Australasian Transport Research Forum 2017 Proceedings
27 – 29 November 2017, Auckland, New Zealand
Publication website: http://www.atrf.info

The role of real-time crowdsourced information and technology in supporting traveller information

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Abstract

This paper presents the findings of research commissioned by NZ Transport Agency investigating the role of crowdsourcing in New Zealand as a source of real-time traveller information to support transport network efficiency outcomes. The purpose of the research is to identify the strategic, legal and policy considerations necessary to enable road controlling authorities and government agencies to lead or support crowdsourced data initiatives.

The research included a literature review and stakeholder consultation to review relevant crowdsourcing applications and to explore matters including privacy, safety, data collection, storage and retrieval, the use of incentives, data quality assurance and organisational barriers to new technologies. The research also included undertaking a pilot trial of a web application for reporting winter road conditions in the Queenstown-Lakes District.

The outputs of the research include practical recommendations regarding potential applications of crowdsourcing in the transport sector and the role of the NZ Transport Agency and other road controlling authorities in supporting a crowdsourcing data ecosystem. The research also identifies technical requirements for appropriate use of crowdsourced data in traveller information systems.

Keywords: **Crowdsourcing, traveller information, real time**

1. Introduction

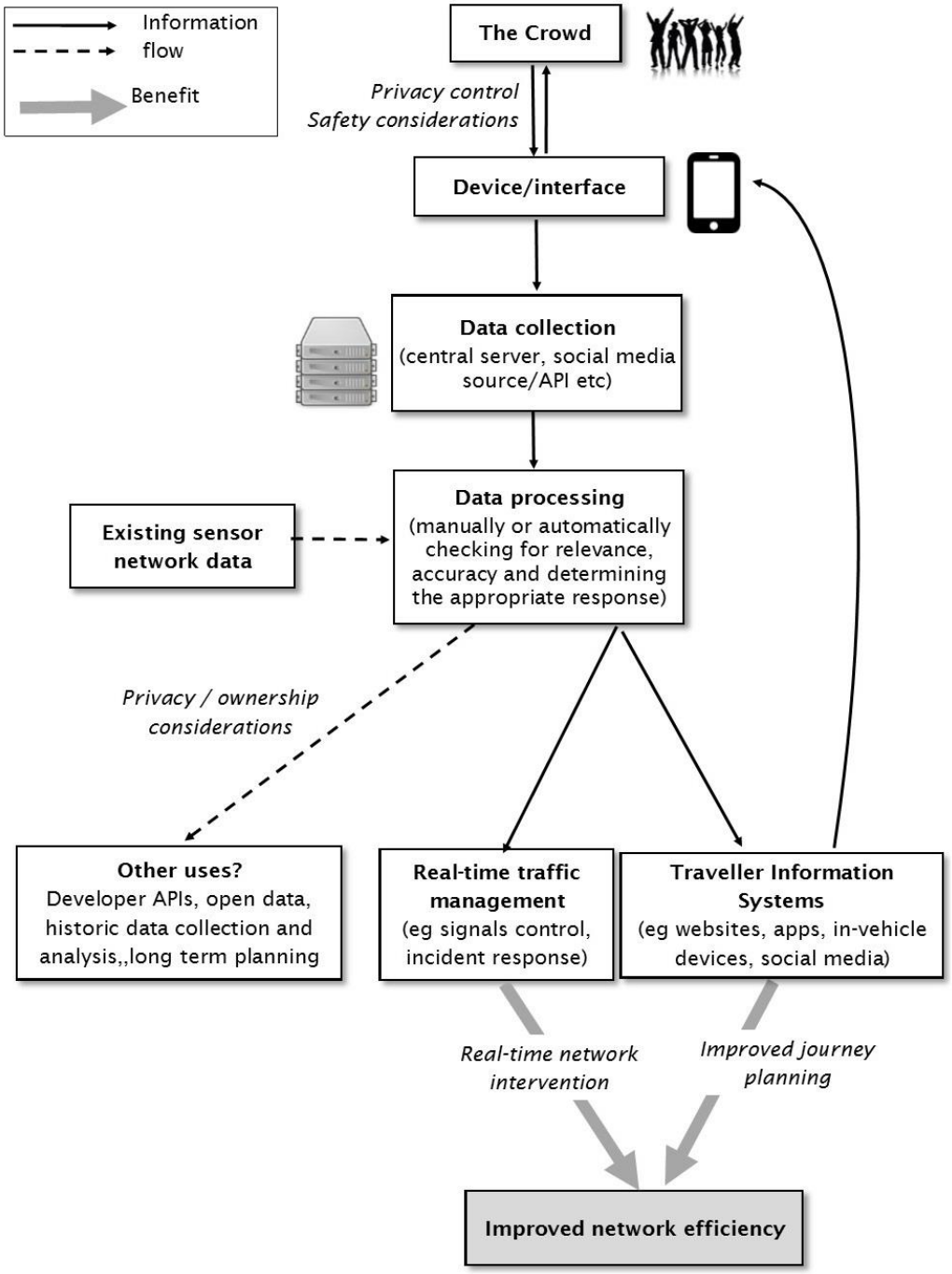
Crowdsourcing is the practice of engaging the services of a large and undefined group of people to provide information or input into a particular task or activity that would otherwise be too difficult or impossible to solve using traditional outsourcing or data collection methods (Howe, 2009). In transport applications, crowdsourcing has the potential to meet information needs across all modes, including public transport (PT), walking, cycling and private motor vehicles. This data can be used for a range of purposes, including the provision of traveller information, and supporting transport network operations, road safety and asset management. Figure 1 demonstrates the relationship between crowdsourced data, technologies and transport applications.

In transport applications, crowdsourcing for data collection relies on the use of mobile devices (eg smartphones) acting as sensors to 'fill a gap' where traditional traffic monitoring sensors do not exist, or cannot report in real time. For some applications, crowdsourcing is a relatively low-cost method for collecting transport data, using human inputs rather than, or alongside, specialised sensory equipment (Ali et al 2012; Misra et al 2014; Marshall 2014). In addition to filling a gap, crowdsourced data can sit alongside traditional transport data sources to help with verification or to provide additional context. Crowdsourcing also brings together a large group of people on the same platform to address common issues that affect its members –

particularly for stakeholders who have a small, but engaged user base (for example cyclists and public transit users) (ibid).

While the collection of real-time data is an obvious application of crowdsourcing, the crowd can also assist in the development of transportation software applications and in the planning and design of transport systems (Sorenson 2010).

Figure 1: A crowdsourcing framework for traveller information and network efficiency



The focus for this research was on the use of crowdsourcing for collecting real-time data for traveller information purposes, using mobile devices to 'fill a gap' where traditional traffic monitoring sensors do not already exist, or cannot report in real-time.

This paper provides a brief overview of the research methodology and outcomes. The research undertaken by Abley Transportation Consultants Limited and was published in 2016 by the NZ Transport Agency, the Crown entity responsible for delivering transport

solutions on behalf of the New Zealand government. Readers interested in the full published report can access this from the NZ Transport Agency website[1].

The objectives of the research project were to:

- Determine the extent to which New Zealand's legal and government policy framework supports crowdsourced data as a means of collecting data for use by government.
- Determine the value of real-time or near real-time crowdsourced data within a transport context, and to what extent can crowdsourced data can contribute to better service delivery and outcomes for the travelling public and NZ Transport Agency.
- Explore the role of the NZ Transport Agency in creating the technical framework and strategy required to support the practical implementation of a crowdsourced ecosystem.

The research underpinning this paper involved eight stages of work, starting from an initial literature and crowdsourcing application review, and finishing with the testing of a crowdsourced application in the Queenstown–Lakes District in the South Island of New Zealand.

2. Literature review

An international literature review was undertaken to explore the role of crowdsourcing in traveller information and intelligent transportation systems (ITS). The review looked at privacy issues, the ownership and licensing of crowdsourced data, safety, data quality and validation, and practical implementation factors which are discussed further in this paper.

A range of crowdsourcing applications and projects across private vehicle, public transport and active modes were also reviewed and are presented in the full research report (Harris et al 2016) to demonstrate these matters in practice. Although it is acknowledged that there are an ever-expanding number of applications and projects, a total of fifteen crowdsourcing applications which met a broad range of transport-related information needs were included in the review. The report also includes discussion on the strategic transport direction of New Zealand government agencies and the traveller information needs of the New Zealand public in relation to real-time crowdsourcing applications.

The literature and technology review identified a clear distinction between passive and active crowdsourced data collection. The passive approach relies on in-built technologies on mobile devices to continuously collect and transmit data about a user's location, speed and direction. Other data from device sensors, including accelerometers, may also be collected. This approach usually requires the user to permit this collection of data by a third party by 'opting-in'. In return, the user may receive localised information or services that helps them to understand the transport network, for example through improved routing, access to mapping applications or improved access to public transport services. The active approach requires users to actively input information, for example about events occurring on a transport network or the quality of the transport service. This could include selecting from a pre-defined list of incidents or quality statements, or providing a qualitative commentary.

2.1 Traveller information systems (TIS)

TIS are the mechanism by which information about the road network and transport systems is distributed to travellers. Successful TIS deliver network efficiency benefits by providing information to road users that enables them to be informed about the modes of transport available, travel time and route choice (Raine et al 2014). Systems for delivering traveller information include traditional sources such as phone services, websites, radio and VMS,

[1] http://www.nzta.govt.nz/resources/research/reports/593/

social media and mobile applications, vehicle information communication systems, vehicle-to-vehicle communication and travel time signage (ibid).

The customer requirements of TIS in New Zealand were explored by Chang et al (2013) and Chang et al (2015). This included identifying the type of information that users would like to receive from crowdsourced origins, including information on public transport, travel times, network events, road conditions, parking availability and information that assists with routing.

2.2 Licensing, ownership and privacy considerations

Crowdsourcing applications can be developed and administered through public agencies, or developed by a third party using government open data sources or private data collections, including crowdsourced data. Third-party applications can be country specific, or have a global application. The choice of application and the types of data that underpin this application can therefore have different standards for licensing, ownership and privacy.

In New Zealand, information collected from individuals by public and private agencies is subject to the provisions of the Privacy Act 1993. In this Act, 'personal information' is 'information about an identifiable individual' and the privacy of this information is governed by 12 privacy principles. There are two laws that govern access to official information in New Zealand, the Official Information Act 1982 (OIA), which governs all official information held by the government, and the Local Government Official Information and Meetings Act 1987 (LGOIMA), which applies to local government bodies.

If a government agency or local authority holds information about an individual, that individual has rights under the Privacy Act 1993 to access and correct this information. Requests for official information about an individual who is not the person requesting that information may be refused on the grounds that it breaches that person's privacy.

Copyright is the property right that exists in some original works, as regulated by the Copyright Act 1994. Under this law, copyright automatically applies to original works, including written works (eg letters and emails) and artistic works (eg photographs, diagrams and maps). When public users add their own copyright content to a social media or other web forum, they retain ownership of the copyright unless expressly agreed otherwise. This content can be reused by the site or application owner only if the owner, either expressly or by implication, confers a licence to use that content, for example through the Terms of Use (DIA 2011). For example, the terms of use for the 'Building our Footprints' project in Christchurch, New Zealand acknowledges the copyright of the individual who submits information, and the user agrees to license this work to the public domain under the Creative Commons Licence.

In general, crowdsourced data should be made public and reusable through a Creative Commons Licence, in terms with the principles of open data. An agency considering crowdsourcing should establish policy about how the data was to be held following collection, and how it was to be re-released without impacting on the privacy of individual contributors.

2.3 Safety considerations

Crowdsourcing applications and TIS provided through a mobile interface can be a source of distraction for motorists. Between 2011 and 2013, 163 drivers in fatal or injury crashes contributed to the crash by being distracted by a cell phone (Ministry of Transport 2014a). Despite the risks attributed to diverted attention, public understanding of distraction is low (Ministry of Transport 2010). A comprehensive literature review on distracted driving and in-vehicle devices was recently prepared by Rickard-Simms (2014) as an internal report for the Ministry of Transport.

The type of distraction involved in active crowdsourced information collection will vary according to the device and application used. Rickard-Simms (2014) provides a number of relevant conclusions from the literature that will need to be considered in more detail when developing a crowdsourcing application:

- The driver is more at risk if the distraction involves more than two seconds of glance time, or if the driver glances at the device repeatedly over a short-period (Zhang et al 2013).
- Audio output from navigation and music systems does not negatively affect crash rates (Ünal et al 2013).
- Voice recognition inputs are less risky than physical input methods, but can be less accurate (Tsimhoni et al 2004). Cognitive distraction through common voice tasks is generally more demanding than natural conversations, listening to the radio, or listening to a book on tape (Cooper et al 2014).
- The screens of mobile devices can be small, and therefore require longer periods of glance time (Ishiko et al 2013).

There are many suggestions in the literature for making in-vehicle devices safer for drivers to use, including forcing drivers to have these devices mounted, restricting touch screen input while the vehicle is moving, and using audio/voice functionality rather than the visual display (Jamson 2012).

2.4 Data quality and validation

Unstructured (and potentially malicious) submitted content requires administration and checking for data quality. The type of evaluation employed depends on the type of data collected and the standard of quality required for the output information. Depending on the application and type of information, user contributions can be checked using either manual screening or moderation of user inputs, and/or automated screening using predefined criteria or algorithms. In some applications, the users themselves verify other users' content through reporting or verification processes.

Most studies on this topic focus on quality assessments for crowdsourced information, or addressing the question of how an organisation can trust these data for incorporation into their own datasets, or release to the public alongside their own data (Johnson and Seiber 2012, Severinsen 2015). When considering the integration of crowdsourced data, government agencies must therefore make a policy decision, addressing the risk of relying on certain pieces of data, while also enabling the realisation of its value.

Severinsen (2015) proposed a trust model to address this balance, which was deployed during the Building Our Footprints case study. The trust model used a number of case specific parameters to algorithmically generate a trust 'rating', and an arbitrary threshold was set for re-release to other members of the public. Data which met this threshold was automatically considered reliable, while the agency's quality assurance resource could then be more efficiently deployed to assess data which fell below this threshold. A different quality threshold could be set or each agency or data type, depending on the need of its end consumer.

In the case of real-time traveller information, a logical distinction could be made between events or reports classed as severe, such as a crash, or those classed as more common or benign, such as wet weather. It is logical that a road controlling agency could consider the latter example using algorithmic trust models, whereas the former situation should receive human intervention to verify its accuracy. The controlling agency must therefore make a considered policy decision about where to impose such a threshold.

In developing a crowdsourced application, a critical decision must be made about where to set a threshold for trust in data. This question could be phrased as, 'which types of report data can we trust through automation, and which require human verification?' Once this question has been answered, there are a number of ways to algorithmically determine trust in these data which are documented in the full research report.

2.5 Practical implementation factors

Successful crowdsourcing involves more than releasing an application or project and expecting an engaged crowd to adopt and use it in sufficient numbers to generate useful outputs.

Effective crowdsourcing requires developing a product that provides an incentive for users to be involved in and collects information in a format and of a quality that is useful to the agency. Doan et al (2011) identify four major areas that crowdsourcing systems need to address to be successful: a) recruiting and retaining the participant base; b) assessing user capabilities; c) aggregating the information provided by users; and d) evaluating the contribution of users.

There must be a compelling reason for people to want to participate. Methods to recruit and support ongoing involvement include:

- Marketing promotions to make people aware of the application or project, including the benefits of being involved and the effort required. Recurring campaigns and marketing strategies will also ensure that people remain curious and involved (Misra et al 2014).
- Incentives are a key driver for attracting ongoing participation and may include financial rewards as well as less tangible incentives such as instant gratification, user rating systems and competition.
- Building a social community around the application and engaging with social media works for many applications.
- The application or project should be fun and entertaining to engage with and designed with ease-of-use in mind.

In developing or considering crowdsourcing options, it is important to consider the types of users and their abilities, including how demanding the activity and how users can contribute (Doan et al 2011). The information collection activity (or activities) should match the abilities of the users. One method of supporting different users is to provide multiple levels of involvement, with users either choosing their level of involvement, or a ranking or point system that unlocks opportunities for higher levels of activity.

Aggregating data from crowdsourcing participants can be a complicated task given the volume of responses received from a diverse pool of crowd participants (Misra et al 2014). Integrating these inputs with other external data sources such as sensor networks present an additional challenge. Aggregating data can be labour intensive or cost intensive as complex data management systems and processes are developed to reduce sources of human error (ibid)

Consideration should be given towards how crowdsourced information is referenced against existing transport datasets, for example traffic count sensor, CCTV inputs and GNSS/Bluetooth sensor networks. Issues with the integration of GNSS and Bluetooth data sources, which are provided with varying levels of detail and granularity, with road centreline dataset(s) were highlighted in Smith et al (2014).

Issues with integrating information sources, including crowdsourced information, for the purposes of customer information delivery were explored by Chang et al (2015). A number of tasks were identified to improve information provision, including the establishment of a transport industry working group to share learnings about information projects, the normalisation of data sources (including crowdsourced information) and agreement on data exchange standards.

Sorenson (2010) explores the types of challenges organisations, particularly transport agencies, may face when implementing crowdsourcing applications or technologies, particularly:

- the ability of the organisation to embrace and implement new technologies

- the extent to which internal guidelines, procedures and organisational culture may preclude crowdsourcing
- risk management processes
- accepting that there is no guarantee that a suitable and capable crowd will participate in the project/application.

Another challenge for organisations involved in crowdsourcing is a workforce that has both the skills and capacity to implement and administer new data collection applications and technologies. This is recognised by the Ministry of Transport's ITS Action Plan (2014b) as a challenge for the wider ITS industry.

3 Stakeholder interviews

The second stage of research focused on interviews with key stakeholders throughout New Zealand. This included interviews with representatives from NZ Transport Agency, Ministry of Transport, public transport (PT) operations, Auckland Transport, Traffic Operations Centres (TOCs), transport user groups and technology firms. The purpose of the interviews was to understand each organisation's transport information needs, and consider whether crowdsourced information could meet these needs. The interviews also explored the data quality needs of each stakeholder, and explored stakeholder concerns regarding privacy, safety, practicality and institutional barriers to crowdsourcing.

Evaluation of crowdsourcing approaches

Using the information obtained in the previous stages, a list of potential transport information needs that could be met through crowdsourcing was identified and prioritised (table 1). Note that information needs where existing sensor networks provide adequate coverage, for example traffic counts, are not included in this list.

Table 1: Transportation data that potentially be sourced through crowdsourcing

Priority	Real-time information needs	Other information needs
High	• PT service occupancy • Congestion monitoring • PT travel times and variability • Private vehicle travel times and variability • Monitoring planned events (such as major festivals) for all modes of transport • Incident reporting for all modes	• Origin-destination/trip length for all modes • Cycle incident reporting
Low	• Reporting dangerous drivers • Parking availability/location • Weather or road information	• Customer satisfaction/perception for all modes • Cycle and walking infrastructure mapping and rating • Throughput (people or freight) for all modes • Requests for service

The information needs identified in Table 1 were then assessed against five potential crowdsourcing strategies:

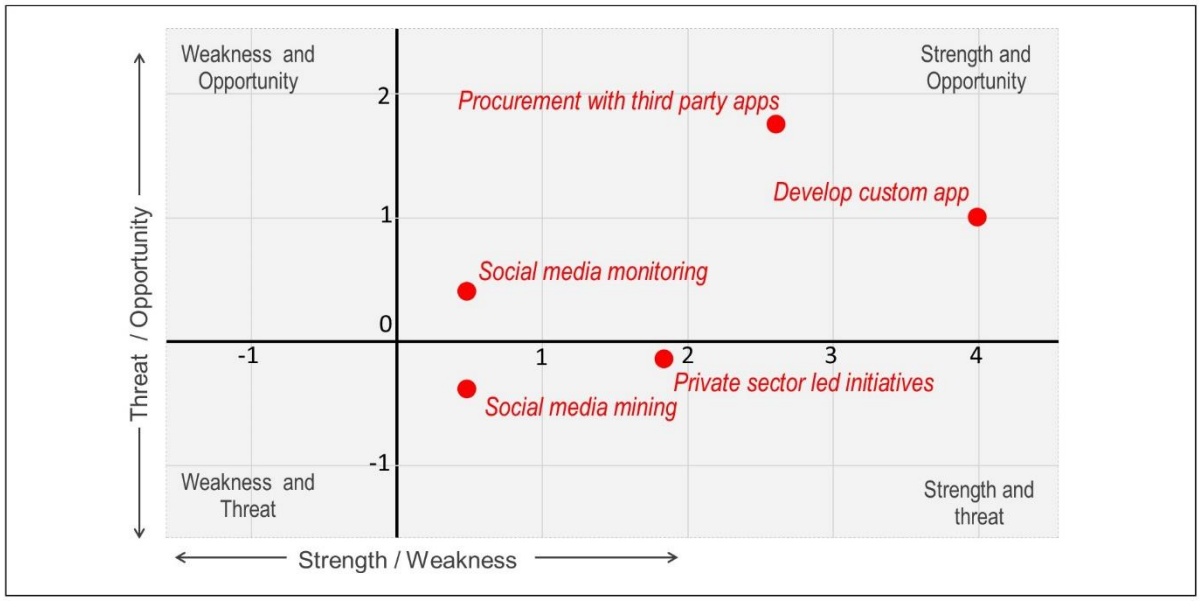
1. *Social media monitoring* – using existing social media services to view and potentially respond to social media alerts regarding transport network operations in real-time.
2. *Social media mining* – using data mining techniques to extract, locate and verify data

from social media sources.

3. *Develop a custom application* – create a bespoke web or mobile application to source data for a specific information need.
4. *Procure third-party data* – use data collected by an existing third-party application. An example of this is Waze[2], a community-based crowdsourcing and routing application.
5. *Support private sector-led development* – provide incentives to support the development of a crowdsourcing platform by the wider development/technology sector. This may include organising 'hack' events, competitions and supporting open data initiatives.

The assessment was undertaken as a SWOT analysis, which demonstrated that social media and customised applications are most likely to meet traveller information needs, but all approaches showed potential value with strengths outweighing weaknesses, and opportunities generally outweighing threats (Figure 2). Given the range of information gaps crowdsourcing can potentially fill, a recommendation arising from this analysis was that Agencies should not restrict themselves to a single crowdsourcing strategy.

Figure 2: SWOT Analysis of crowdsourcing engagement approaches



4 Crowdsourcing trial

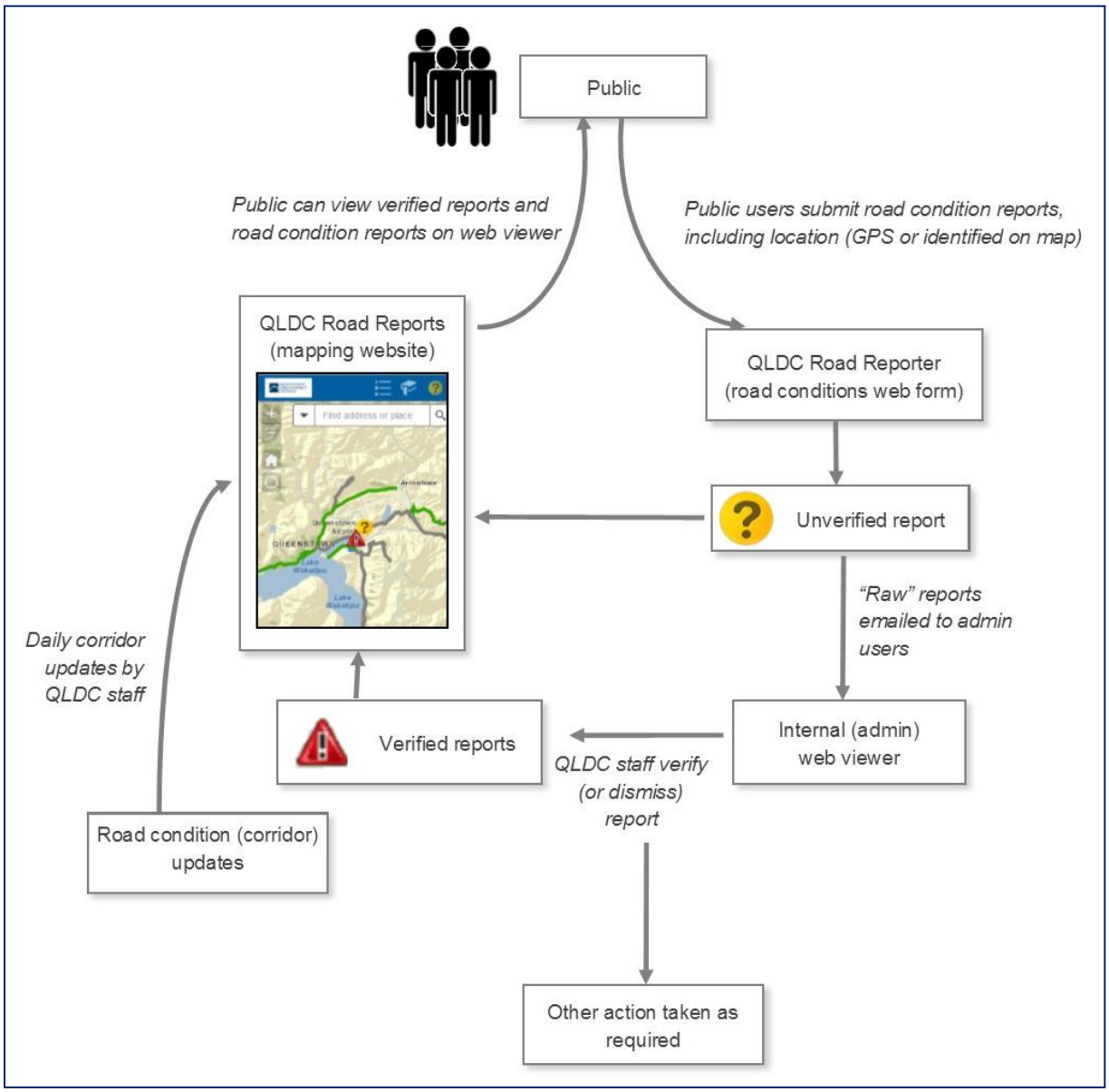
To put into practice the initial findings of the research, a trial was undertaken to collect crowdsourced information on winter road conditions within the Queenstown-Lakes District Council (QLDC) local authority boundary. This district has a mix of both urban and rural road networks, an engaged social media user base, and faces frequent winter weather events that affect key routes such as the alpine Crown Range Road between Queenstown and Wanaka.

The trial was undertaken over a three-month period between July and September 2015 with a further follow up trial undertaken in the winter of 2016 and a custom-built application was designed and developed by the research team in conjunction with QLDC, Christchurch Transport Operations Centre and NZ Transport Agency staff, incorporating feedback from stakeholders in the wider consultation process.

The team custom built the application rather than procuring a third party application as there were no crowdsourced applications in the market which fully met the stakeholder's needs. Figure 3 provides an overview of how the crowdsourcing web application was developed.

[2] www.waze.com

Figure 3: Crowdsourcing web application framework



Using a web-based form, users could report a predefined range of incidents such as crashes, road damage, snow and ice (see Figure 4). The location of the incident could be picked using the device's location service, or could be selected from a map screen or address. Users could also provide comments or photos to support their report.

The QLDC communications team and the Christchurch Transport Operations Centre (CTOC) staff would be alerted to verify the report, which may also include alerting contractors or the Police, or updating their travel information channels.

A separate web mapping application "QLDC Road Reporter" was developed to display verified and unverified reports (see Figure 5). To encourage greater usage, QLDC staff also published corridor status updates on the map alerting travellers of winter road conditions and restrictions, including open/closed status and notifications regarding ice, snow and whether chains on vehicles are required.

Figure 4: Crowdsourced submission web form

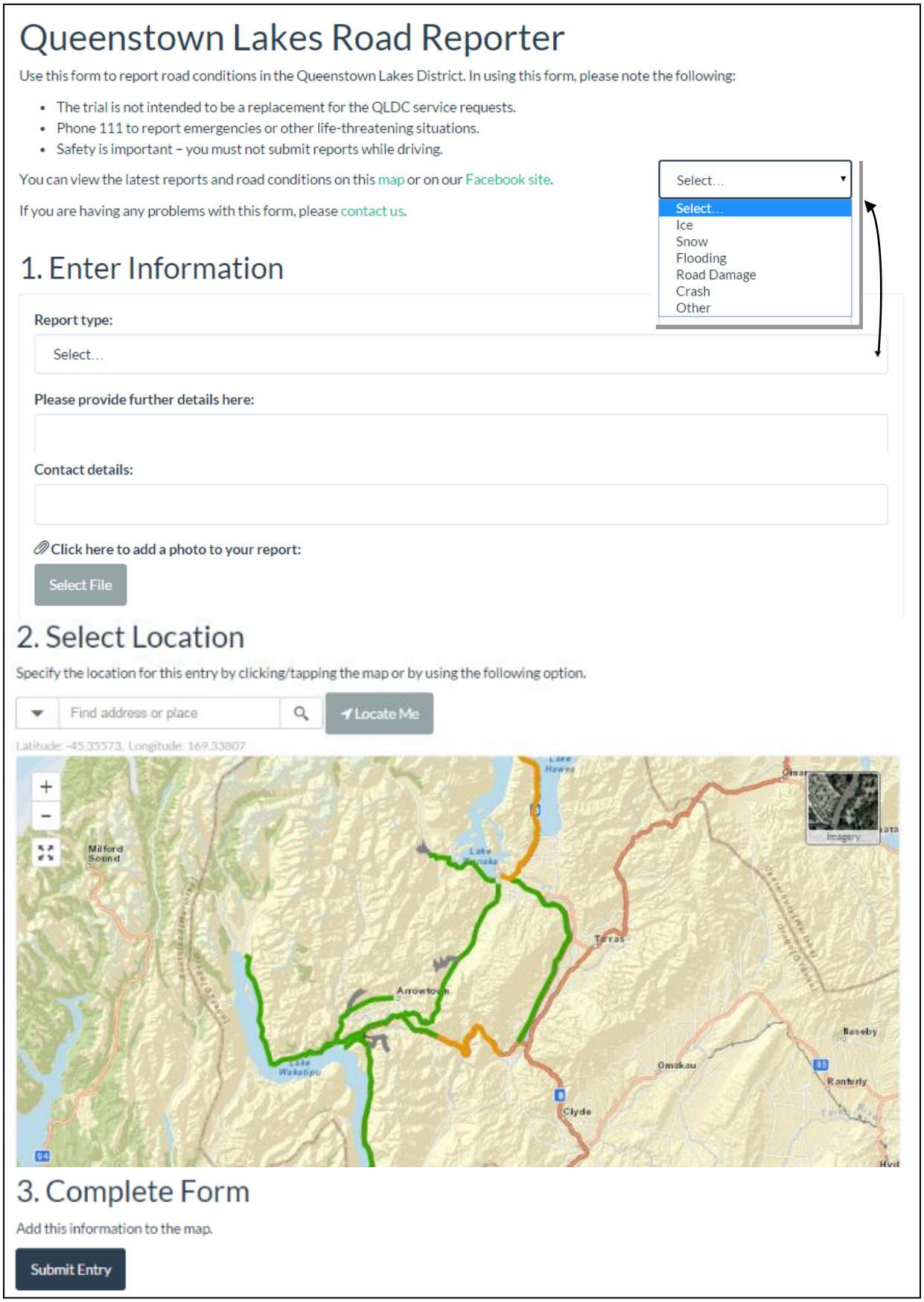
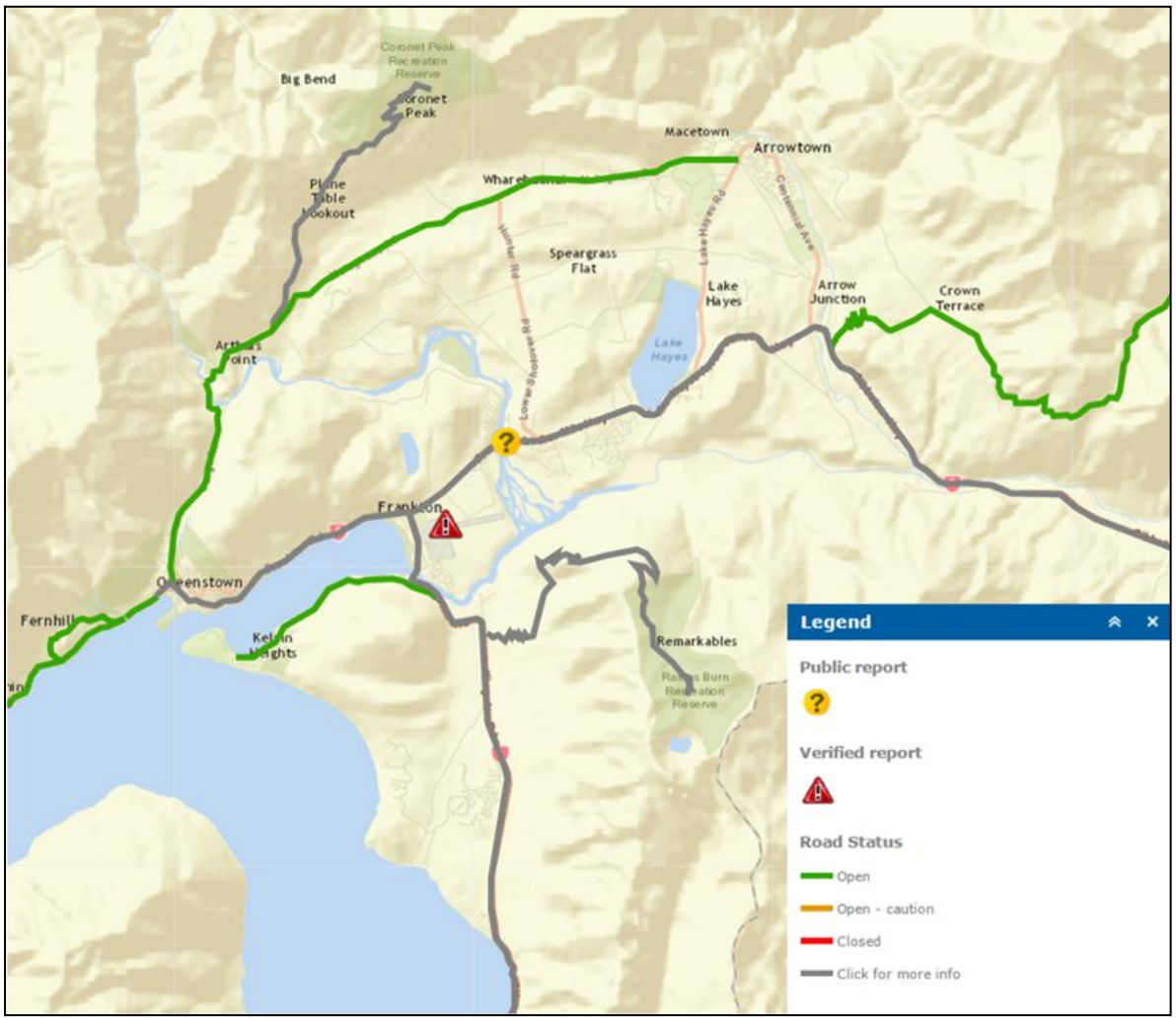


Figure 5 – Screenshot of the 'QLDC Road Reports' road conditions webmap



While the trial was running, the project team also monitored the QLDC's Facebook[3] site which is a key source of traveller information on road conditions in the District. Of particular interest to the project team was the role of Facebook as a crowdsourcing platform, and the extent to which users reported road conditions on this site.

4.1 Trial analysis and results

The success of the trial was measured through using webpage analytics, follow-up surveys and interviews. There were approximately 2,000 views of the web application (map) during the trial, with the highest number of views (358) coinciding with a major snowfall event and Facebook promotion of the site in early September.

Five reports were submitted during the trial using the web-based reporting form. Most of these were reports of ice or snow, with one report identifying dangerous potholes on a state highway which contractors were unaware of. Although five reports were fewer than the number expected, the low number could be due to the trial starting in mid-winter after a number of significant snowfall events had already passed and the novelty of winter weather conditions dissipated. Also as snow and ice is a widespread problem for local road users, travellers only tend to report unique or exceptionally dangerous road conditions.

[3] https://www.facebook.com/QLDCinfo/

Compared to the web application, the QLDC Facebook page had a much higher rate of usage, with as many as 15,000 views a day during the trial period. During the trial, 24 public reports of road conditions were posted to this page. As well as being an information 'push' channel, the QLDC Facebook page also performed a sharing function, with other users also posting public comments and updates on road condition reports. The success of Facebook as a crowdsourcing information source can be largely attributed to QLDC's reputation for publishing timely and trusted travel information, and by responding to user comments in a timely manner.

The research team undertook follow-up surveys of users with a total of 392 responses, and supplemented this feedback by undertaking interviews with QLDC and CTOC staff involved in designing and administering the trial. The results of these surveys and interviews made it evident that Facebook is the preferred travel information channel for most travellers in the District, therefore improving links between the Facebook page and reporting web application could improve uptake and increase the number of reports received.

The findings from the trial highlighted the increased value of combining traveller information provision and crowdsourcing in a single platform. The trial also highlighted that crowdsourcing platforms should be closely integrated with existing travel information channels to make it easy for users to report road incidents.

5 Research findings

The research identified a number of conclusions and recommendations across a wide number of areas. Key recommendations and conclusions relevant to the wider ITS community are summarised below.

5.1 The state of crowdsourcing and transport in New Zealand

In New Zealand, the Ministry of Transport and NZ Transport Agency provide a clear mandate for the use of technology in transport. This is also reinforced through the broader data management goals of the New Zealand Government, which support the use and sharing of data to deliver social and economic value.

One of the themes arising from the stakeholder engagement was that although there is strong interest among both public and private sector agencies in supporting transport crowdsourcing initiatives, there is often a disconnect between the strategic directions of some organisations, and how this is applied in practice. Because crowdsourcing applications are inherently new and innovative, they are considered risky investments and therefore existing risk management and procurement practices can be barriers to their implementation.

Resourcing was also raised by stakeholders as a concern, with transport agencies unsure of how to integrate crowdsourced information into their day-to-day workflows, and as to how much effort is required to process and verify this data. In light of this, one of the recommendations is to undertake specific scoping of those applications that will deliver the greatest value beginning with small-scale pilot projects to test assumptions around risk and resourcing.

5.2 The value of crowdsourcing in transport

One of the drivers for this research is to identify the value of crowdsourcing for real-time traveller information applications. In this respect, the research concluded that crowdsourcing delivers the greatest value supporting information gaps that cannot be filled using existing technologies and sources, or where crowdsourcing is the best solution in terms of quality, coverage or cost. This includes public transport service occupancy and capacity, monitoring the transport impacts of major planned and unplanned events (such as a national sporting event or natural disaster) and incident and hazard reporting.

Feedback from stakeholders and the findings from the trial also suggests that crowdsourcing delivers greatest value when directly coupled with a traveller information service, rather than

being a standalone application, this is because users who submit information receive instant gratification by seeing their reports published. The crowdsourcing collection method is promoted directly or indirectly through the service interface, and the service creates awareness of the value of public reports for other transport users.

5.3 Data validity and trust

The challenge surrounding the validation of crowdsourced information to establish trust was a common concern raised among stakeholders and during the trial. Transport operators are particularly concerned about how they would identify when traveller information should be issued to the public following a report of an incident or event on the network.

Given the range of crowdsourcing approaches and applications, there is no one-size-fits all model to validating crowd-submitted data, however there is a 'toolkit' of methods available that can help a transport agency develop a trust policy for crowdsourced information. Validation methods that can be readily applied include developing trust models based on user ratings and track history, analysing spatial precision, semantic text analysis, and using the number of reports as a guide to the severity of the network event. Before deciding which methods to explore, a transport agency should clearly evaluate:

a) The resources available to the project in terms of people available to moderate reports or tools that can help automate the verification process.
b) The number of crowdsourced reports that might be received.
c) The format of the information and platform on which the information is collected.
d) Who will view the information and how it will be used.
e) Whether user information will be collected to establish reputation or to judge the quality of the report.
f) How the spatial location of the report will be recorded.

In any instance, it is recommended that trust and validation matters are considered early in any crowdsourcing project, although the exact specifications or policy for this may need to be developed over time due to uncertainty.

6. Recommendations

Specific recommendations arising from the research towards implementation of crowdsourcing technologies and other related future initiatives include:

1. Establishing a formal process for reviewing privacy issues before a crowdsourced application is developed, or where crowdsourced data will be sourced from a third-party supplier. This process can be equally relevant for other ITS applications where personal data is collected, including the movements of individual transport users.
2. Consult/collaborate with other government agencies regarding potential safety issues of any proposed crowdsourcing application or service being undertaken by the NZ Transport Agency or other Road Controlling Authority.
3. Consider potential crowdsourcing options when developing Traveller Information Systems to integrate crowdsourcing data collection and traveller information provision into a single easy-to-use platform.
4. Investigate potential for crowdsourcing in meeting non-real-time needs, especially regarding public transport, walking, cycling, ridesharing and other emerging applications.
5. Ensure crowdsourced data is made public and reusable through a creative commons licence, taking into account the privacy of individual contributors.
6. Monitor the usage of third-party applications (and any new applications that arise) to determine future potential.

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