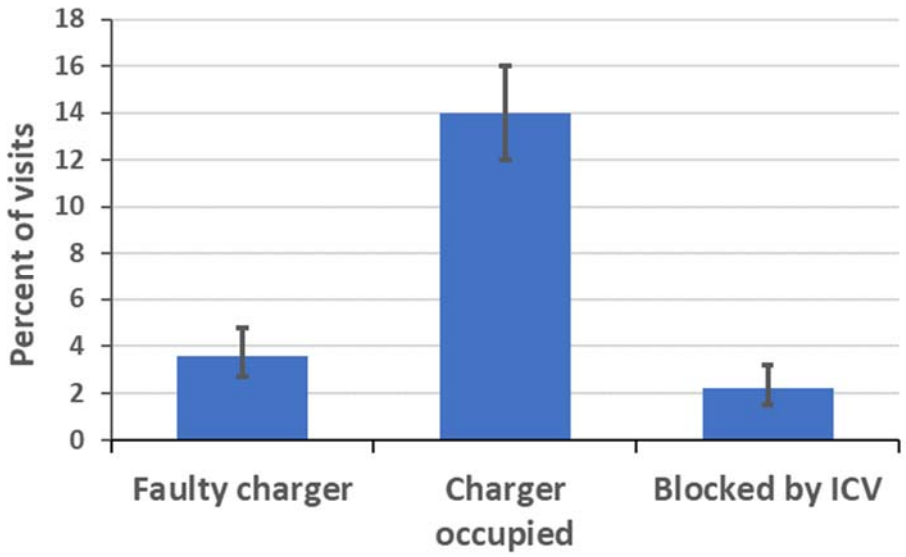

Figure 6. Percent of visits to a fast charger where the BEV driver could not immediately charge because of a faulty charger, occupation of the charger space by another BEV, or occupation by an Internal Combustion engine Vehicle[24].

Several comments left by respondents indicated that stability of service was important e.g. "*The most important factor is an operational charger. I use the Te Kauwhata charger to get to Auckland. If I get there and it is out of action I would be stuck with insufficient range to get back or go on*". Sometimes it is not that the charger is out of order for a long time, just that it requires time to reboot: "*I have noticed that with some high use fast chargers like the Takanini and Greenlane ones, I get the "Charger error. Car must be turned off" message, when trying to charge (and the car is already turned off).*

Yesterday in Takanini, I had to restart the charger seven times before it would charge properly". One respondent lamented that the Vector chargers were "*often broken*".

One respondent affirmed the "awesome" system of reporting faults when they do occur, and another "*Tech support available if there's a problem*".

Comments suggested that the choice model had covered the bases well e.g. "*I want something to do while I charge - knowing I can get back to my car quickly when required (if someone on PlugShare is waiting for instance) I stop, go toilet, grab a snack, maybe get some stuff for home and then head off*". Another highlighted that a nearby café provides "*coffee, cover, toilets, warm place to sit, food entertainment for kids*". Other respondents are content to stay near their car and so the immediate surroundings matter less: "*Relevance of choices to me is difficult to assess as I very rarely rapid charge and usually stay with the vehicle*".

The choice experiment identified the importance of immediate availability of the charger as the top priority. This was corroborated by many comments that waiting to get your turn to charge is frustrating and adds to the inconvenience of the time spent while the charging is underway. One respondent said "*it's almost all about availability*". One who used lots of local free slow public parking said "*when on the road i.e. driving big distances, AVAILABILITY of FAST chargers is the only really important thing!".* Two respondents pointed out that reliability is particularly important at this early stage of BEV uptake while there still are so few alternatives available, so the preferences reported here may not be as relevant in years to come.

There is no doubt from the heat in the Facebook exchanges that "being ICEd" causes intense frustration. But sometimes other BEV owners are to blame for delays: e.g. "*An issue I have encountered more than once at the rapid charger I use is that of people leaving their cars in the charger (which usually takes 25-30 mins for full charge) and then not returning in reasonable time. Thus, their car is fully charged but is blocking access. The last time this happened, the person was overdue by at least an hour, which I estimated from the time I had arrived until the second charger in the facility became available, and I had then fully charged and was ready to leave. I placed an acerbic note on the person's windscreen, but what else could I do? Regrettably, I guess this behaviour just demonstrates that even people enlightened enough to own an EV can still be damned inconsiderate!*".

One respondent pointed out that "*The factors aren't always the same. If I NEED a toilet, that becomes primary. Otherwise it may not be relevant. Same for food. At meal Time, it matters. Otherwise not. Security? More relevant at night*"[25].

Many BEV drivers, particularly women, prefer chargers to be in a highly visible and well-lit space so as to increase personal safety and reduce the chance of vandalism or theft from the car if they leave during charging[26].

Other needs

The survey asked whether there were any features of rapid charger services or their placement that were important but had not been included in the choice experiment.

Some respondents highlighted that charging spots were not always comfortable, clean or dry places. For example, one said: "*I'd like the chargers located so I can walk round the front of the car without*

walking on a muddy grass verge (Otaki), without getting bird poo on my hands, clothes or car (Palmerston North). In a perfect world I'd like a roof so we can charge without getting wet, much as ICE drivers can refuel under cover".

The attraction of free charging in some places no doubt affects the use patterns and problems that have been reported in this survey e.g. "*Free chargers are much better than pay chargers*"; "*Free charging, but this is not a big consideration. I often use SLOW CHARGE free charging". Others said "Price is important, as some chargers are currently free. I very rarely use rapid chargers myself but would like to see more available to encourage EV use all round*"; "*At the moment some are free and others have a cost, so cost comes into the equation also*".

The most frequent suggestions for improvements at the charger sites related to cover and protection from the weather: e.g. "*Cover from rain (and snow down south) would help*"; "*A cover like a carport so you have shade on a sunny day and don't get wet on a rainy day*".

Additional responses included:

- Pre-warning through PlugShare and/or ChargeNet if the charger is unavailable[27]
- Signage advising people to check in on the PlugShare app if they are going to leave their vehicle
- Vector's EV Charger app for iOS frequently freezes. The respondent wrote: "I wish Vector would dump their app and network their fast chargers with PlugShare instead"
- Chargers should be coming up in google maps as an alternative to means of transport, or an alarm that tells you "coming up to a charger-fast charger, etc."
- A single directory of charger locations
- Need to be well signed and easy to find from main routes
- Proper positioning of the charger relative to the EV carparks, with charging cables long enough, to support EVs with charge ports in different locations
- Ease of parking - ability to get alongside the charger, EV car parks wide enough[28]
- longer car space, so the car / van is not part blocking the drive lane, while charging and parked deep as possible in charge bay against the kerb
- The placing of some chargers would be better if their screen faced away from the sun
- Plenty of space to manoeuvre in and out[29]
- Enough parking if we have to wait for charging
- A clear method for 'queuing' if the charger is occupied
- The possibility of being able charge a number of vehicles (up to four) at a time
- There would be less anxiety about charger failure if charging sites had more than one charger.
- Ability to report ICE vehicles blocking EV charging car parks

- Inclusive cabling options (i.e. no adapters needed for alternative BEV models)
- Access to a car vacuum cleaner while charging
- Internet (Cell or Wifi) available) so I can work online while I wait.
- Instructions on how to use the charger

Future needs

Many of the comments by respondents emphasised that the rapid charger network still has large gaps e.g. "*The existence of a fast charger is the most important thing. If there are none all the rest is irrelevant*". Some are still waiting for a charger in their neighbourhood ("*Just having one would be great*"), and some pointed out gaps in the network that still need to be plugged ("*Distance between chargers remains a problem. I own a Gen1 Leaf with an open road range of about 80k in summer and 70k in winter. I cannot travel either north or west of Christchurch for lack of chargers within range*"). Others expressed their gratitude for the systematic way the charging network is being rolled out ("*From what I can see the implementation of the fast chargers so far has been well thought out*").

One respondent suggested a target to have rapid chargers every 50 - 60 km[30], whereas other public comments suggest that the immediate goal is to have one every 75 km on main routes[31]. Some emphasised specific routes that need additional chargers[32]. More general comments included: "*More AC Destination chargers needed for PHEVs*" and "*We need rapid chargers set up along the motorway at service centres, e.g Drury, Bombay would be ideal for long distance travel*". Some suggested that the need for more chargers is greater outside the cities e.g. "*Completing the network of chargers to allow people to get from place to place. We have a 2011 Leaf which is basically the round town car only because our next centres are 80+ km away.*" While important for those BEV owners who regularly travel far from home, nearly all of the charging is done at home[33].

Nearly all respondents indicated that more rapid chargers are needed (Fig. 8). Only 5% of respondents thought that there were sufficient to meet current demand. Unsurprisingly, there was a 96% probability that respondents who had waited more often for immediate access to a rapid charger over the past three months were more likely to consider the number of rapid chargers was insufficient.

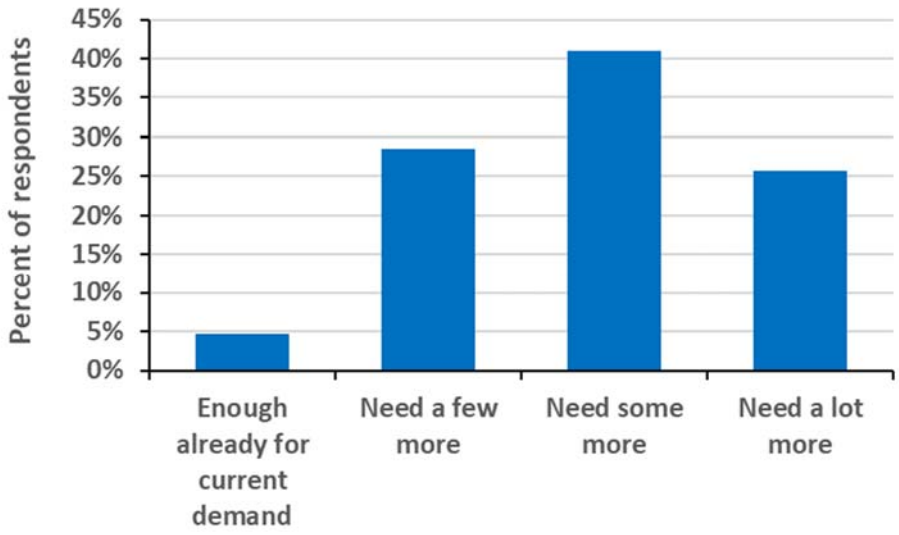

Figure 8. Responses of BEV owners to the question "Are there sufficient rapid chargers in your region?".

Some respondents commented on the value of integrating AC chargers into the network for longer distance travel. eg. "*Make AC chargers (30/32amp) available at the same location as the rapid charger but at lower cost (say 30c/kw or free initially) but perhaps time limited to an hour or two. Orion have time limited some of their AC chargers in Canterbury. That way, if someone is happy to take a 20-45 km charge over an hour or two and go for a walk or shop, it will free-up the higher cost rapid chargers for others*".

Others identified speed of charging as a bottleneck ("*must be able to complete an 80% charge in 20 minutes or less*") and look forward to the super-fast chargers under development overseas ("*Can't wait for 350 kW*"). Hubs with multiple chargers is an obvious way to build the infrastructure i.e. "*Of course, as 40, 60 or even 100 kWh batteries become common, there may be main hubs with multiple chargers and that each one can handle much higher charging rates. I imagine these will be like large highway petrol stations are today. Obviously, the immediate electrical infrastructure in the area would need to handle the MW draw*".

One respondent drew attention to a looming shift in investment from wide spacing to locating the new chargers at particular destinations i.e. "*Possibly distance between chargers vs placement at popular destinations. Right now they are being set up in paths between cities which is smart. But once these electric highways are complete there will be decisions around back roads or "dead end" roads with popular attractions*".

Responses to the choice experiment and survey

Participants were asked to critique the choice experiment and survey method. About equal numbers of comments criticised the methods as affirmed them. One group found the similar nature of the questions generated for the choice experiment to be disconcerting and irritating[34], especially at the start[35]. Therefore some worried that participants would change their preferences as the experiment

unfolded[36], not fully concentrate, or give up[37]. Amongst those who struggled with the format, three suggested use of ordinal scoring or ranking methods[38]. Others enjoyed the experimental method[39] and found that the method was interesting[40], valuable[41], and that it clarified their preferences[42].

Future research suggestions

Suggestions for future surveys and research included:

- Tech specs for charging cable e.g. CHAdeMO, "Type 2"[43], own cable etc
- Ask what and how people charge from home and how essential public chargers are on a daily basis or whether it is just for special trips
- Explore why people use rapid chargers: "*It probably makes a difference when you consider WHY people would use a rapid charger. E.g. have to park on the street so no access to home charger; going on a road trip and need a rapid charge in a convenient spot, drive longer distances every day*".
- "Let's do one on slow/medium chargers in public places as well"
- "Another survey could explore collocation scenarios and ideas for EV rapid chargers at existing petrol service stations"
- "Charging as a service while being a customer (accommodation, shops, restaurants) and charging included in vehicle purchase, insurance or other package offering".
- "How much would you be willing to pay for semi-rapid charging Vs rapid charging?"
- "Maybe do surveys on routes to identify the most important gaps"
- Do a case study of the importance of rapid chargers for uptake i.e. "*is there a region where EVs have taken off because infrastructure is there?*"
- "How long do people typically spend at the charger?"
- "What kind of plugs are used and needed?"
- "What would be an ideal spacing in kilometres between the chargers"
- "Evaluation of coverage along major intercity routes i.e Auckland to New Plymouth, Palmerston North, Wellington and back up the east coast using type2 coverage".
- "Percent chargers type2 enabled in North and South Island"

One respondent highlighted the need to "*keep the questionnaires coming, as the growing demand will make current questionnaires out of date!*".

Discussion

Reliability of this survey

Reliable inference from the choice experiment and survey can only be approximate because of the relatively low sample size (n=108) and potential lack of representativeness of the participants who took part. It is possible that BEV owners experiencing greater frustration with the availability of rapid chargers were more likely to participate than those who were more content. The choice experiment's results are also potentially weakened by the way some participants found it too complex or too tedious an exercise, even though others found it straight forward and that it forced them to crystallize their thinking. A lack of concentration of some of the participants is likely to have blurred the degree of difference between the criteria. If so, preferences may have been stronger than the choice model suggests.

The choice experiment was undertaken in preference to the simpler and quicker ranking survey methods in order to get a quantitative measure of the difference in preferences between the criteria and their different levels. The simple ordinal scale that emerges from ranking would not have detected the relatively large gap between importance of immediate availability and all other considerations, nor show just how close the average preferences were amongst a middle group of criteria (ranking methods force larger and artificial partitions between options when in fact they may be almost equal). The choice experiment also measured gender differences between men and women in a more nuanced way.

Application of the choice experiment results to prioritise charger placements

The utilities are interesting clues about the way BEV users experience the rapid chargers, but they can also be used in formal selection processes when choosing between competing sites for new chargers. Table 2 sets out a largely hypothetical example for choosing between nine potential rapid charger sites around Dunedin. The example is prepared for illustrating use of the tool, not as a definitive or exhaustive exercise - any number of potential sites could be ranked in reality, and more information is needed to estimate immediate availability scores in particular. The tool has the advantage that individual vested interests can be side-lined to some degree in favour of emphasising what the group of BEV owners as a whole prefer. The relative importance of the criteria can then guide the search for a fuller range of sites for consideration. This makes the whole selection process more transparent and objective and makes it more likely that group satisfaction is maximised. Of course, there will be many other commercial considerations about the final choice of sites, including the cost of the land or supplying electricity to the charger, which rightly rest with the partners in the investment. The choice experiment is merely a tool for ensuring that the users' needs are maximised within these commercial constraints.

Table 2. Application of the utility estimates from a choice experiment to rank nine potential sites for new rapid chargers around Dunedin. The utilities estimated by the choice model are in yellow cells. The combined utility and ranks are shown in green cells.

Potential Charger sites	Proximity to main route	Visibility	Immediate availability	Proximity to shops & food	Proximity to public toilet	Proximity to recreational amenity	Rank	Total score
Utility for 'High'	**17**	**16**	**30**	**12**	**15**	**11**		
Utility for 'Medium'	**10**	-	**17**	**7**	**9**	-		
Utility for 'Low'	**0**	**0**	**0**	**0**	**0**	**0**		
Mosgiel shopping centre	Medium	High	High	High	High	Low	1st=	82
South Dunedin shopping area	Medium	High	High	High	High	Low	1st=	82
Cumberland Street, by the University Science Library	High	High	Medium	High	Medium	High	3rd=	81
Toitu Museum / Chinese Garden	High	High	Medium	High	Medium	High	3rd=	80
St Clair	Low	High	High	High	Medium	High	5th	77

Old petrol station, Waitati turnoff	High	Low	High	High	Low	High	6th	69
Filleul St Car Park	Medium	High	Medium	High	High	Low	7th	69
Old pub, Warrington turnoff on SH1	High	Low	High	Low	Low	Low	8th	54
Dunedin Stadium	Medium	Low	High	Low	Low	High	9th	50

Which charger locations are best for users?

The choice experiment and commentaries underscored the importance of getting immediate access to the charging space when the users first drive-up[44]. The average time of additional waiting was only 10 minutes, but this is an added concern on top of having to accommodate the charging time on long trips e.g. One respondent said: "*It's frustrating that more chargers are not going in on the main routes. Charging itself adds 20 mins to the journey, and then you find they are busy. I think a charge should be introduced [some of the chargers are free]. I'm trying to drive 150 km and have to wait for people to charge on their way home from work to save charging at home*". Although some are clearly frustrated when having to wait or that there are generally not enough chargers in their region, some commentators accept that this expected e.g. "*this is pretty understandable at this point in BEV uptake*".

Problems of accessibility to rapid chargers is important for national BEV uptake as well as users who already own a BEV. Widespread concern about range anxiety and the practicality of making long trips is a perception issue that may prevent many people from purchasing a BEV until battery size and the number of chargers increases[45].

The choice experiment revealed that personal security while charging, especially at night, was more important for women (Fig. 2). Men placed relatively more emphasis on proximity to main routes and shops & food. The majority of the respondents to the survey were men so their preponderance would swamp the results if the combined survey sample was pooled. Accordingly, we balanced the relative importance given by men and women in the 'average' preferences in Fig. 4 and in Table 1 by taking the midpoint of the average utilities for each gender. Gender balance seems most appropriate because the national goal is for the entire population to eventually be driving BEVs, and women are increasingly becoming interested in BEVs[46].

How well are BEV owners currently served by rapid chargers?

The near unanimous declaration amongst BEV owners that we need more fast chargers (Fig. 8), and several comments about specific gaps in the network, underscore that current availability is not yet ideal despite recent claims that the network is "almost in place"[47]. Users are already being forced to wait their turn to charge on 14% of visits. Even though the wait is relatively short on average (10 minutes), one respondent had to wait 45 minutes. The unpredictability of getting immediate access adds to the frustration from the additional time required for the journey. Calls for the chargers owned by one of the suppliers to be better maintained to minimise breakdowns underscores the overarching need for supply of energy to be stable and predictably available.

Ten percent of the respondents had not used a rapid charger at all in the preceding three months. The remainder used rapid chargers 5-8 times on average in the last three months, which translates to 20 - 32 times on average per year. If the sample is representative, New Zealand currently has a group of around 10% of BEV owners that hardly ever use a rapid charger, and a majority that visit a charger on average once per month, and a small group (probably less than 5%) that on average use the chargers once a day (Fig. 2). Perhaps these high users regularly travel long distance from their homes

for work or lifestyle reasons, or perhaps they do not retain an ICV as a second family[48] car. Increasingly people may buy BEVs even though they do not have a safe place to charge at home, but generally New Zealand BEV uptake is less constrained by lack of home charging facilities than in places like Japan or where a large portion of the population lives in apartment buildings[49].

Nearly all to the Otago participants in this survey were from Dunedin, so the exceptionally high rate of being blocked by ICVs in the 'Otago' sample is certainly a reflection of the placement of their single rapid charger in a busy central public car park. ICVs regularly ignore the signs to leave the park for BEVs and no enforcement is legally possible. Most BEV owners are acutely aware of the competition for the charging spot and so are likely return to the vehicle within half an hour, but ICV owners have been known to block the space for hours on end. Comments from the NZ EV Owners and Dunedin EV Owners Facebook group indicate intense irritation of BEV owners when "being ICEd" is the reason for not getting immediate access[50]. It also sometimes results in conflict between ICV and BEV owners[51]. Solutions could include improved design and layout of the charging location such as not placing the charging unit on the edge of the parking area limiting the parking spaces to two, rather placing the unit so that four parking spots surround it. Avoid placing charging units in coveted locations such as near entrances to supermarkets which will increase conflict with ICV owners and cause resentment and complaints of preferential treatment. Better signage, local bylaws to enforce restriction of the parking spaces for use by BEVs only, and a national education campaign to alert ICV owners of the need to not park in the BEV spaces might all help reduce the charger congestion problem.

Occasional problems are being reported where other BEV owners remaining in the charging spot long after charging was complete. Also sometimes the longer stay of a large BEV like a Tesla causes frustration amongst those with smaller batteries that are charged within 20-30 minutes.

One respondent also pointed out that another indirect benefit of high charger visibility is that there is an "*added advantage of reassuring potential new EV owners that they are available even though in reality most people charge at home*".

Free public charging: is it incentivising or hindering BEV uptake?

The availability of free rapid chargers is a temporary benefit to individual BEV owners, but it may be slowing investment in rapid chargers by commercial interests, and it certainly may have affected the results reported from this survey. If users pay a fee to use a charger the cost is around two-thirds to three quarters of what an owner would need to pay for petrol in an ICV to cover the same distance. Therefore the insertion of free chargers at the beginning of the BEV uptake trajectory could be a powerful incentive. On the other hand, it has increased charger congestion at the few available free charger sites e.g. one participant said "*All Vector stations are free but pay stations are a lot dearer than charging at home*" Another said: "*Dunedin has one slow hard to access rapid charger and over 250 EVs. It's all because it's free and no one else will put a paid one in. The sooner it is not free the better. Dunedin needs at least three urgently*". Another suggested a research topic on the theme: "*It would be interesting to know how far people are prepared to drive for a free charger when there are pay chargers closer*".

Further study is needed to determine whether provision of free rapid chargers increases the overall rate of BEV uptake in the neighbourhood by increasing local ownership, or if it slows overall uptake by undermining investment in more rapid chargers overall. If the latter is shown to be occurring,

perhaps those generous spirited electricity suppliers who currently provide a free service could be persuaded to charge even a modest fee to discourage recharging for local everyday use? If the price to charge was the cost price the BEV user would still make considerable savings compared to petrol. However, including one fee for the time spent at the station as well as a fee for the electricity uploaded, as currently done by ChargeNet, has an added benefit of incentivising the shortest possible stay on the charging site and thereby reducing congestion and waiting time. Experience at the Dunedin site is that some BEV owners use the free charging service at the outset of ownership but soon start charging almost exclusively at home, so provision of the free service is probably not important for perception of the cost-effectiveness of BEV in the longer run.

Prospects for the future

At the moment BEV owners are grateful to take what they can get - so additional attributes like provision of shelter and public toilets being nearby are secondary. However, as chargers proliferate and competition for customers intensifies, these secondary factors are likely to become more important. The choice experiment and participants' comments can help guide subsequent investments to improve the quality of the rapid charger service. For example, provision of public toilets nearby might follow the installation of the charger, and this additional investment might usefully be provided by local government as part of municipal services. Many respondents especially lamented the lack of cover and protection from inclement weather at some sites. Coupling BEV charging facilities with existing petrol station amenities is an obvious business opportunity, although stations will need to provide safe lounging space for customers while they wait for their car to charge.

Increasing congestion at rapid charger sites presents a growing risk for BEV uptake because of the perception amongst ICV owners and businesses that they would be delayed on long trips if they switch to a BEV. A background contributor to charger congestion is the escalating number of BEVs in New Zealand and the relatively low number of rapid chargers. Limiting the speed of charging of 40 kWh Leafs (when the battery gets overheated) is already causing frustrating delays at chargers in the UK, and this could emerge as an exacerbator of charger congestion in future in New Zealand. BEV owners are already beginning to notice an increased congestion at some chargers over the past year when the overall number of BEVs has more than doubled e.g. "*The Vector free charging network in Auckland is frankly excellent. But whereas one year ago it was easy to find a spot, their charging stations are much more frequently occupied*". It is therefore unsurprising that nearly all BEV owners think we already need more rapid chargers (Fig. 8), and national and local government policy interventions to accelerate their installation is an urgent priority.

However, some changes may alleviate congestion as the public charging network matures[52]. For example, a BEV driver will increasingly be able to drive a short distance to find an unoccupied charger if the first one is occupied. Rapidly increasing range of the BEVs will help as drivers can simply run their battery low so as not to be forced to wait for a specific charger to be vacated. New technology to increase the speed of charging itself may dramatically reduce the congestion issues identified in this study.

The importance of the secondary attributes of rapid charger sites may increase as more long-distance travel occurs in future. e.g. "*The questions* [asked explored in this experiment and survey] *are perhaps more relevant in the context of travelling some distance from home and seeking a rapid recharge before proceeding. At the moment, this does not apply to us (partly because lack of rapid charge*

infrastructure en route from Auckland to places we visit), so in our urban environment, proximity to toilet or shops is rarely an issue. The overriding priority for us now is how quickly we can access the rapid charger and get away."

Future research priorities

Developing a method to predict competition for the available charger space would be a particularly useful tool to help set priorities for siting new charging stations because it targets the key attribute of rapid charging services identified in this study - immediate access to the charging port. Likelihood of having to wait is probably related to:

- spacing of the chargers scaled against traffic passing down that route
- local population density (some unknown proportion of the use will be by local residents rather than long distance travellers)
- whether the users have to pay for charging or not
- availability of other free rapid chargers in the locality[53]
- availability of more than one charger at the site

The value of tighter integration of medium speed and rapid chargers was highlighted by participants in this study. Medium speed (24kW) chargers are much less expensive than rapid (50kW) chargers, so there is scope to combine a service of more, but slower chargers, alongside the rapid ones. The difference in service between the two types may not be as great as seemingly apparent from their peak rating, because there is a rapid decay in energy delivery rate after first plugging in to a 50 kW charger[54]. We expect the delivery curve to be flatter in the 24 kW unit, so time for the total charge will be less than double that provided by a 50 kW rapid charger. More recently released BEVs are also be able to charge nearly twice as fast by using connectors (most Nissan Leafs are limited to a 3.3kWh systems). Some types of destinations like airports and workplaces are ideally suited to these mid-speed charging infrastructure because users are normally parked there for longer periods and the need for speed is reduced. A valet or charge management system for rotating medium speed charging around assembled vehicles could optimise utility of such clusters of outlets. Combinations of AC chargers alongside DC outlets also has the advantage that overall power drain of the site can be evened out to lessen the impact on the local electricity grid demand.

Case studies of efficiency gained at sites with multiple chargers, and the development of software to optimise current drawn by the individual chargers operating at the site, would be extremely valuable to minimise impacts on the local and national electricity supply grid.

This was a preliminary and small survey. It provides a pilot trial of a method and preliminary benchmark for guiding future investments. We recommend that something like the survey used here is repeated at six monthly intervals. However completion rates of the surveys was reduced by the rather complicated choice experiment that we also tried - clearly some respondents were put off by the method. We recommend that further choice experiments, if done at all, be completed in a 'focus group' context where a facilitator guides the process in successive groups of BEV owners, and that the wider and simpler surveys of experiences at rapid chargers occurs as a more frequent and quite separate exercise. Consideration should be given to include new questions in the monthly data queries by *Flip the Fleet* that monitor the number of times a participant had to wait for access to a charger and for how long.

Conclusions and recommendations

This research emphasised the importance for BEV travellers to get immediate and predictable access to electricity when they arrive at rapid charging sites. Proximity to the main routes and high visibility of the site to promote personal safety and reduce risk of vandalism to cars and equipment were the next most important. Proximity to shops and food, and public toilets were less important, and the ability to walk to recreational amenities like parks, beaches and playing fields while the car was being charged was the lowest priority. Provision of better shelter from inclement weather and sun was the most frequent additional request from the participants in this study. Women place relatively more emphasis on high visibility, and men more on proximity to main routes and shops and food. We recommend that the needs of men and women are prioritised equally when selecting sites.

The choice experiment tried here should be shortened or simplified, or a simpler ranking exercise could be substituted. Whatever method is used, a systematic way of trading-off multiple criteria should be deployed for selecting specific charger sites to maximise the utility of the charging network for everyone in the longer run. Maximising the comfort and quality of the charging experience will help minimise a perception amongst prospective BEV purchasers that long distance travel is a serious inconvenience for families and businesses.

Commitment to regular maintenance of the charging equipment and providing immediate help when breakdown occurs is essential and so far, variable between providers.

Extending or standardising the plug connectors would allow all BEV models to better share the same network. Accelerating uptake of BEVs in New Zealand requires a supply of a wider range of BEV models to meet variation in the needs of diverse businesses and families. Ensuring that they can all be accommodated on most of the chargers could help immensely.

This study underscored that the rapidly increase in charging infrastructure is a great relief and valued service for existing BEV owners. It pointed to the need to fill remaining gaps in the wider regional network. The New Zealand Government's investment in partnership with business through the Low Emission Vehicles Contestable Fund has been a crucial help in extending the wider charger network. The focus on spreading the charger network was the logical first step and still needs completion, but our research also suggests a need to start infilling around the infrastructure to relieve looming threat of increased charger congestion at existing sites. This will require innovative ways of encouraging investment in regions that already have thinly spread rapid chargers.

Multilateral efforts are now needed to reduce congestion. A stronger role for partnership investment by local and municipal authorities could future proof continued growth of electric transport for tourism and regional business and promote community and environmental health. This could be facilitated by Local Councils investing in chargers themselves or co-investing with businesses to capture efficiency and reduce costs. They might also facilitate the private investment in chargers by expediting planning and regulatory requirements. Provision of multiple chargers at each site, and provision of a mix of medium and rapid chargers to meet different users' needs, would increase the probability that a charger is available when a user arrives. Effective regulation to ensure that charging parks are limited to use by charging BEVs only. But in most places (Dunedin is an exception), this is more upsetting to many BEV owners than a large charger congestion causing problem. BEV owners

themselves could help the situation by using PlugShare to signal their use of the charger and minimising the time they stay in the charging spot. Provision of multiple chargers, perhaps including options to use medium speed chargers, could be a cost-effective method of reducing congestion.

There is no formal research to test the importance of improved rapid charging infrastructure for accelerating EV uptake, but our survey shows that existing BEV owners are nearly unanimous that more are needed (Fig. 8). There is ample evidence that many prospective buyers are put off by range anxiety, even though BEV owners themselves quickly learn the limits of their vehicle and successfully integrate their vehicle's use into daily routines[55]. The vast majority of charging happens at home where it is convenient and reliable[56], and does not incur any of the occasional frustrations reported at public charging stations that were reported in this survey. However, perception is as important as practical reality for building confidence in new technology like BEVs. Continued rapid growth of New Zealand's BEV fleet will still require urgent, innovative and collaborative investment in its rapid charging infrastructure for years to come.

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Appendix 1: Glossary and abbreviations used in this report

Abbreviation	Description
BEV	Battery Electric Vehicles are cars that move using a large electric battery powering an electric motor or motors
FtF	The *Flip The Fleet* project
ICE	Internal combustion engine
ICV	A vehicle powered solely by an internal combustion engine
PHEV	Plug-in hybrid electric vehicle. An electric motor and an ICE directly propel the vehicle. These models are sometimes also referred to as a "Parallel PHEV".

Endnotes

[1] A list of abbreviations used in this report is in Appendix 1.
[2] Larger models like Tesla require an hour.
[3] http://flipthefleet.org/2017/getting-stranded-by-running-my-battery-flat-is-a-real-worry-for-me-1-click-survey-9/
[4] Respondents to Flip the Fleet's 1-click surveys have repeatedly highlighted the challenge of building infrastructure before there are sufficient BEV users to pay for them, yet people are reluctant to buy BEVs until the infrastructure is in place. Some put it this way: "Buy and they will build – build and we will buy": http://flipthefleet.org/2017/when-should-people-buy-first-ev/
[5] https://www.stuff.co.nz/motoring/102777328/nzs-electric-vehicle-infrastructure-is-almost-in-place--now-all-we-need-is-the-cars
[6] Many electricity distributers have installed rapid chargers in their district, and in the meantime many of them offer free charging as a way of encouraging BEV uptake and minimising business administration costs from collecting fees.
[7] https://www.eeca.govt.nz/funding-and-support/low-emission-vehicles-contestable-fund/
[8] Ivanov & Moller (2017).
[9] The study was originally designed for Otago BEV owners, but the initial results were so striking that we decided to extend the choice experiment and associated survey to BEV owners from throughout New Zealand. in order to put Otago's experience into a wider context.
[10] https://www.1000minds.com/
[11] Note that Criterion #2 and #6 only have two levels. This was to speed the selection.
[12]Four members of Flip the Fleet trialled and critiqued earlier versions of the choice model and linked survey.
[13] https://www.wufoo.com/
[14] https://www.facebook.com/groups/403816650002889/
[15] https://www.facebook.com/groups/NZEVOwners/
[16] Gelman et. al. (2013)
[17] For number of fast changes and wait time
[18] For proportion of faulty charger, charger ICEd, and times that have had to wait to use the charger
[19] Bürkner (2017)
[20] R Core Team (2016)
[21] A further 9 partly completed experiments and 2 incomplete surveys were eliminated from the analysis.
[22] Two women and three men did not record their age and so are not included in the figure.
[23] Data from Otago excluded.
[24] The percent for charger occupied category combines instances where the space was taken by another BEV and an ICE vehicle.
[25] Similarly, respondents commented: "*a lot of the choice depends on who you are with, time of day, previous charges or range etc. A lot of the time you don't get to choose. Especially out of Auckland*"; "*There are variables which would dramatically change my answers - mainly why and where am I charging? If I am on holiday, and needing to get to a destination then being able to charge right away is the most important. While having toilets and shops nearby is desirable, I can drive to those things when I'm finished charging. However having something to do in the area of charging, especially when trying to get to a max charge is preferable, whereas when just needing a top up near home, I won't be as long and don't really care what's nearby*".
[26] One instance of a driver becoming concerned by a man's approach to her BEV charging at night was recorded in the Dunedin Facebook pages early in 2017. The concern is underestimated by some men e.g. "*I was surprised at the emphasis on security since I have never encountered this problem. However I am an old male and never go out at night when females may be worried*".
[27] There were two other similar comments
[28] There were two other similar comments
[29] There was another similar comment

[30] *"Filling in the gaps" to have them at about 50-60 km apart, especially on SH2, would facilitate more EV use as a longer range vehicle*"

[31] https://www.stuff.co.nz/motoring/102777328/nzs-electric-vehicle-infrastructure-is-almost-in-place--now-all-we-need-is-the-cars

[32] *The route between Auckland / Hamilton / Tauranga is a significant charging hole in the network. The provision of one charger (Matamata) will close the gap and allow travel further south. A second charger (Tokoroa) would open up the whole North Island. The rest of the country is far better served with lower numbers of potential customers*". Other comments about gaps were: "*We need more between Christchurch and Blenheim, between Christchurch and Nelson, and between Christchurch & Greymouth*"; "*Need some rapid chargers through SH2, Waihi and Pairoa*"; "*Looking forward to the one in Bulls opening so we can safety drive to Rotorua*"; "*The route from Tauranga to Auckland has huge holes in it*"; "*I would like to drive from Whakatane to Christchurch, I don't think I've got the range to Wellington, certainly the top of the SI is totally out*"; "*Experience tells us we need more rapids along major highways for frequently travelled routes e.g. Gen 1 users travelling to Christchurch from Dunedin currently need Waikouaiti or Palmerston to comfortably do the journey north*"; "*no or little infrastructure around Whanganui or Taranaki*"

[33] e.g. "*I do practically all my home-region charging at home, and the fast chargers I care most about are the waypoints along the state highway network*".

[34] "*Questions were a little annoying*"; "*boring*"; "*I understand what you are trying to do, but the questions are a bit tedious*"'; "*Slightly long. Had to wait until holiday time to fit it in. Good instructions and layout. For those not familiar with choice quiz a note to explain why it will seem repetitive may help?*"; "*Easy, boring but probably a good idea*"

[35] "*First part was a bit confusing*".

[36] The method assumes that the preferences scored early in the experiment remain the same until the end. However, one respondent wrote "*My mind changed to my children during the question, so toilets became more important*".

[37] "*Very thorough but lazy people will probably give up half way through*"; "*I'll view the results with a grain of salt - I suspect most people, me included, stopped thinking about the questions after a while and just started clicking*"; Nine discontinued part way through and their data has been eliminated from the analysis.

[38] "*Maybe use a slider with weighted voting rather than scenarios. Just ask me what is most important and 1-5 votes with 5 for most important and 1 for the least*"; Another suggested "*Perhaps additionally having the option to rank the things in order, i.e. 10 points to spend, 1 point for a toilet 5+ mins away, 2 points for 2-4, 3 points for 1 min away, etc.*"; "*Felt like you were trying to do a 3 factor factorial when you should have just asked people to rank proximity, shopping and toilets*"; "*I felt the choice experiment was over-complicated. I think a slider for each topic (security, availability, proximity etc.) would have been better, where we could rate the importance of each topic with a 1 to 10 score*".

[39] "*good*"; "*very thorough*"; "*cool*"; "interesting"; "*choice experiment was clear and easy to complete*"; "*All good!*"; "*All clear*".

[40] "*Good survey with reasonable choice experiment scenarios, easy enough to answer. Looking forward to seeing the results of the survey*"; "*All the subjects in the questionnaire are important considerations*".

[41] "*I think that it's a really good question that you've asked*"; "*Clear, relevant questions*".

[42] "*Easy to complete"; "Questions seemed very repetitive but did make my preferences clearer to me as I went through them*"; "*All good and interesting approach*"; "*Seems a useful way of sorting out people's priorities for charger attributes. Easy to do*".

[43] 'Type 2' connectors are mainly used by European BEV models (BMWi3, VW eGolf, Renault Zoe) and Hyundai Ioniq, Tesla and Renault Kangoo). See Magnussen (2018) for a detailed explanation of plug and cable types.

[44] e.g. "*Longer term I see waiting time as very important. Filling will take 30 min if you can connect immediately, but 60 to 90 minutes if you have to wait your turn or miss your turn if someone queue jumps. Recharging takes far too long compared to a few minutes for petrol*".

[45] Moller, Ivanov & Dew (2017a).
[46] Hayter et al. (2018).
[47] https://www.stuff.co.nz/motoring/102777328/nzs-electric-vehicle-infrastructure-is-almost-in-place--now-all-we-need-is-the-cars
[48] Moller et al. (201b) estimated that 79% of New Zealand families who own a BEV also retain at least one ICV for specialist uses like towing or long trips.
[49] Stephenson et al. (2016a,b).
[50] "Put up a huge sign saying "Electric Vehicle Charging only. ALL OTHER VEHICLES WILL BE TOWED AT THE OWNERS EXPENSE 24/7"; "Leave a note - If you do that again we'll let the air out of your tyres".
[51] "I think we're at crisis point at the fast charger folks. Today I was called an effing whore by an SUV driver who simply failed to agree that parking in the EV Park was remotely a problem. The conversation descended into abuse so quickly it was scary. I've had enough, quite frankly. His mother started banging on my window too but by that point I'd got into my car and locked the door. Very angry young man".
[52] "Distance apart will not be as important in future. There are petrol stations every 50 km of so - even though we are told petrol is so energy dense that you can travel 100s of miles, much more than an EV can go on a full battery. Hopefully charging for EVs will evolve to achieve the same coverage" I've found an unoccupied charger twice, and pressed ahead past an occupied charger once.
[53] Some users are likely to just top up a minimum amount at chargers where they must pay in order to reach the next free charger further down the chain.
[54] Software in the vehicle throttles the rate of charge to minimise battery temperature rises.
[55] https://flipthefleet.org/2017/getting-stranded-by-running-my-battery-flat-is-a-real-worry-for-me-1-click-survey-9/
[56] https://flipthefleet.org/2017/convenience-home-charging-compared-filling-petrol-1-click-survey-10/
[57] http://scienceintoaction.nz/