SideWaze

Crowdsourced sidewalk condition data for your neighbourhood

Capstone Project — Creative Component

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This document describes research into sidewalk conditions and whether data could be gathered using crowdsourcing in a timely and effective manner.

First, interviews were conducted with three representative stakeholders. Insights were distilled from those conversations, and key tasks and workflows were explored.

Next, competitive research was conducted to learn how others were addressing similar or analogous challenges. The broader sidewalk ecosystem was explored.

From the stakeholder insights, task and workflow breakdowns, and competitive research, opportunities were identified and a preliminary scope established for SideWaze.

Finally, a protoype was developed to help answer the question of whether a smartphone application could be used to gather sidewalk condition data. The prototype was tested with representative users and its usability assessed.

This research was done within the Region of Waterloo, Ontario, Canada.

To learn more about this capstone project please visit:

http://hci598.rasterville.com

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1.1 Primary stakeholders

The primary users of SideWaze are those who use sidewalks and whose mobility and freedom are negatively affected by impediments. This user group includes:

- *parents with strollers and small children*;
- *wheelchair users*; and
- *those with mobility concerns*, including the elderly, and those with mobility aids (e.g., walkers, canes).

1.2 Secondary stakeholders

Secondary users of SideWaze are city and region staff, and third party private companies, especially those who are responsible for:

- construction and works;
- snow clearing;
- by-law enforcement;
- GIS systems management; and
- urban planning.

Property owners (especially residential owners) are also secondary stakeholders although, depending upon the ability to instil a sense of sidewalk ownership, they may be considered primary stakeholders (see *§2.2.1 Report sidewalk condition*).

1.3 Additional stakeholders

Other stakeholders–by virtue of being affected by sidewalks and management of their condition–include:

- those interested in fostering 'smart cities'; and
- institutional management (e.g., universities, hospitals) reponsible for large volumes of pedestrian traffic.

1.4 Stakeholder interviews

Three representative primary stakeholders were identified and interviewed. Interview participants were informed of the goals and nature of the research (that it was an individual research project in an educational context).

Figure 1. Meghan on her tree-lined, urban street. She lives there with her family of six. They walk as much as possible. Photo by Peter Lee, Record staff.

Figure 2. Margaret (center), a Kitchener resident and city councillor, out for a walk in her neighbourhood. Photo provided by Margaret Johnston.

1.4.1 Meghan

Meghan (Figure 1) is a mother of four children, between the ages of one and nine. She and her husband live in an established neighbourhood in Kitchener, a mid-sized city in Ontario, Canada. The family moved to the neighbourhood, in large part, to allow for more active transportation options, especially when walking their children to school or day care, or when walking to and from work.

Each week day, one parent walks the two older children to school while the other parent walks the younger two children to day care. Depending upon the season, this is done using a combination of stroller, scooter, sled, and walking. A round trip from their home to school or day care is approximately 2 km.

Some of the ways sidewalk condition affected Meghan and her family include:

- having to guess which route to take each winter morning: snow covered sidewalks often prevent the use of the stroller, even though a stroller is the preferred method of transporting small children (it is easier to keep them warm);
- often having to 'portage' her stroller or sled at intersections that haven't been cleared of snow properly; this requires her to unload her small children into the street, lift her stroller or sled across a bank, navigate the street, and then repeat on the other side;
- having to walk in (already narrow) winter streets when the sidewalks are inadequately cleared; this endangers the family; and
- having to reroute while running errands as a result of construction; this affects walkers a lot more than someone in a car and might make a 20 minute errand take twice as long in some cases.

Meghan and her family are active during all seasons, but love to ride their bikes and scooters during the summer.

1.4.2 Margaret

Margaret (Figure 2) lives with her golden retriever dog, Angus. Several times each day, they walk together around the neighbourhood. Margaret works at a local university, and has also been recently elected as a city councillor, and has extensive knowledge of the ward, having walked to

each and every house and apartment during the recent election.

She considers sidewalks the primary means of connecting neighbourhoods, both physically and socially. She is an advocate of evidence-based decision making, active transportation, and citizen engagement.

She spoke of connecting with people through her walks in ways that don't happen in cars, for example. She looks for evidence of someone being ill (newspapers not taken in), or crime.

As a councillor in a city with an enviable history of innovation, she is excited about the role technology can play in improving the lives of residents. But she is also concerned that services and products work for all people, not just affluent, able-bodied ones.

1.4.3 Edward

Edward (Figure 3) is the Executive Director of KW AccessAbility, a non-profit dedicated to helping those with physical disabilities. His organization provides resources and advocacy for those who use wheelchairs, are paralyzed, require aid getting around, etc.; as he says, his members represent "a melting pot of physical disabilities." Edward uses a powered wheelchair.

Members of KW AccessAbility represent a broad range of capabilities, socio-economic class, and lifestyles. Edward told stories of how sidewalks are both absolutely necessary for those with physical disabilities and the source of much frustration, especially during winter months.

Edward was instrumental in understanding that not only do those with physical disabilities use sidewalks more than most, they are least able to adapt to conditions which preclude their use (due to many being on disability pension).

Figure 3. Edward, the Executive Director of KW AccessAbility. His organization advocates for and helps adults with physical disabilities. Photo by Robert Wilson, Record staff.

1.5 Identifying system users

During the course of user research, it became increasingly clear that the number of stakeholders, system complexity, and variety of interactions involved with sidewalk conditions were more than originally thought. However, the primary stakeholders–those who need to deal with the impact of poor sidewalk conditions–did not change as a result of the interviews.

There is a heuristic within user experience design which states that if you design for the extremes, all users will benefit. This rule of thumb informed the decision around who to design for and test with during SideWaze development.

The definition of primary users (see *§1.1 Primary stakeholders*) was a reasonable one. Where possible, the ideal of designing for and with those users who have physical disabilities was explored.

1.5.1 Primary users skills and backgrounds

There was diversity within the set of primary users; the only constant requirement for consideration was that they were sidewalk users. This meant that the range of skills, backgrounds, education, socio-economic situation, and family dynamic was considerable.

1.6 Engaging with system users

All three interview subjects volunteered names of other individuals for whom SideWaze would either be a solution to an identified problem, or who may provide additional perspective as to how sidewalks get used. This proved incredibly helpful as a way to connect with specific user groups, such as those with physical disabilities.

CivicTechWR, a local group dedicated to the use of technology within the civic space for social good, was identified as an excellent learning resource (e.g., learning how municipalities share data, how policy around snow clearing is created, etc.).

2.1 User goals

Broadly speaking, there were two user goals to consider:

- **Reporting sidewalk condition.** This task involves identifying a section of sidewalk in the physical world (intersection, GPS coordinates, etc.), describing the undesirable condition (perhaps with a photo), and, optionally, associating themselves with that reporting action (e.g., providing a phone number so that city officials could follow up with the reporter).
- **Learning about sidewalk conditions.** This task involves incorporating local knowledge about sidewalk conditions into planning. Examples of similar tasks include looking up traffic information before driving somewhere, or reading the weather forecast before heading out in the morning–both activities add to an understanding of a journey and its planning.

From a system architecture view and with respect to the use of sidewalk condition data, these goals corresponded to the roles of *producer* and *consumer*, respectively. These are not mutually exclusive roles, as a user may both contribute and use sidewalk data.

2.2 User tasks

Three user tasks were evident, presented as user stories.

2.2.1 Report sidewalk conditions

As a sidewalk user, I want to quickly, easily, and accurately report poor sidewalk conditions to whomever is responsible for their maintenance so that future sidewalk users won't be in danger or inconvenienced.

Task step	*May use...*
Note location	Smartphone GPS, street signs, street address, landmark, public transit stop number
Phone call centre	Cell phone, home phone/land line, awareness of call centre service
(or) Use Pingstreet	Cell phone camera, smartphone GPS

2.2.2 Track status of sidewalk condition report

As a sidewalk user, I want to learn the outcome and status of my sidewalk condition report so that I can feel like I improved city life and hold municipal government accountable.

Task step	*May use...*
Phone call centre	Cell phone, home phone/land line, awareness of call centre service
Use Neappoli 311 (where available)	Smart phone, Neappoli 311 app, smartphone GPS
Visit location	

2.2.3 Plan travel using sidewalk condition information

As a sidewalk user, I want to learn about sidewalk conditions as they relate to travel plans so that I can reduce frustration and schedule my life more efficiently.

Task step	*May use...*
Open mapping web site or app	Smartphone, desktop computer and browser, smartphone GPS, browser location services, destination address and route information
Look at sidewalk information	Preferred route information, local knowledge
(opt) Open bus schedule web site or app	Knowledge of bus routes and stops

Figure 4. This intersection crossing does have an accessible curb cut, but the snow makes it inaccessible. Pedestrians are forced to climb over while wheelchair users are blocked.

Figure 5. Bus stop which has been 'cleared' by a plow after a large snow fall. This stop is inaccessible for both pedestrians and wheelchair users.

Figure 6. Narrow, poorly cleared bus stop, created by trampling. A wheelchair would be unable to use this stop even though all local buses have been accessible since 1992.

User and competitive research revealed several key insights. Each had the capability to influence SideWaze both in terms of scope and implementation.

First, there was **no universal way to report undesirable sidewalk conditions**. How a resident reported this information varied by city and may have depended on type of concern or property in question (e.g., private property, city property, or pseudo-public like public transit stops).

Second, **technology requirements should be considered carefully**. Many of the most dramatically affected sidewalk users were not necessarily in a position to utilize something like an app. Edward indicated that many of their members participated in the Ontario Disability Support Program (ODSP) and are unable to afford smartphones or data plans. Meghan stated that she does not have a data plan for her smartphone as she doesn't see the need.

Third, **sidewalk data is not stored, managed, or owned by a central entity**. While some users might use Google Maps to plan a trip, others might use OpenStreetMap or Bing. Cities may use different GIS systems or approaches to storing sidewalk data. Data siloing prevents broad adoption by those who are best in a position to contribute and use that data.

3.1 *Impact of poor sidewalk condition*

By interviewing (only) three representative users, a wide array of undesirable situations were described, all caused by poor sidewalk conditions.

- **Snow bank 'portaging'**. Meghan described having to lift small children and her stroller over snow banks at intersections that hadn't been cleared (Figure 4).
- **Being in a maze**. Both Meghan and Edward described having to double back and change their route on the fly when they couldn't traverse a section of impassable sidewalk (due to snow or construction).
- **Being stuck in snow**. Edward described situations where wheelchair users had become stuck in snow to an extent where they needed to ask for assistance from other pedestrians or call a friend to come help them.
- **Inability to run errands**. Edward described situations where wheelchair users would have no way of knowing if sidewalks or bus stops were accessible on a given day. He spoke of members needing to decide what to do when they couldn't get to grocery stores due to snow covered sidewalks.
- **Scheduling lead time**. There are a limited number of accessible taxi cabs in Kitchener. If someone with a physical disability was unable to use public transportation (i.e., they couldn't get to a bus stop; Figures 5 and 6), they need to hope they can get a taxi cab (or schedule one through the public bus service one week out).
- **Unsafe road use by pedestrians**. All three users interviews spoke of having to use the road when a sidewalk was deemed unusable. In the past month, this has been observed on several occasions in Kitchener (a mother with a stroller and small child, pedestrians, and someone with a power wheelchair).
- **Unsafe conditions**. Meghan spoke of slipping on ice covered sidewalks, and children falling off of scooters due to uneven sidewalk slabs. Edward spoke of being stuck in the road, unable to get onto the sidewalk.

3.2 *Current task failures*

For the City of Kitchener specifically, there were officially supported mechanisms (call centre, Pingstreet, web site) in place to allow people to report poor sidewalk conditions. There were opportunities for improvement with, in particular, online services to make them more usable, and expansive in scope and supported issues.

None of the systems supported integration of sidewalk condition data in mainstream channels. Rather, users were expected to collect data from multiple sources (public transportation web site, mapping service, list of road closures from city web site, sidewalk data from a dedicated app like Neappoli 311, etc.). This segregation of information placed undue onus on the user.

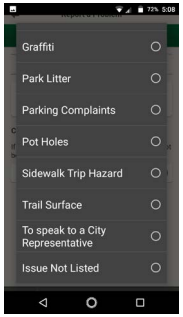

Figure 7. Pingstreet's range of support for user-submitted issues.

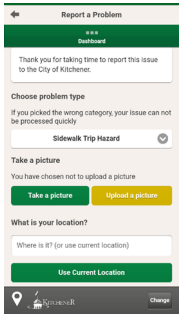

Figure 8. Pingstreet's facility to submit sidewalk issues.

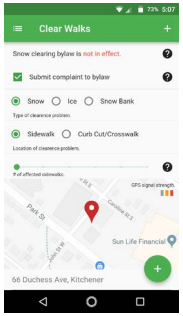

Figure 9. ClearWalks allows users to report uncleared sidewalks.

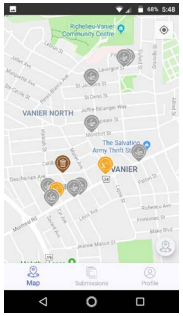

Figure 10. Neappoli 311 presents flagged issues on a city map.

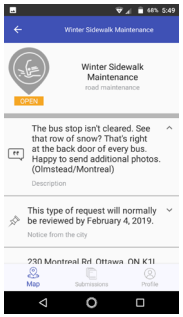

Figure 11. Describing a new issue within Neappoli 311.

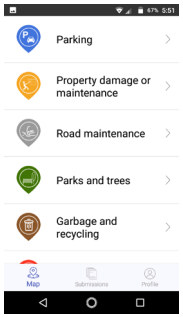

Figure 12. Categories of issue supported by Neappoli 311.

3.3 Current approaches

3.3.1 City cell centres

Most cities operate a call centre, designed to allow residents to connect with city staff for the purpose of raising an issue, lodging a complaint, or asking a question. The City of Kitchener operates a call centre that is available 24 hours a day, seven days a week.

Anyone can call the centre, speak with another person, and raise an issue about sidewalk conditions. Depending upon the type of concern (snow cover, damage, accessibility, construction, etc.) the appropriate city department will be notified and an internally trackable issue created.

3.3.2 Pingstreet

The City of Kitchener uses a custom smartphone app called Pingstreet as part of its customer service strategy. This app, available for iOS, Android, and Blackberry devices is intended to allow residents and visitors to get helpful city information and report issues (Figure 7).

Relevant to SideWaze is Pingstreet's facility for reporting sidewalk trip hazards (Figure 8). Users are able to report an issue, take a picture, and associate a location (either through a description or the current location).

As a supported and official channel for communicating to the City of Kitchener, Pingstreet enjoys tight integration with its systems. It does, however, require a smartphone (ideally with a data plan), and the patience to work through a somewhat crowded app (Pingstreet has 16 top level areas of functionality).

3.3.3 City web sites

The City of Kitchener publishes information about planned and exceptional construction and road closures. This can range from closures caused by broken water mains, planned work on street infrastructure, or detours due to events.

While useful, such information is often too coarse to be useful in the context of SideWaze: it doesn't address sidewalks specifically and, if the work is being done by third party contractors, infrequently updated.

3.3.4 ClearWalks

In 2018, a resident created ClearWalks (Figure 9), an Android app designed to collect reports of poor sidewalk conditions due to snow and ice. It informs users if there is a snow event[1], allows them to describe a problem, and optionally have ClearWalks automatically submit a by-law enforcement request to the City of Kitchener.

The goal of ClearWalks is to learn if there are patterns in snow clearing behaviors and to streamline the process of informing by-law officers of a possible infraction.

ClearWalks does not allow a user to see sidewalk condition data; it is for submission only.

3.3.5 Neappoli 311

Neappoli is an Ottawa, Ontario-based startup and the creators of Neappoli 311. This smartphone app is designed to allow citizens to report issues–potholes, graffiti, sidewalk issues, etc.–to the City of Ottawa.

The app uses a series of flags tied to specific locations on a map to inform users of known issues (Figure 10). New issues can be described by users (Figure 11), categorized (Figure 12), associated with a specific location within the city, and sent on to city staff. As with Pingstreet, Neappoli 311 is integrated with city systems.

Also like Pingstreet, the map presented within Neappoli 311 is a dedicated one and no additional information is presented (for example, bus delays aren't shown on the same map as flagged issues, etc.).

3.3.6 WalkOn

Originally called MySidewalk, WalkOn is a smartphone app designed to crowdsource the collection of sidewalk data. As with this project, WalkOn authors wondered whether the public would engage with the platform in sufficient numbers to be effective (Erraguntla et al., 2017).

WalkOn uses smartphones and, in particular, the GPS sensors within, to permit participating users to catalog sidewalk position or absence (Figure 13). Sidewalk condition can also be noted, but must be done manually by the user (Figure 14).

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[1] A snow event is triggered when a substantial amount of snow falls. Snow clearing by-laws are not enforced during a snow event.

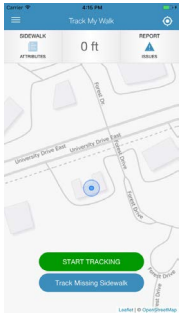

Figure 13. WalkOn allows for sidewalk inventories using GPS traces.

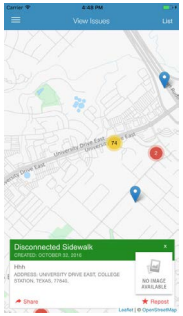

Figure 14. WalkOn allows flagging of issues, tied to a specific location.

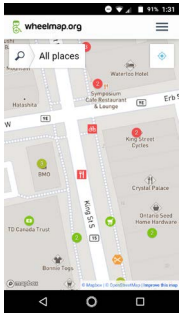

Figure 15. Wheelmap tags locations on a map as to their wheelchair accessibility.

Figure 16. Waze displays near real-time traffic information.

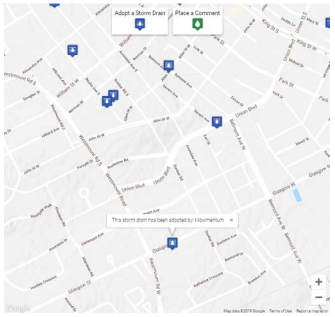

Figure 17. REEP's Adopt a Drain website is a niche website allowing residents to commit to keeping storm drains clear. This has no standing with the city, but is a grassroots approach.

Interestingly, while WalkOn does not present information about sidewalk condition within the app, it does store such data as separate geospatial data so that it might be reused in other contexts (Erraguntla et al., 2017) such as a geographic information system (GIS).

3.4 Sources of inspiration

3.4.1 Wheelmap

Wheelmap.org is designed to show wheelchair accessible places on a map. Anyone can contribute information about accessibility using a simple traffic light metaphor (where red indicates inaccessibility, amber indicates partial wheelchair accessibility, and green indicates full accessibility).

Wheelmap is interesting in that it uses an existing map provider (OpenStreetMap) and *layers on* crowdsourced data. This allows for a specialized application of the accessibility data (as the wheelmap.org web site and dedicated smartphone apps) without diluting the applicability of the mapping data to a broader audience or for other purposes (Figure 15).

3.4.2 REEP Adopt a Drain

REEP is an environmental non-profit located in Kitchener, Ontario. Recently, they launched a web site (Figure 17), "encouraging people in Kitchener to work together to prevent flooding from clogged storm drains" (REEP, 2017).

This website uses an interactive map to allow city residents to 'adopt' a storm drain and commit to keeping it clear. Using a sense of ownership to engage residents in infrastructure is not unique (Adopt-a-Hydrant, n.d.; Code for America, n.d.), but likely appeals to those already involved in their neighbourhood.

REEP's Adopt a Drain website has only been active for a month or two, but already there is a sense of gamification as well, with drain adopters come up with interesting team names; this is reminiscent of the now deprecated Foursquare practice of naming the most frequent visitors to a business as 'mayors' (Foursquare, n.d.).

3.4.3 Waze

Google's Waze app (Figure 16) is designed to gather, consolidate, interpret, and share information about traffic conditions on roads and highways. While recent versions of the program have introduced advertisements, when first introduced Waze was an innovative solution to gathering real-time traffic information. By utilizing GPS information of the smartphones of drivers, traffic patterns could be inferred reliably.

Waze represents an elegant solution to the problem of gathering high quality data without requiring a lot of user energy. It prompts the question: Are there comparable techniques to gather sidewalk condition data efficiently?

3.4.4 Snow Moles

The city of Ottawa, Ontario recognized that gathering quality information about the condition of its sidewalks is difficult and labour intensive. To help improve the situation while simultaneously encouraging older residents to get outside during the winter, The Council on Aging of Ottawa have created a program called Snow Moles.

Snow Moles are "volunteers who report on what it's like to walk outside on a winter day in Ottawa" (Snow Moles, n.d.). Information about the walkability of sidewalks in Ottawa is gathered and shared with the City of Ottawa to help improve winter walkability.

This program shows that innovation can occur without the introduction of technology in some cases, especially when those affected might not be comfortable or have access to smartphones, etc. (as is the case with some SideWaze primary stakeholders).

3.5 Opportunities for improvement

Several questions emerged, hinting at opportunities for improvement over the workflows presented in existing systems:

- Is snow clearing and sidewalk coverage unique and important enough to require a specialized workflow?
- Are there opportunities to describe sidewalk condition data in general enough ways to encourage integration with existing and future components?

- How can we maintain a comparably featured experience for primary users when technology levels may differ dramatically?
- How an we integrate existing sidewalk condition data into more mainstream planning applications? (e.g., mapping or public transportation systems)

As evidenced by the focus of existing systems (see *§3.3 Current approaches*, and *§3.4 Sources of inspiration*), there is a strong emphasis on data gathering (as opposed to distribution of aggregate or locale-specific sidewalk data).

3.6 Project scope and constraints

As mentioned, the complexity of the existing infrastructure around sidewalk condition is a bit daunting. There are a large number of moving parts associated with sidewalk maintenance specifically and municipal interaction in general. In the short term, SideWaze is not intended to replace any of the identified channels.

However, SideWaze can provide value by:

- Developing a prototype for sidewalk condition data gathering which includes the ability to **delay submission until a WiFi connection is available** (an 'offline' mode) and explores **more usable designs for issue creation**.
- Presenting a prototype **integration of sidewalk condition data into a representation of a mainstream planning platform** (e.g., Google Directions/Maps, public transportation planning app, etc.). This may require (from a practical point of view) the use of a more open platform like OpenStreetMap, even though its broad adoption is called into question due to concerns about quality (Mobasheri et al., 2017).
- Exploring the value of **capturing personal impact at the time of sidewalk condition data gathering**. This is a stretch goal for this project as it represents something radically different than what exists right now.

At a system level, there needs to be an acknowledgment that any viable component needs to 'play well with others' and integrate competently. However, this integration piece was not explored beyond what is necessary to fulfill concrete work on the submission or sharing pieces.

Instead SideWaze represents a reference design for the collection and sharing of data. In order to be consistent with the principles of harmonious co-existence with the current system, and the desire to work with those most affected by poor sidewalk conditions, SideWaze will be presented (as time allows) as both a web site and a dedicated smartphone app. These two modalities provide enough coverage and flexibility to work in a variety of contexts and with a variety of users.

3.7 Project context

This project was conducted within the Region of Waterloo (Figure 18), a regional municipality of approximately 550,000 residents. The Region of Waterloo represents three cities (Kitchener, Waterloo, Cambridge) and four townships (Wellesley, Wilmot, Woolwich, and North Dumphries). The cities of Kitchener, Waterloo, and Cambridge are adjacent and their boundaries indistinct–you can easily miss the transition from one city to the next. They are, collectively, called the 'tri-cities'.

This blended geography, with blurred political boundaries, means that residents are often unsure who is responsible for municipal infrastructure. Within the region, you may be at an intersection with sidewalks maintained by either the region, one of two adjacent cities, a private citizen, a commercial enterprise, a regional transit organization, or a federal postal service.

This ambiguity is important to remember when looking at the workflow of residents in reporting issues such as poor sidewalk conditions. Using the City of Kitchener as a representative example, there are no fewer than six channels in place to facilitate municipal interaction with residents. Additional channels exist for data publishing (e.g., GIS maps). Taking the regional government into consideration increases the number of channels.

In short, sidewalk maintenance and condition reporting is deceptively complicated.

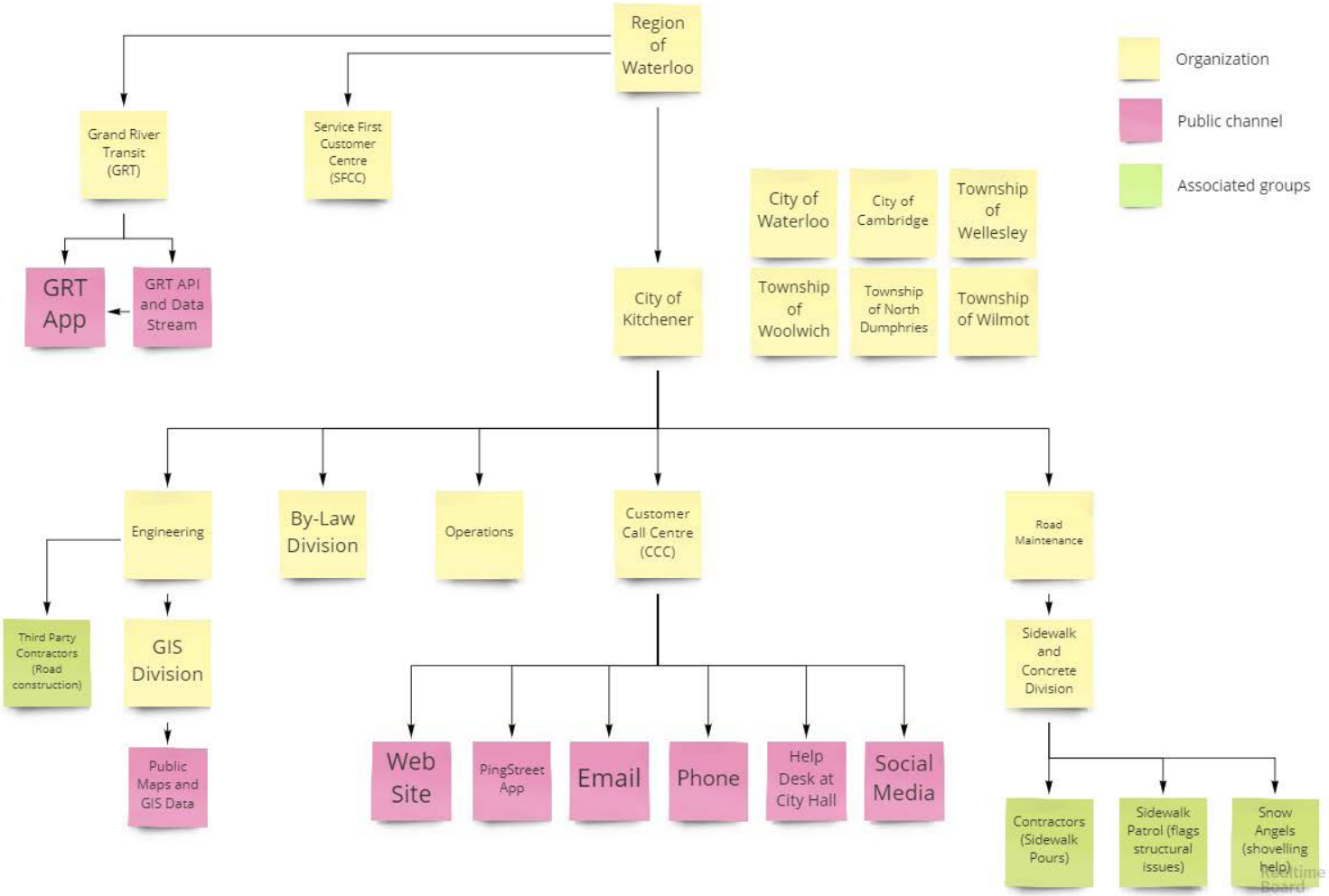

Figure 18. Schematic representation of key organizations and public-facing interfaces for the Region of Waterloo and City of Kitchener (with consideration for entities related to sidewalks).

Two primary user goals were identified during interviews and research. First, **users want to report sidewalk conditions that affect their use**.

Second, **users want to learn about sidewalk conditions** so that they can better plan their travel, feel like their neighbourhood is being maintained, and ensure sidewalks can be used safely.

4.1 Reporting sidewalk conditions

User story: *As a sidewalk user, I want to quickly, easily, and accurately report poor sidewalk conditions to whomever is responsible for their maintenance so that future sidewalk users won't be in danger or inconvenienced.*

From this user story, several functional requirements follow:

- The system shall allow the user to **describe the sidewalk condition**.
- The system shall allow the user to **identify the location** of the sidewalk being reported.
- The system shall allow the user to **characterize the impact** of the sidewalk condition in a way that makes sense to them.
- The system shall allow the user to **associate a date and time** with the sidewalk condition report.
- The system **shall not require knowledge of sidewalk ownership** (region, city, government organization, etc.) in order to report sidewalk conditions.

4.2 Learning of sidewalk conditions

User story: *As a sidewalk user, I want to learn about sidewalk conditions as they relate to travel plans so that I can reduce frustration and schedule my life more efficiently.*

From this user story, several functional requirements follow:

- The system shall identify sidewalk condition areas **visually and tied to a geographic location**.
- The system shall **describe the nature and severity** of sidewalk condition issues.
- The system should **incorporate public transportation information** such as routes, stops, and system information.

4.3 Issue tracking and accountability

User story: *As a sidewalk user, I want to learn the outcome and status of my sidewalk condition report so that I can feel like I improved city life and hold municipal government accountable.*

From this user story, several functional requirements follow:

- The system shall **provide progress updates** and information about how an issue is being addressed.
- The system shall **not require personal identification** to observe progress updates.

4.4 Inclusivity

Sidewalks are public infrastructure. There are no fees or licensing required for their use, no specialized equipment is necessary, and they are nearly ubiquitous. Similarly, the channels through which information about sidewalks flows should be available to as many people as possible.

User story: *As a sidewalk user, I want to be able to call attention to poor sidewalk conditions without the need for specialized technology or cost so that I can allocate my income to other things.*

User story: *As a sidewalk user, I want to be able to learn about the status of existing sidewalk condition issues without the need for specialized technology or cost so that I can allocate my income to other things.*

While these are both strong user needs, there are existing channels to facilitate these interactions (e.g., City of Kitchener help desk at City Hall or customer support phone number). However, several functional requirements follow:

- The system should **work in as many existing support contexts** as is feasible.

5.1 Tradeoffs

The scale of the system within which sidewalk maintenance (local to the Region of Waterloo) must be considered is daunting. In order to mitigate the risk associated with trying to solve every issue for every stakeholder, the following tradeoffs were considered.

5.1.1 Stakeholder coverage

A key decision, made early on, was to prioritize some of stakeholders above others; these were the primary stakeholders described in *§1.1 Primary stakeholders*. It was recognized that any longer term, widely adopted technology solution for sidewalk condition data would need to address the needs and concerns of secondary and tertiary stakeholders.

Secondary users of SideWaze are city and region staff, and third party private companies especially those who are responsible for:

- construction and works;
- snow clearing;
- by-law enforcement;
- GIS systems management; and
- urban planning.

Property owners (especially residential owners) are also secondary stakeholders although, depending upon the ability to instil a sense of sidewalk ownership, they may be considered primary stakeholders. Other stakeholders–by virtue of being affected by sidewalks and management of their condition–include:

- those interested in fostering 'smart cities'; and
- institutional management (e.g., universities, hospitals) reponsible for large volumes of pedestrian traffic.

This project prioritizes primary stakeholders, recognizing that there is risk associated with not investing in broader, more in-depth user research across the system. This risk was mitigated by positioning SideWaze as an exploratory vehicle and keeping integration of data in mind during ideation.

5.1.2 'Traditional' vs. 'innovative'

The near ubiquity of connected smartphones makes it a reasonable technology option for SideWaze. However, there is a definite tradeoff between the relative low risk of established technology (and user patterns) and potential for truely innovative ways of solving a problem.

During ideation, some of the more interesting ideas generated included:

- Internet of Things (IoT) devices scattered throughout the city (e.g., at bus stops) with simple, hardware based feedback mechanisms (like Happy or Not's Smiley Terminal; see Figure 5).
- Drones, working on pre-defined routes and fitted with cameras, used to measure sidewalk coverage and condition using computer vision.
- Leveraging Canada Post delivery staff to identify troublesome sidewalk conditions.
- Developing technology to infer sidewalk condition using probabalistic models and data gathered from smartphone sensors or fitness devices like Fitbit (inspired by Lu and Karimi, 2015).

Decisions affected by this tension–between the use of more established technology and non-traditional, unproven research-based solutions–were incredibly difficult. Ultimately, the user research indicated that deliberate and measured changes to existing channels would likely be sufficient (to meet user's needs for offline reporting, travel planning, and impact characterization) and would reduce risk.

5.1.2 Utility vs. engagement

Residents of the Region of Waterloo are actively discussing the role of sidewalk conditions. There is a tradeoff between utility of a proposed solution like SideWaze and the need for engagement (or capturing the imagination of the public). Speaking to stakeholders and being able to keep their interest while describing yet another app often overshadows the goals of the project. The decision to be more conservative in the approach for SideWaze was, in part, made in deferrence to the limited time for this work.

Figure 19. A Smiley Terminal, created by Happy or Not. Retail users can provide feedback on their experience by pressing on one of four face buttons. (Photo by Happy or Not).

5.2 Constraints

A design should be informed by the population it is intended to serve. When the population in question is hundreds of thousands of people within a large metropolitan area, resource constraints influence several elements:

- **Accessibility** of the solution. Should the solution be translated into more than one language? Can the solution be used by those with visual impairments, who use screen readers, or who are colour blind? Is the solution responsive to different form factors and presentation settings such as high contrast, increased font size, etc.? SideWaze will not explicitly address any of these concerns due to resource constraints.
- **Availability** of the solution. Do the vast majority of intended users have straightforward, inexpensive access to the solution? Does the solution require or expect specific skills or equipment? Is the solution supported in reasonable ways? As presented, SideWaze will be useable via a smartphone app or a web site in order to accommodate more users.
- **Privacy** of users. Does the system need the user to create a profile and login? What value is added by requiring authentication? Is any personal data stored or transmitted without being secured? A key insight during ideation was that there was no obvious value gained by requiring authentication and, as such, SideWaze will not require it.

Creating reliable, accessible software solutions for large populations can be complicated and expensive. The constraints mentioned above are the most relevant for this project.

5.3 Future technologies and social implications

For several reasons, the state of the Region of Waterloo in 2018–2019 represented a perfect environment for research into sidewalk conditions and their impact. Looking to the future, there are several technologies and social shifts that will have an impact on the problem of sidewalk conditions affecting livability.

5.3.1 Light Rail Transit (LRT)

In 2009, the Region of Waterloo started exploring the possibility of constructing a light rail transit (LRT) network in the area to support a growing population in a sustainable way (Figure 20). In 2014 LRT construction work began in Kitchener and Waterloo. The Region, as well as both Kitchener and Waterloo, used this sustained construction window to perform major and necessary infrastructure upgrades of their own, such as road rebuilds and water main replacements.

During these changes, not only were the public consulted about a variety of construction projects (raising their collective awareness of urban design, active transportation, etc.), they were subjected to protracted periods of inconvenience due to those same projects (Figure 21). Sidewalks users grew used to navigating detours (if posted) or climbing over piles of dirt (if not). Newer by-laws, designed to promote active transportation, were in play for some road rebuilds, resulting in sidewalks being created where once there were none.

The decision to build the LRT infrastructure has had and will continue to have an effect on how residents get around the Region. In particular:

- regional and municipal governments are **revising policies around snow clearing** to incorporate expected LRT pedestrian traffic as well as track clearing; and
- an **increased weighting of active transportation proximity** when determining whether sidewalks are required during road reconstruction (in other words, if a street is near a trail, a bus stop, an LRT stop, etc., there is a greater chance the city will build sidewalks where there currently aren't any).

5.3.2 Smart cities

In 2018, the Region of Waterloo was announced as one of five candidates in the $50M category for the Government of Canada's Smart Cities Challenge.

The City of Kitchener's Digital Strategy describes a city that is "connected, innovative, on-demand, and inclusive" (City of Kitchener,2017, p. 1). As part of this work, the city has installed LED lighting into all of its streetlights, con-

Figure 20. LRT train for the ion system within the Region of Waterloo (photo by Youngjin Ko, used under CC BY-SA 3.0).

Figure 21. Construction for the LRT system required major infrastructure work, including road reconstruction (photo by David Bebee, Record staff).

nected by a narrowband network, and made high speed public wireless internet access available within the city core. There is a recognized opportunity to use existing infrastructure–like streetlights–to apply technology to a broader set of problems, both geographically and by focus.

As work such as this moves out of the design phase, stakeholders need to reexamine problems, such as sidewalk condition, to see if broadly available network connectivity might be of use. For example, if ubiquitous, free internet access is available within the city, data plans for smartphones are of less importance and more people can use technology based channels for municipal interaction.

5.3.3 Gentrification and urban reinvention

As with all cities, Kitchener, Waterloo, and Cambridge change over time. As industries grow or shrink, so does the make up of the residents, the nature of businesses, the decisions of the government, and political direction.

A half century ago, Kitchener was widely regarded as a manufacturing hub. Today, with many of those factories closed, Kitchener and Waterloo are considered a major innovation centre in Canada. The make up of the workforce has changed correspondingly.

With these changes comes changing attitudes about home ownership, car ownership, public transportation, and civic responsibility. Local city planning is increasingly biased towards higher density, mixed use buildings and, as such, younger professionals are opting for condominium living, often without owning cars. This trend may influence how sidewalks are used, what sort of technology those users have access to and are willing to use, and whether they feel a responsibility to maintain civic infrastructure.

As Kitchener's core undergoes gentrification, many of the social support services–which were located there for reasons of easy accessibility via public transit–are being relocated due to increasing rents. As these services are moved outside of the core, the importance of sidewalk condition is paramount. Any solution to gathering and sharing sidewalk condition data needs to work outside of an urban core, with consideration for many types of users: young tech professional, suburban parent, and everything in between.

5.3.4 Social responsibility

Getting people to shovel their driveways is an issue of motivation. But it is also part of our social contract, of living in close proximity to other people who share an investment, via taxes, in society's infrastructure.

This winter, as the region is battered intermittantly by ice and snow, social media is filled with people unable to get where they need to get using sidewalks. Wheelchair users are unable to get onto the public transit they need to navigate the city. In fact, a local advocate feels that "the ability to move safely and freely through a city is a fundamental human right" (Mazumder, 2019).

5.3.5 Normalization of gamification

Gamification of tasks is a relatively recent phenomenon. However, as gamification becomes more widely used and accepted, its use for social motivation becomes more realistic. How might sidewalk condition be improved by incorporating gamification? Some ideas, inspired by existing services include:

- Allowing a resident or business to 'adopt' a section of sidewalk, committing to keeping it clear. This is inspired by everything from 'adopt a hydrant' programs (Code for America, n.d.) to Foursquare's (now deprecated) feature of calling the most frequent visitor to a business its 'mayor' (Foursquare, n.d.).
- Strava, a social network for avid bicyclists and runners, allows for members to create and name various routes. Other members can then see the route on a map, travel it themselves, or talkabout it. Allowing a group of neighbours to define and care for a stretch of sidewalk not only brings people together to care for a common asset, it also motivates people to do their bit so as not to 'break the chain' of that route.

The primary stakeholders for this project represent a distinct subset of the known stakeholder group for sidewalk condition data within a system such as is evident in the Region of Waterloo. Even with such restrictions, the workflows that need to be supported and the types of users in question necessitate two separate modalities: a smartphone app and a web site.

The decision to support two modalities was made to allow for rich data collection when out in the city (smartphone app) but also allow those without a modern smartphone access to the information they need to plan their travel (web site).

The two modalities are described below (*§6.1 SideWaze app* and *§6.2 SideWaze web site*). There are, by design, commonalities between the two modalities, including the use of an incremental 'wizard' to create and submit a sidewalk condition report. This design decision was made so as to not overwhelm someone with a monolithic form; by clustering logically related information, leading the user from page to page, they can focus on the task at hand without distraction. This also has the effect of making individual steps much cleaner and less dense.

The design does not preclude, necessarily, the use of a single backend architecture, serving content and providing business logic for two different 'views' (one the app, another a web site).

6.1 SideWaze app

The SideWaze app is not a lifestyle app. It isn't something one would think of using on a regular basis. But Meaghan, the mother of four mentioned earlier, might keep it installed so that she can let the city know that she can't get her stroller and two young children over the windrow left by the plow at the corner. Or perhaps she'll check to see if there are issues between her house and the primary school she walks her sons to each morning–her younger children need to come, but should she take the stroller or the sled?

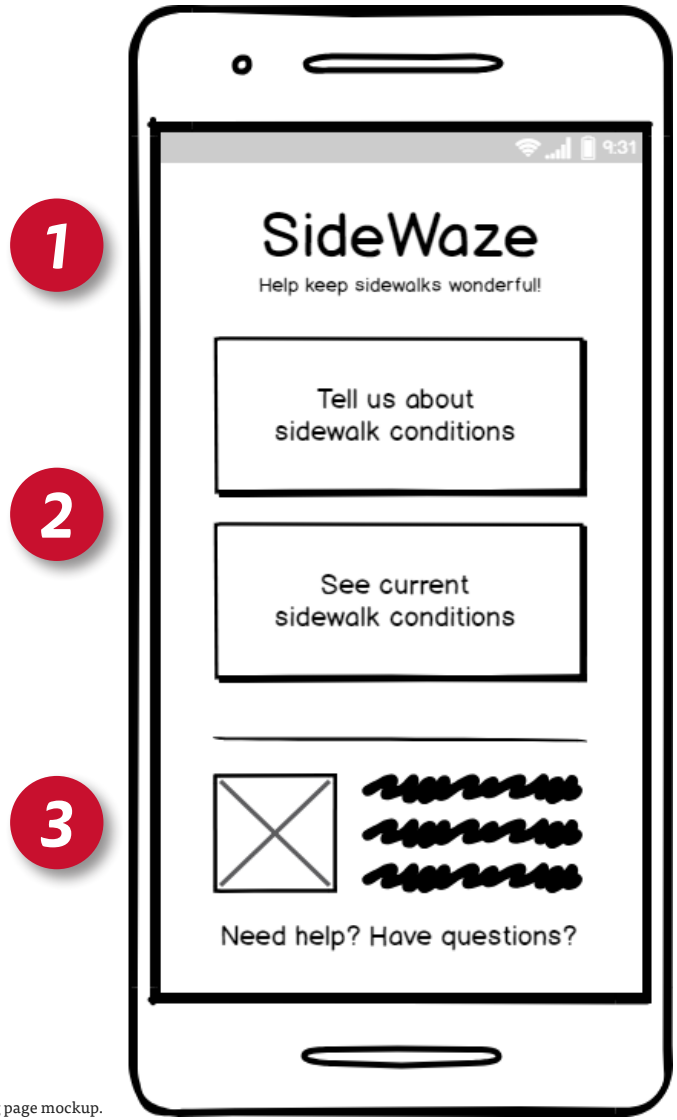

Figure 22. Smartphone app landing page mockup.

6.1.1 Landing page

The initial page presented to the user of the SideWaze smartphone app is intended to:

- succinctly convey the goal of the app (①);
- the core features of the app (②); and
- the organization associated with the app (③).

While some users may use this app on a regular basis (e.g., those sidewalk users who have mobility concerns or use a wheelchair and can use the application to plan travel), it is expected that many users will use it infrequently, to report a particularly frustrating issue. As such, there is no need to bog down the experience with unnecessary copy or authentication.

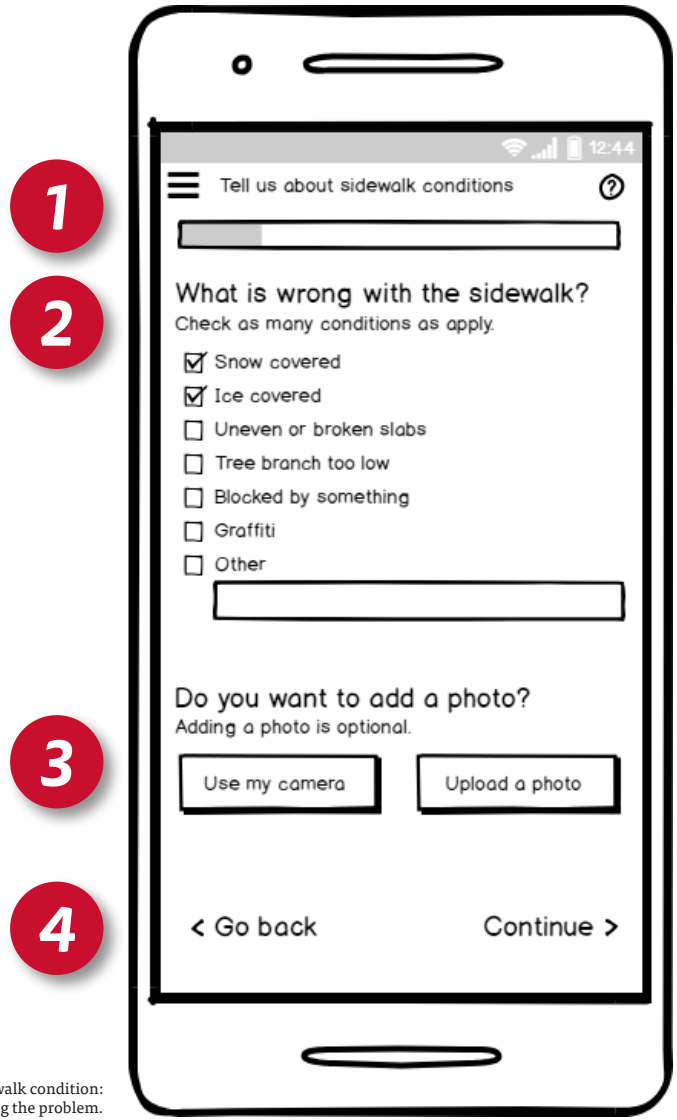

Figure 23. Step 1 in reporting an issue with sidewalk condition: categorizing and describing the problem.

6.1.2 Describing the problem

This screen contains a few elements that are carried throughout the app, including an app menu, breadcrumb, and access to help (①). Specific to the reporting workflow are a progress indicator (①), and workflow navigation buttons (④).

The goal of this screen is to determine the nature of the issue being reported (②) and, if desired, a photo of the environment (③).

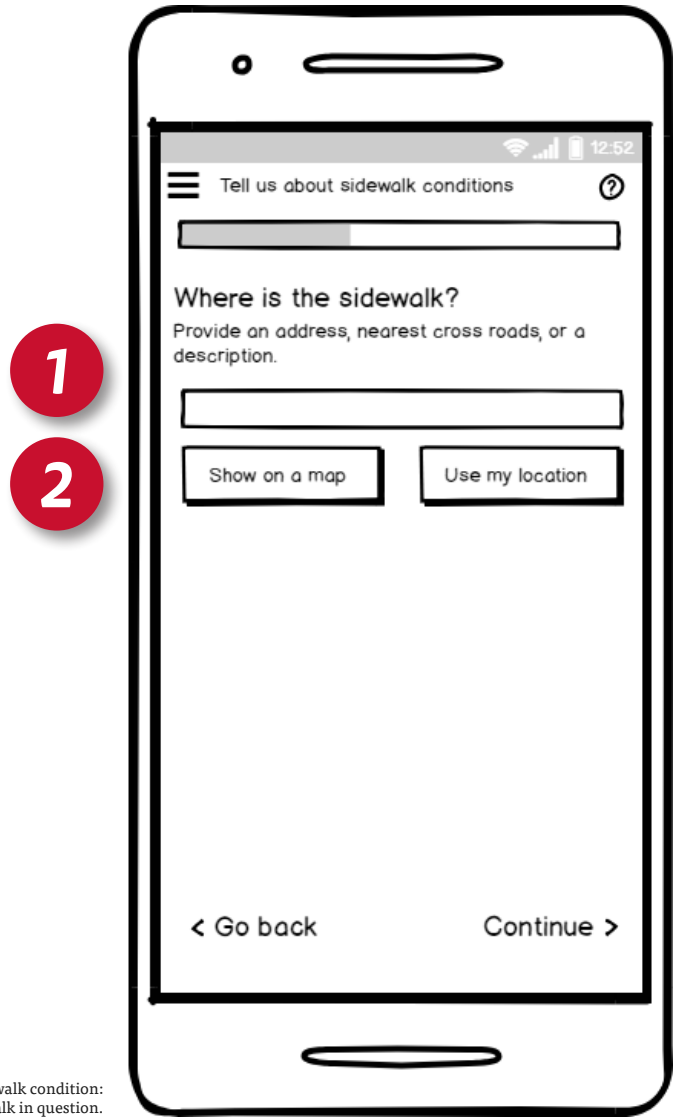

Figure 24. Step 2 in reporting an issue with sidewalk condition: describing the location of the sidewalk in question.

6.1.3 Associating a location

Knowing the location of the sidewalk in question is imperative, as is supporting a variety of ways to describe that location (①). In particular, the SideWaze app should allow users to visually tag the location using a map or the smartphone's current location (via GPS; ②).

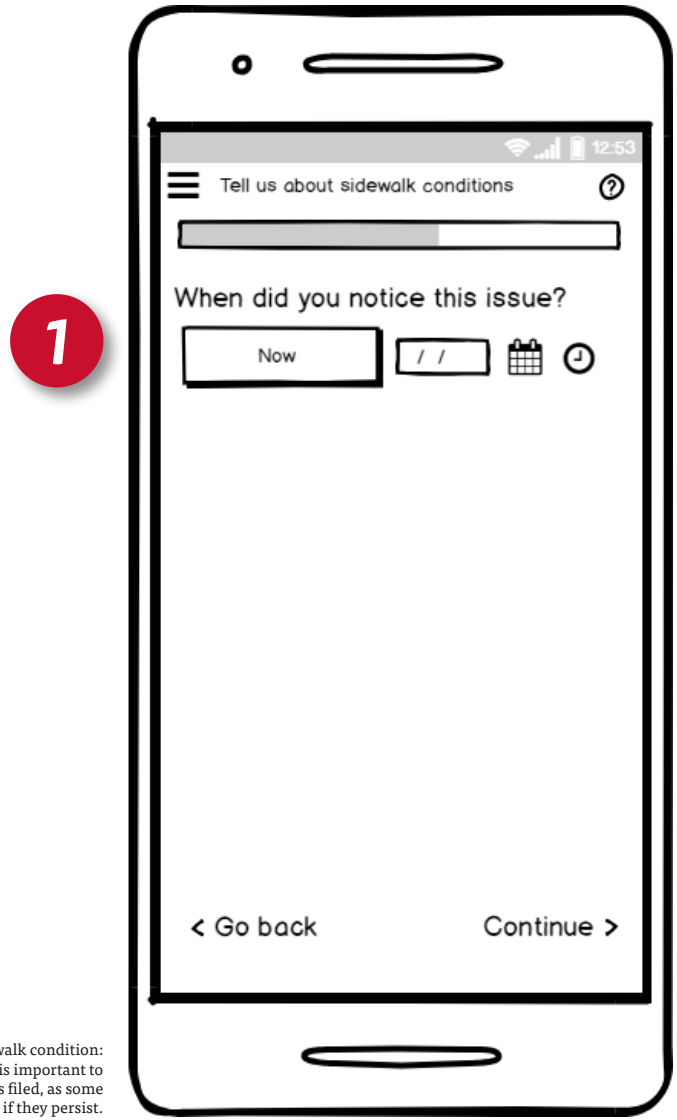

Figure 25. Step 3 in reporting an issue with sidewalk condition: associating a date and time with the report. It is important to capture independently from when the report is filed, as some users may choose to report conditions if and only if they persist.

6.1.4 Timestamping the report

This screen will allow a user to indicate when the issue was observed (①), using a manual date and time picker, or the current device time.

Capturing this information is important because often people give their neighbours a 'grace' period to see if the sidewalk conditions improve. This workflow element also allows users to defer a report until their schedule allows (back from dropping the kids off at school, returning from errands, etc.).

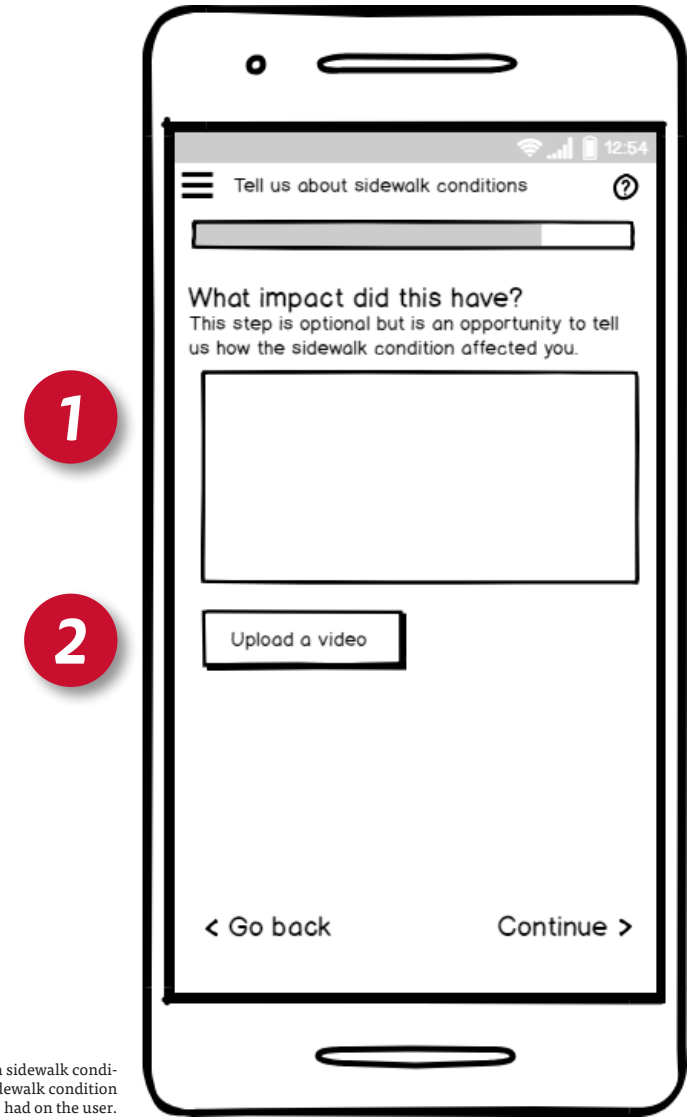

Figure 26. Step 4 in reporting an issue with sidewalk condition: optionally describing the impact the sidewalk condition had on the user.

6.1.5 Describing the impact

When looking at other technology-based solutions that dealt with sidewalk or municipal reporting, none allowed a user to describe the impact of the poor sidewalk condition on their life. This screen allows users to describe the impact by writing (①) or by creating a video (②).

Allowing affected users to describe impact in a way that makes sense to them is important as it informs decision making around active transportation and community well-being. Knowing that someone in a wheelchair had to reschedule a medical appointment because the bus stop wasn't cleared properly is a story decision makers should know (for example; this story was relayed during user research).

Figure 27. Step 5 in reporting an issue with sidewalk condition: confirming your report prior to submission.

6.1.6 Summarizing the report

Prior to submitting the sidewalk condition report, the user is provided with a summary of the information they've submitted. In the same way as Amazon and other online retailers ask you to verify your order prior to final submission, SideWaze will 'read back' the report prior to it being sent on.

A description of the issue, in prose (①), as well as any photos or videos (②) that were uploaded, is provided to the user before they send the report (③).

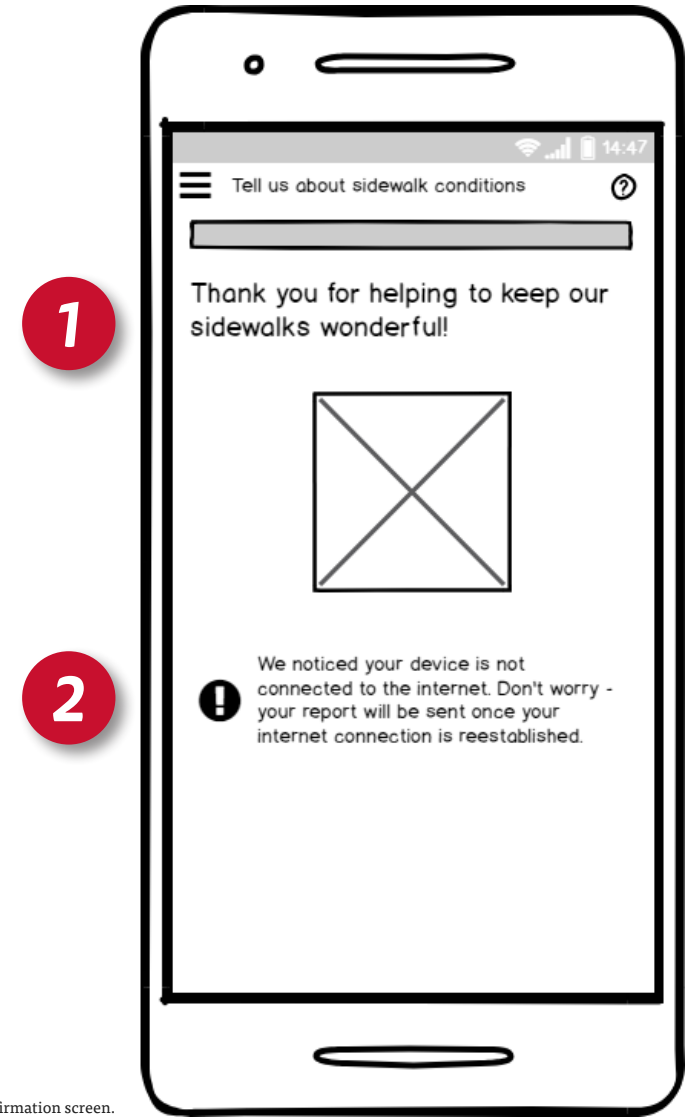

Figure 28. Post-submission confirmation screen.

6.1.7 Confirmation for the user

After reviewing their report and deciding to submit it, this SideWaze screen confirms it was sent on and thanks the user for their contribution (①).

During user research it was noted that several interviewees did not have a data plan for their smartphone and any practical solution which used smartphones would need to work in an offline mode (②).

Figure 29. On the map, known sidewalk condition issues are flagged and identified as open (red) or resolved (green).

6.1.8 Map of sidewalk issues

The other facet of the SideWaze app is the ability to learn about current sidewalk conditions visually, on a map (③). The map displays streets, parks, and so on, but also highlights current open sidewalk condition issues (in red) and recently resolved sidewalk condition issues (in green).

As with the reporting screens, the current sidewalk condition screen contains app menu, breadcrumb, and help button (①). Simple instructions are also provided (②).

User research suggested that there was significant value in presenting sidewalk condition data alongside public transit information. The user has the ability to toggle the display of public transit stops and routes on the map (④).

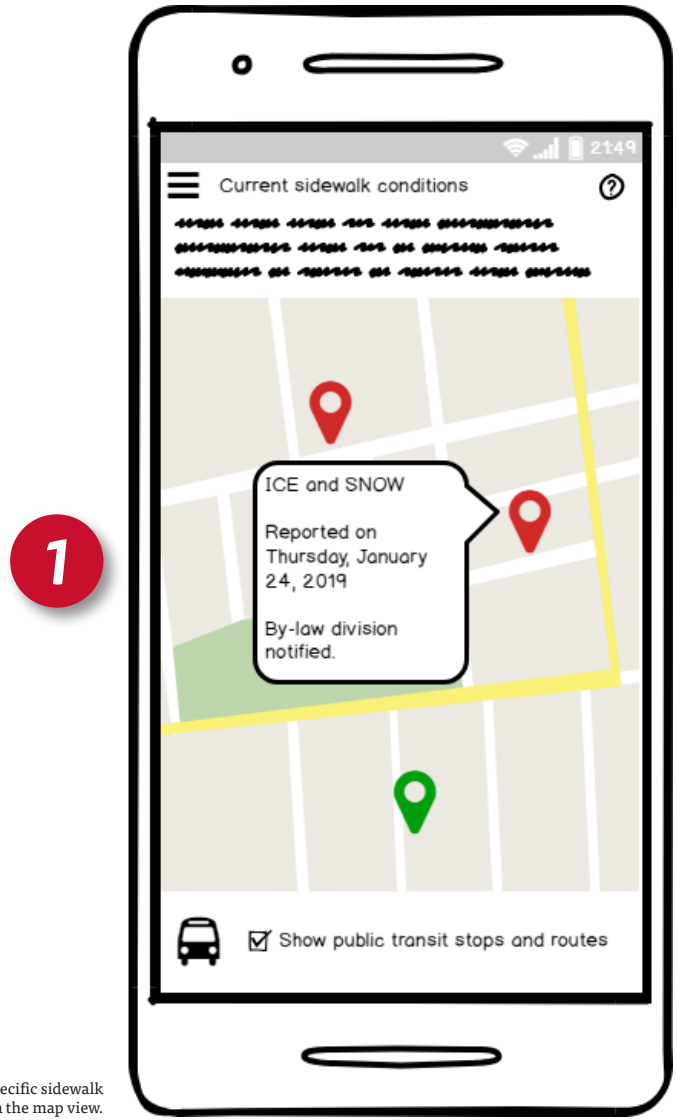

Figure 30. Users may learn more about a specific sidewalk condition issue within the map view.

6.1.9 Information about an issue

Flags on the map represent known sidewalk condition issues. Clicking on the flag will display additional information *in situ* (①).

Information displayed for a given issue will likely mirror that collected, including type of issue, when the issue was reported, and how the issue is being addressed. Knowing the current state of resolution is important for users so that they feel like the work they do is valuable and that their municipal government is capable.

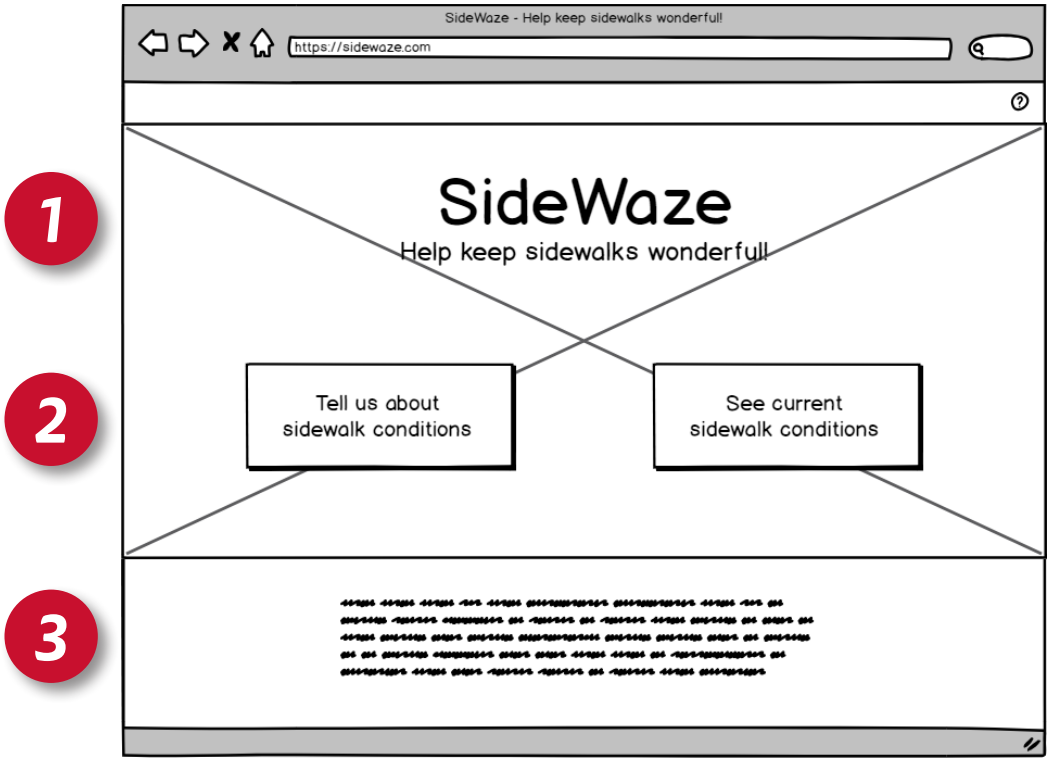

Figure 31. The web site home page.

6.2 SideWaze web site

Edward, the Executive Director mentioned earlier, told of members of his organization having to turn back to their apartments, unable to make it to an appointment or to the grocery store. The problem? A single section of sidewalk that was impassible for a wheelchair. In some cases, individuals would get stuck in the snow or construction and were forced to ask for help from a passerby or call a friend for help.

But what if they could check to see what the sidewalk conditions were before they left their home, in the same way many drivers do with apps like Waze? They could add that additional information to their decision making process and change routes, reschedule an errand, or arrange for an accessible taxi.

6.2.1 Landing page

Like the SideWaze app, the web site provides limited functionality. The landing page describes the goal of the site (①), lists the two features of the site (②), and provides some instruction in case it is needed (③).

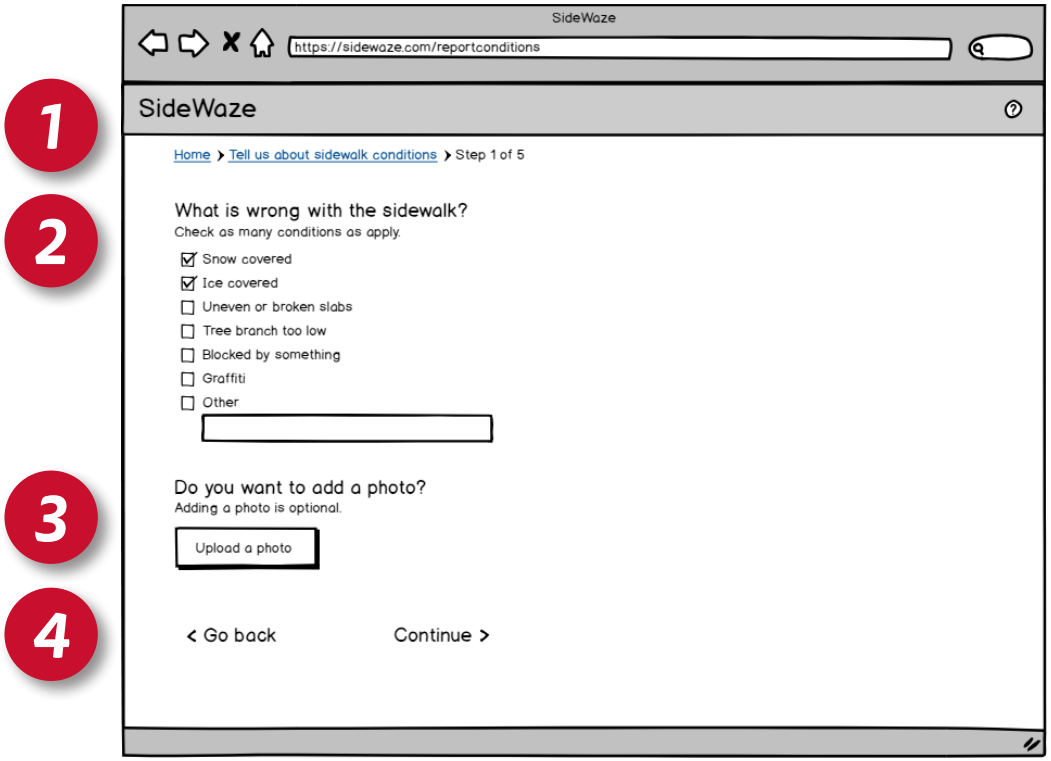

Figure 32. Web site page designed to allow the user to describe the sidewalk condition issue.

6.2.2 Describing the problem

As much as possible, the design of the SideWaze web site mirrors that of the app so that users can transition between the two easily should they need to (and, as already noted, to facilitate a single backend architecture if possible).

Common page features include a breadcrumb for navigation and wayfinding (①), as well as workflow navigation buttons (④).

Users describe the problem by identifying which conditions apply (②) and optionally uploading a photo (③).

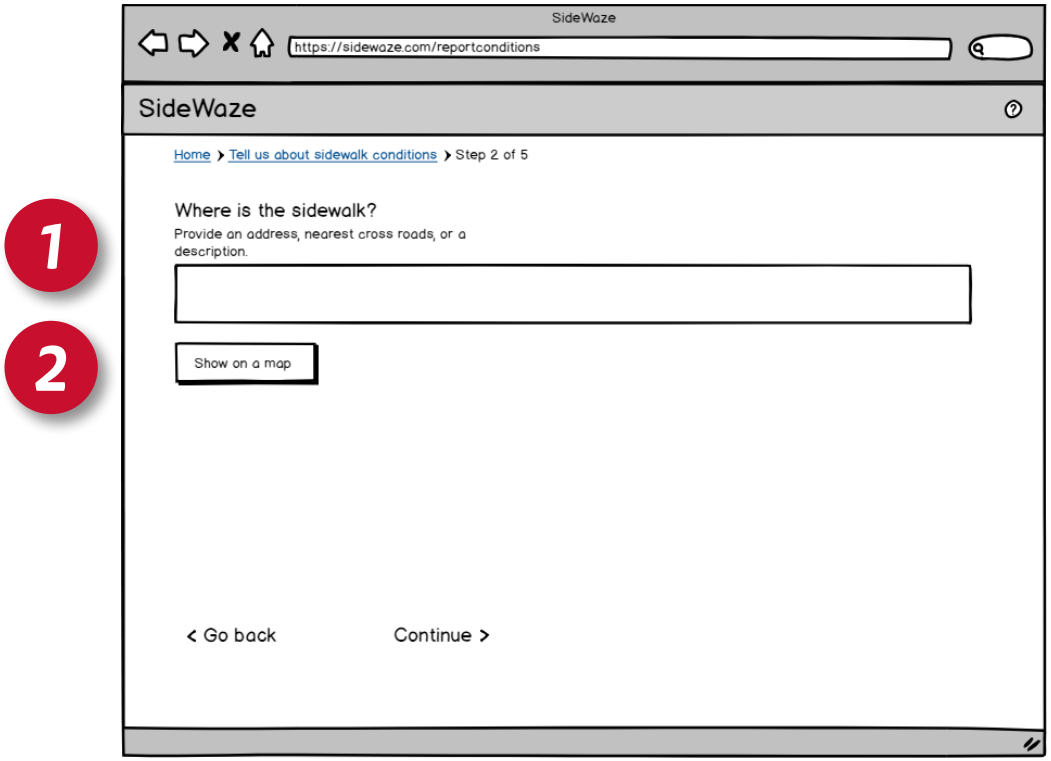

Figure 33. Web site page designed to allow the user to indicate the location of the sidewalk condition issue.

6.2.3 Associating a location

Knowing the location of the sidewalk in question is imperative, as is supporting a variety of ways to describe that location (①). In particular, the SideWaze app should allow users to visually tag the location using a map (②).

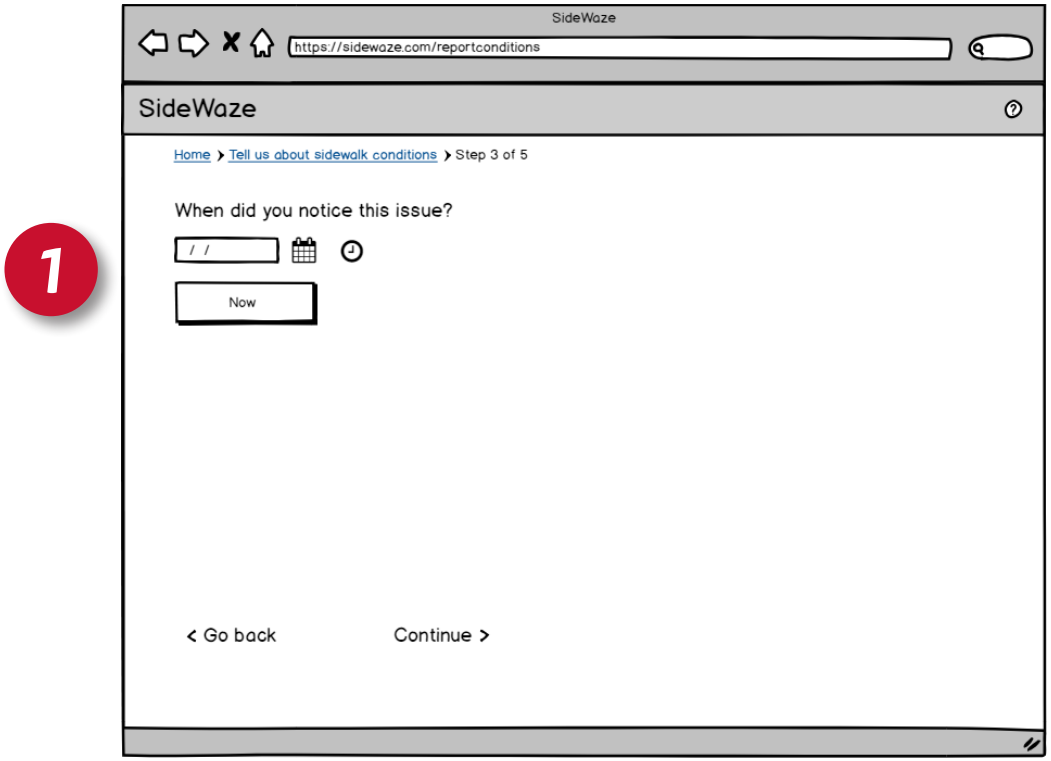

Figure 34. Web site page designed to allow the user to specify when the sidewalk condition issue was observed.

6.2.4 Timestamping the report

This web page will allow a user to indicate when the issue was observed (①), using a manual date and time picker, or the current device time.

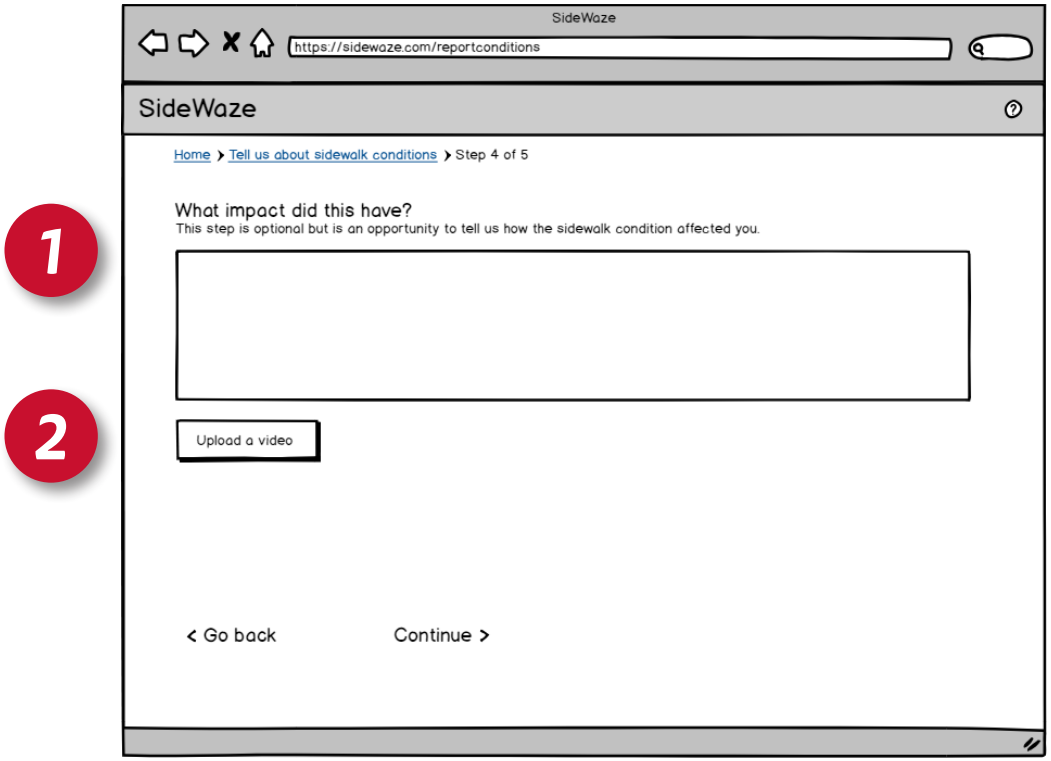

Figure 35. Web site page designed to allow the user to describe the impact of the sidewalk condition issue.

6.2.5 Describing the impact

As with the SideWaze app, the web site will allow the user to submit an impact statement, either as a written description (①), or in an uploaded video(②).

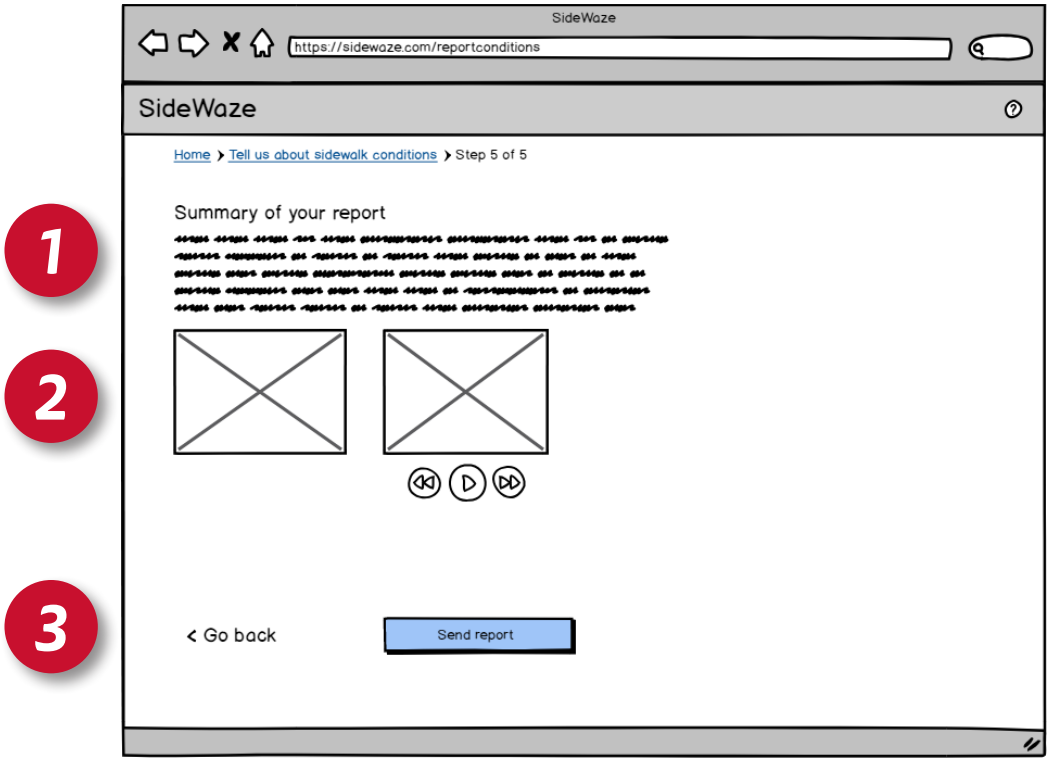

Figure 36. Pre-submission summary web page.

6.2.6 Summarizing the report

Users are provided with a summary of the report information prior to submitting it. A plain language description (①), as well as all photos and videos (②) they've uploaded are included.

A call to action button (③) is provided to send the report.

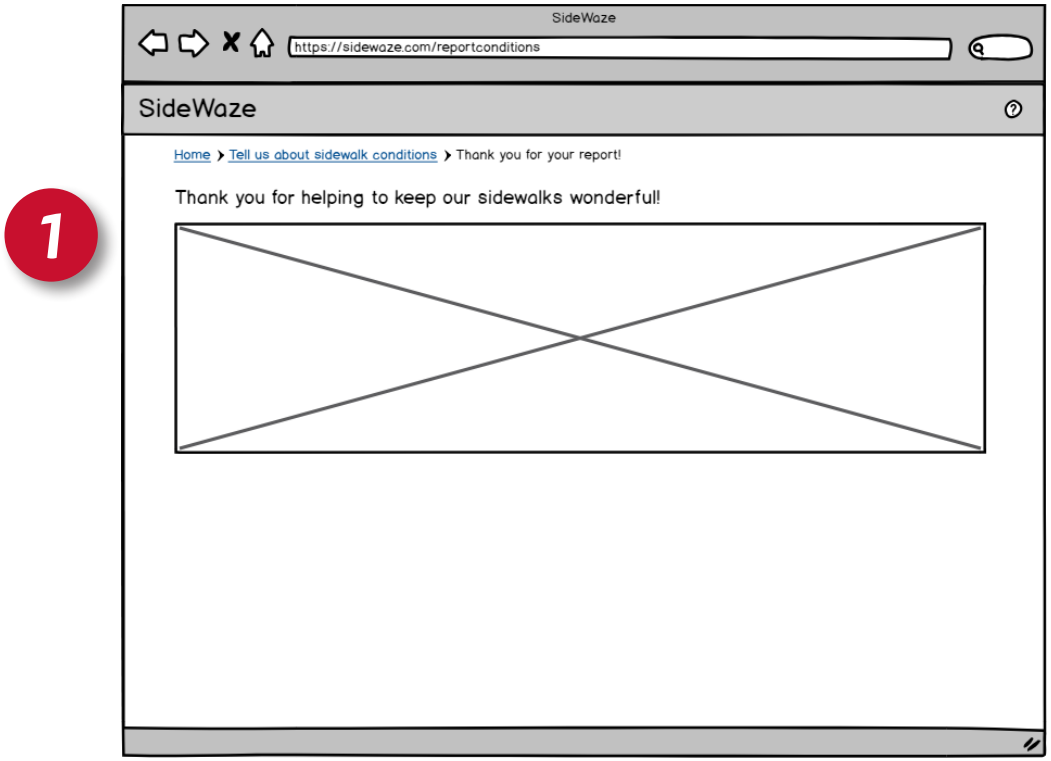

Figure 37. Post-submission thanks and confirmation web page.

6.2.7 Confirmation for the user

After a report has been submitted, the SideWaze web site will confirm receipt of the report and thank the user for their contribution (①).

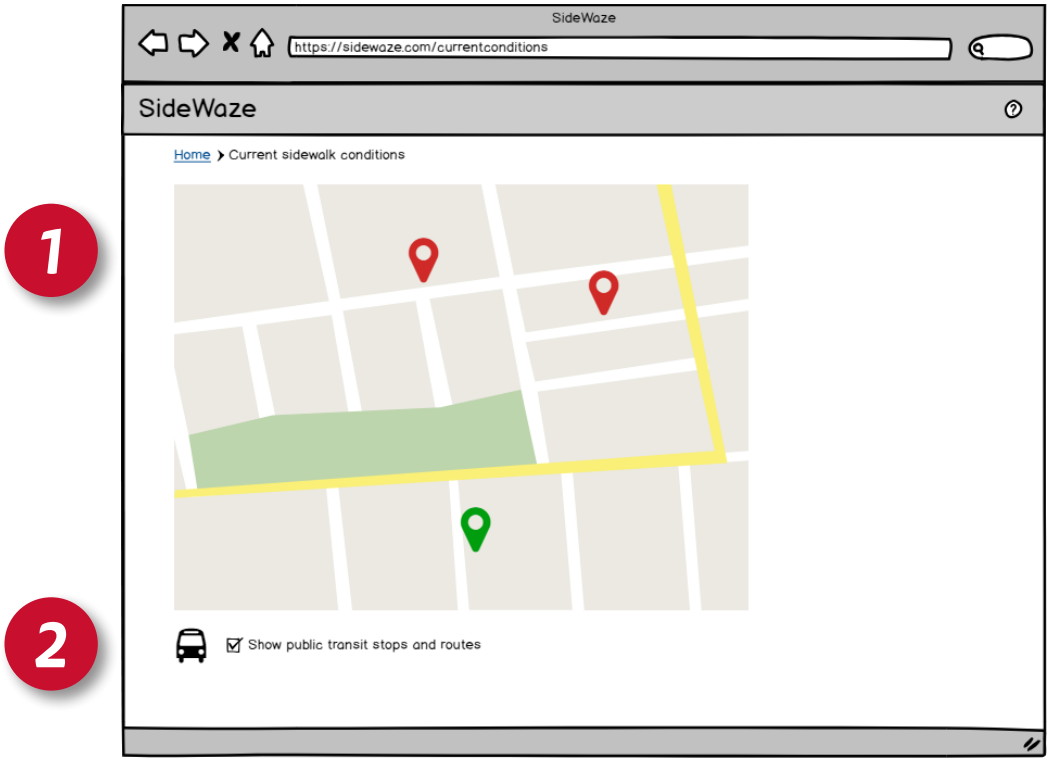

Figure 38. Visual representation of known sidewalk issues on a local neighbourhood map.

6.2.8 Map of sidewalk issues

The other facet of the SideWaze web page is the ability to learn about current sidewalk conditions visually, on a map (①). The map displays streets, parks, and so on, but also highlights current open sidewalk condition issues (in red) and recently resolved sidewalk condition issues (in green).

User research suggested that there was significant value in presenting sidewalk condition data alongside public transit information. The user has the ability to toggle the display of public transit stops and routes on the map (②).

There are two main workflows supported by the prototype smartphone application: submitting sidewalk condition information; and learning about sidewalk conditions.

Each evaluation session involved the following components:

- discussion and signing of the informed consent form;
- brief introduction to the study and its purpose;
- discussion of expectations for the usability tests (speak out loud, try to work through things if you get stuck, we are testing the app and not your performance, etc.);
- running of the usability tests; and
- wrap-up.

7.1 Workflow 1: Submitting sidewalk condition data

The workflow to allow the user to submit sidewalk condition information used a 'wizard' pattern (Tidwell, 2011), presenting multiple screen to facilitate gathering and structuring information.

7.1.1 Approach

Participants were introduced to the study, provided informed consent, and presented with a smartphone running the SideWaze prototype application.

A scenario was given to the participant to provide context. Next, the participant was asked to perform specific tasks.

The participant attempted to complete the tasks, speaking aloud while doing so. If the participant encountered a part of the prototype that was incomplete or non-functional, or if they became insurmountably stuck, the administrator of the test stepped in to provide guidance.

The participants were not timed and were informed that the usability test was not a race.

During the usability test, notes were taken by the administrator if any of the following were observed:

- positive or negative comments about the flow or app design ("Ooh, I like that...", "I don't like...");
- unexpected or unusual questions that hinted at a deficiency in the interface or preferred workflow;
- the participant performed an action that was unhandled beyond the known limitations of the prototype.

The goals of testing this workflow were to identify where users were encountering problems or confusion; where they were experiencing delight or validation; whether the prototype represented a reasonable solution for them and their lives; and to gather additional feedback about the challenge and how it might be addressed (i.e., using the prototype and usability tests as a conversation starter).

Given the current state of the prototype, the well defined workflows, and the expectation that–even within the primary stakeholder group–there would be a diversity of impressions, a usability test was used to evaluate the prototype. This approach also meant that very little training was required for the participant, that the testing could be done in a variety of locations, and that the time commitment for each test was fairly low (approximately 30 minutes per participant session).

The current state of the prototype and its limited functionality outside of the scripted path was such that capturing task completion time was unrealistic.

Rather, using the system usability scale (SUS) allowed for a well rounded assessment of the usability of the prototype for this workflow. The SUS is approachable to users as it uses simple language and non-numerical evaluation.

7.1.2 Testing environment

Minimal specialized equipment was required. A digital audio recorder was used, with permission, to record the test to assist with notetaking.

A Google Nexus 4 Android-based smartphone was used to present the prototype application. Adobe XD was used to create and present the prototype and all files were local to the smartphone. The smartphone was operated in 'airplane mode' to eliminate performance lags caused by

Figure 1. A representative setup for usability testing. Participants were situated on one (far) side while the facilitator was on the other (near). Task cards were presented individually. The audio recorder was located centrally. The smartphone was flat on the table in front of the participant.

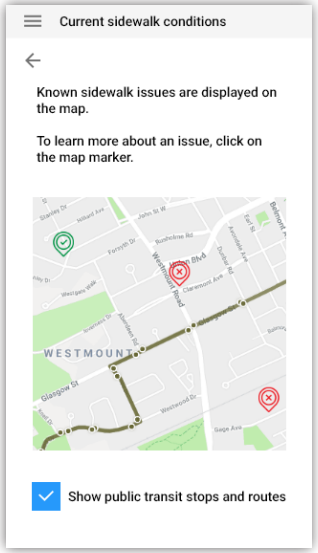

Figure 2. SideWaze prototype interface designed to present sidewalk condition information visually using a two-dimensional map. Markers indicate active issues (red with × icons) and recently resolved issues (green with check icons). The bus route is shown, with stops, in olive green.

network activity and to reduce the chance of notifications distracting the participant.

The prototype application was designed to have a platform-agnostic visual design. That is, it did not appear to be either an iOS- or Android-based smartphone app and no platform-proprietary interface widgets were used.

All usability tests were performed in reasonably quiet locations with large tables (Figure 1). Testing was performed with the smartphone laid flat on a table in order to facilitate observation. Participants were situated on one side of the table with the smartphone. The facilitator was opposite them, managing task cards, taking notes, etc. In the middle of the table was a digital audio recorder.

Each participant session took approximately 30 minutes.

7.1.3 Participants

Six participants (n = 6) were engaged to test the workflow around submitting sidewalk condition data. Four participants were female and two were male. Participants ranged in age from 37 to 76, with a mean age of 47.17 years (s = 14.36).

Participants were chosen from the researcher's network. Attention was paid to having representatives from several elements identified in the primary stakeholder group. In particular:

- one participant was an older adult whose spouse is legally blind (and who uses sidewalks and public transit, with a cane, often);
- two participants were parents of young children and frequent sidewalk users; and
- all participants engaged in active transportation (walking on sidewalks or cycling, etc.) although this was not an experimental variable.

7.1.4 Tasks

This workflow involved nine discrete tasks.

The participant:

- Read and understood a scenario.
- Interpreted the main page of the SideWaze prototype and started the process of submitting sidewalk condition data.
- Indicated the issue was with snow cover.
- Added a photo of the sidewalk to the report.
- Wrote a description of the location of the issue.
- Used a calendar widget to set the date the issue was observed.
- Uploaded a video describing the impact of the sidewalk condition.
- Reviewed a report summary prior to submitting the report.
- Read the confirmation message and returned to the main app page.

7.1.5 Evaluation

After completing the scenario-based tasks for this workflow, participants were given the SUS questionnaire. A brief explanation of the answering system was provided, the participants were given a chance to ask questions, and then given time to answer the questionnaire.

Post-experiment, any notes taken during the session were reviewed and an open coding exercise was performed in order to harvest data and identify insights and patterns.

Using affinity mapping, these insights were clustered around commonalities.

7.2 Workflow 2: Learning about sidewalk conditions

The interface used to share sidewalk condition information was centered around a two-dimensional map presented on a single screen (Figure 2).

7.2.1 Approach

The approach to testing this workflow was very similar to that used to test the 'submitting sidewalk condition data' workflow (see *§7.1.1 Approach*): participants were introduced to a scenario, provided with tasks to perform, asked to speak out loud, informed we were testing the app (not them), and asked to try to solve problems independently as much as possible. Observation notes were taken.

The 'learning about sidewalk conditions' workflow differed in its presentation, however, as it used a single screen (as opposed to a multi-screen wizard pattern used

with the 'submitting sidewalk condition data' workflow). Given the non-linear nature of the interface being tested, the facilitator expected to see participants explore the screen outside of the guidelines presented by the scenario and script.

In cases where the participant did explore the interface (out of order relative to the script and task set), observations became especially important. As with the first workflow usability test, notes were taken by the facilitator if any of the following were observed:

- positive or negative comments about the flow or app design ("Ooh, I like that...", "I don't like...");
- unexpected or unusual questions that hinted at a deficiency in the interface or preferred workflow;
- the participant performed an action that was unhandled beyond the known limitations of the prototype.

As mentioned, this workflow was less of a journey, with a well-defined starting point and destination, and more of an exploration. Correspondingly, the tool to evaluate its usability needed to allow for more flexibility than that provided by an SUS instrument.

The feedback grid was chosen because of its conversational tone and flexibility. It allows the facilitator to gather feedback on four important aspects of system usability: what was liked, what could be improved, questions that were generated, and new ideas that could be evaluated. It also allowed for the participant to let the facilitator know what they really thought of a system, free from the confines of a Likert scale.

With specific reference to this workflow, user research showed that how people plan their travel varies a fair bit. While some may look out the window to see if it is snowing (and opt to drive instead of walk), others might look at different sources of weather and traffic information. In other words, the evaluation instrument needed to be as adaptable as the participants' route planning was varied.

7.2.2 Testing environment

The testing environment for this workflow was identical to that presented in *§7.1.2 Testing environment*.

7.2.3 Participants

The same participants were used to test this workflow as were used to test the submitting sidewalk condition data workflow. See *§7.1.3 Participants* for descriptive statistics and information about the participants.

7.2.4 Tasks

This workflow involved several discrete tasks.

The participant:

- Read and understood a scenario. This required the user to reconcile their location and destination.
- Discovered how to display public transit information on a map.
- Established a mental model for interpreting the maps use of markers to display known and resolved sidewalk condition issues.
- Identified which flagged issues on the map might be relevant to their route planning.
- Learned about an issue displayed on the map.
- Returned to the main SideWaze app screen.

7.2.5 Evaluation

After completing the scenario-based tasks for this workflow, participants were led by the facilitator through a retrospective exercise designed to elicit structured feedback. This process was unscripted but centred around gathering data to populate a feedback grid.

Post-experiment, the contents of the feedback grid and any notes taken during the session were reviewed and an open coding exercise was performed in order to harvest data and identify insights and patterns.

Using affinity mapping, these insights were clustered around commonalities.

8.1 Workflow 1: Submitting sidewalk condition information

8.1.1 SUS results

As provided by study participants (Table 1), the prototype SUS scores had a mean of 88.3, with a range of 77.5 to 95.0 (s = 6.055). By comparison, an SUS score of 85 corresponds to an adjective rating of 'excellent' or a grade scale of a B (Brooke, 2013). Three of the six participants gave the usability of the workflow an A grade.

8.1.2 Affinity mapping

Facilitator observations and participant comments clustered around two themes: *navigation* and *action confirmation*.

The navigation theme referred to elements of the usability related to moving through the workflow. The action confirmation theme referred to how the app informed the user that their actions were legitimate and accepted (or not).

THEME: *Navigation*

- Two users were initially confused by having to click 'Next' in order to progress through the wizard. They both figured it out (after a while) without assistance and were able to use the affordance from then on.
- One user found it odd that the ability to upload a photo was separate from the ability to upload an impact video ("I'd prefer they were connected").
- Prototype 'hit' testing didn't always work for some users. They would have to click multiple times with different finger profiles (pointy, flat, etc.).

THEME: *Action confirmation*

- All six users were confused by the lack of confirmation by the system after having associated a photo or video with the report. They repeated the same action multiple times before concluding no confirmation was coming, and proceeding via 'Next'.

	Participant Responses					
SUS questionnaire questions	P01	P02	P03	P04	P05	P06
1. I think that I would like to use this system frequently.	5	3	5	4	5	4
2. I found the system unnecessarily complex.	1	2	2	1	2	2
3. I thought the system was easy to use.	4	4	5	5	4	5
4. I think that I would need the support of a technical person to be able to use this system.	1	1	1	1	1	1
5. I found the various functions in this system were well integrated.	4	3	4	4	5	5
6. I thought there was too much inconsistency in this system.	1	1	1	1	1	1
7. I would imagine that most people would learn to use this system very quickly.	5	5	5	4	4	5
8. I found the system very cumbersome to use.	4	1	2	1	2	1
9. I felt very confident using the system.	5	2	4	5	4	5
10. I needed to learn a lot of things before I could get going with this system.	1	1	1	1	1	1
Per participant SUS scores	87.5	77.5	90	92.5	87.5	95
Corresponding grade scale	B	C	A	A	B	A

Table 1. Unadjusted, per participant SUS scores. Ideal answers alternate by question (5 is ideal for odd questions, 1 is ideal for even questions). Green represents ideal, white neutral, red poor.

8.2 Workflow 2: Learning about sidewalk conditions

8.2.1 Feedback grid

Table 2 aggregates all feedback provided by participants for each of the four categories.

8.2.2 Affinity mapping

Feedback grid data were combined with the few facilitator observation notes that were taken. Together, they clustered around several themes: *flags*, *system integration*, *prototype limitations*, *information presentation*.

The flags theme referred to elements of the visual representation of known sidewalk condition issues on the map. The prototype limitations theme referred to elements of the app which were not working as planned or incomplete, but which had an influence on the testing. The system integration theme refers to how the application works with other components of a larger system, both human and computer. The information presentation theme referred how the app displayed information.

THEME: *Flags*

- (2×) Colour coding for flags (red to green to fade away) was liked.
- Flag colour and meaning were unclear.
- When do issues get resolved and flags updated?
- Did the green flag mean the issue was resolved?
- Are these flags the known issues or the bus stops?
- What are these flags?
- Green flags might not be enough; what about email, SMS, or app notifications?
- Instead of flags, show a segment of the sidewalk in colour/as being affected.

THEME: *Prototype limitations*

- (2×) Test felt contrived; wish I could zoom map.
- Map location wasn't familiar to me, so test might be 'wrong'.
- Prototype showed same thing if I clicked on red or green flag.
- Suggest alternate routes/routing information.

THEME: *System integration*

- Would I need to authenticate/login to this app?
- Who marks issues as resolved; app users or the city?
- Would this be as quick as calling in?
- Can we show colour coding for roads as well?
- What if we could contribute/add data to an existing issue?
- Upvoting to validate (or invalidate) an issue.
- Display bus stop information and times.

THEME: *Information presentation*

- (2×) Ability to see known issues visually was liked.
- The data appears to be timely/up to date.
- (2×) Bus routes are presented visually was liked.
- Glad the bus routes can be toggled.
- Intuitive that all the data is shown on one screen; no need to flip around.
- Language is simple and easy to understand.
- System is similar to other mapping applications, so I can apply learned knowledge from them.
- Good 'mashup' of both sidewalk condition and public transit information.
- Helpful to have info visually; I can reroute and relative to bus routes as well.
- It is hard to see where the bus stops are; too small.
- Bus route (when shown) was hard to see.
- Map wasn't explicitly north/south oriented.
- Bus stops should have a dedicated icon (not just a small circle).

FEEDBACK GRID

Tell us what you think.

Like

(2×) Ability to see known issues (e.g., ice).
(2×) Colour coding for flags (red to green to fade away).
The data is timely/up to date.
Routes are presented visually.
Showing bus routes is great, and glad it can be toggled.
Intuitive that all data is shown in one screen; no need to flip around.
Language is simple.
Similar to other mapping apps, which is easy to learn.
Good mashup/display of both sidewalk and transit information.
Issue categorization seems 'right' (just enough detail).
'Helpful' to have info visually–I can reroute, and relative to bus routes too.

Improve

Test felt contrived. Would have liked to have ability to play more (zoom, etc.)
Wasn't familiar with location, so test might be 'wrong'.
Prototype didn't distinguish between clicking on red flag or green flag; was confusing.
Issue categorization should be more detailed for winter (not just snow and ice).
Prototype should support zooming; this is limiting.
It is hard to see where the bus stops are; they are too small!
Bus route (when shown on the map) was hard to see/notice.
Flag colour and mapping to meaning was unclear.

Questions

When do issues get 'resolved'? Do flags change?
Was this map oriented north/south? It should be explicit.
What about authentication? (would trade volume of data for need to authenticate)
Did green flag mean the issue was resolved?
Are these flags the known issues or the bus stops? I want to zoom to see.
Who marks issues as resolved; people using the app or the city?
Would this be as quick as calling it in? App is only useful if timely.
What are these flags?

New Ideas

Can we show colour coding for road condition as well?
(2×) What if we could contribute/add data to an existing issue?
Upvoting to validate (or invalidate) an existing issue.
Issue categorization should include shrubbery (blocks views around corners).
Green flags might not be enough; what about email, SMS or app notifications?
Display bus stop information and times.
Suggest alternate routes to avoid issues.
Bus stops could have a dedicated icon (not just a small circle).
Instead of flags, show a segment of the sidewalk as being affected.

Overlap Associates_

Table 2. Aggregate enumeration of feedback provided by all participants using the feedback grid instrument.

9.1 Conclusion

The usability test data suggested that:

- As a system, **participants felt the prototype app was very easy to use**, with a high average SUS rating.
- The **prototype app should acknowledge photos and videos being uploaded**. All users identified this, either explicitly or by confusion, as a significant problem.
- **Presenting sidewalk conditions visually and spatially on a map resonated with users** and allowed them to apply learned knowledge and patterns from other systems.
- The use of **flags to communicate sidewalk condition was not universally understood**. Given they form a critical part of the information visualization, they should not be considered successful in their current form.
- The **reporting workflow may need to be simplified**, as it seemed cumbersome to some users. This is especially relevant if we consider the need for high volume data entry by users.

Primary stakeholder user research identified two key workflows; the prototype supported them both with a few exceptions.

9.2 Design implications

Considering the data gathered through usability tests, the following design changes should be considered:

- Several options exist for the display of sidewalk condition information on a map (flags, segments, different colours/icons, etc.). Multiple, incremental designs should be explored, prototyped, and tested to move closer to a design that is more universally understood, more quickly.
- All user actions should be confirmed in some way; this was a significant shortcoming of the prototype as tested. Platform guidelines (e.g., iOS guidelines, Android Material Design guidelines) should be followed or, in the absence of any guidance, comparable products should be examined to utilize learned knowledge (e.g., What does Google Maps do?).
- The current prototype is not designed for high volume reporting. Future iterations should explore either forking workflows (e.g., beginner vs. advanced) or, if research supports it, separate systems. For example, if postal workers were recruited to submit sidewalk condition information, would they need a dedicated workflow? (e.g., speech interface, tactile interaction with an smartwatch, etc.).
- A research question for this work was to determine if crowdsourcing could help with the collection and sharing of sidewalk condition data. After developing and testing the prototype app, users echoed this concern, worried about coverage and timeliness of the data; as well as the time required to submit a single report. Users felt that if coverage wasn't timely and near universal, they might not be confident in the app (exclusively).
- As a general rule, the size of interface widgets should be increased before further prototype testing. Users were observed struggling with hitting some smaller widgets (e.g., check boxes, 'Next' button).
- Integrations with other parts of the sidewalk ecosystem are key. This was hinted at by some users ('who would update the status of an issue?') but, from an architectural viewpoint, is critical for such a solution to be useful in a variety of situations and by different users, scalable across differently sized installations, and replicable across a country with its variety of municipalities.

Considered in isolation, the SideWaze prototype app fared well during usability testing (with the exceptions noted above). Revisiting the goals of this research puts the app into a different context, however. Should this work continue, a change in focus would be prudent: away from the end user technology to the systems, needs, and data flow of the supporting organizations (call centres, city departments, etc.).

9.3 Process reflection

The processes used to evaluate the two workflows of the prototype seemed reasonable and effective. By using a combination of qualitative (feedback grid, open coding

of notes) and quantitative (SUS) methods, it seemed as if a good variety of feedback was captured in an efficient manner. While the prototype was the subject of the evaluation, given this was the first time it was shown to users, it was appropriate to allow for aspects of user research as well (to guide further development beyond that provided by the SUS questionnaire).

The number of participants was appropriate for a prototype of this maturity. While it is always tempting to iterate on feedback from as few as one participant, testing with a handful of participants is advised, with the maximum benefit/cost ratio occuring with four participants (Nielsen and Landauer, 1993).

The tools used to create and test the prototype were stable and effective. While Balsamiq was used to create the wireframes earlier in the project, Adobe XD was used to create testable digital prototypes. It was important to be able to demonstrate the prototype on an actual smartphone and, ideally, without having to rely on a network connection to a cloud-based document; Adobe XD provided both features. As the prototype evolves, work can continue using this tool given its ability to model functionality at a reasonably high fidelity.

Investing in the development and play testing of scripts and artifacts (scenario and task cards, informed consent document, etc.) for the usability tests was time well spent. This process identified gaps, flow issues, and opportunities to either tighten up or relax evaluation methods (e.g., the formality of the SUS questionnaire versus the conversational approach of the feedback grid).

Adopt-a-Hydrant. (n.d.) Retrieved from http://www.adoptahydrant.org/

Brooke, J. (2013). SUS: A Retrospective. *Journal of Usability Studies*, 8(2), 29-40.

City of Kitchener. (2017). Digital Kitchener [PDF file]. Retrieved from https://www.kitchener.ca/en/resourcesGeneral/Documents/COR_TIS_Digital-Kitchener-Strategy.pdf

Code for America. (n.d.) *Adopt-a-Hydrant - Code for America*. Retrieved from https://www.codeforamerica.org/past-projects/adopt-a-hydrant

Durão, L.F.C.S., Kelly, K., Nakano, D.N., Zancul, E., & McGinn, C.L. (2018). Divergent prototyping effect on the final design solution: the role of "Dark Horse" prototype in innovation projects. Procedia CIRP 70 (2018) (pp. 265-271).

Erraguntla, M., Delen, D., Agrawal, R. K., Madanagopal, K., & Mayer, R. (2017). Mobile-Based Sidewalk Inventory App for Smart Communities, Health, and Safety. *Suburban Sustainability*, 5(1).

Foursquare. (n.d.) In *Wikipedia*. Retrieved February 2, 2019, from https://en.wikipedia.org/wiki/Foursquare#Former_features

Lim, Y., Pangam, A., Periyasami, S., & Aneja, S. (2006). *Comparative Analysis of High- and Low-fidelity Prototypes for More Valid Usability Evaluations of Mobile Devices*. In Anders Mørch, Konrad Morgan, Tone Bratteteig, Gautam Ghosh, and Dag Svanaes, Paper presented at the 4th Nordic conference on Human-computer interaction: changing roles (NordiCHI '06) (pp. 291-300). New York, NY: ACM. http://dx.doi.org/10.1145/1182475.1182506

Lim, Y., Stolterman, E., & Tenenberg, J. (2008). *The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas*. ACM Transactions on Computer-Human Interaction, 15(2), Article 7. http://dx.doi.org/10.1145/1375761.1375762

Lu, Y., & Karimi, H. (2015). Real-Time Sidewalk Slope Calculation through Integration of GPS Trajectory and Image Data to Assist People with Disabilities in Navigation. *ISPRS International Journal of Geo-Information*, 4(2), 741-753.

Mazumder, R. (2019, February 16). Sidewalk Snow Clearance is a Human Rights Issue [Blog post]. Retrieved from https://medium.com/@robinmazumder/sidewalk-snow-clearance-is-a-human-rights-issue-ec8d798b64de

Mobasheri, A., Sun, Y., Loos, L., & Ali, A.L. (2017). Are Crowdsourced Datasets Suitable for Specialized Routing Services? Case Study of OpenStreetMap for Routing of People with Limited Mobility. *Sustainability*, 9(6), 997. https://doi.org/10.3390/su9060997

Nielsen, J., & Landauer, T.K. (1993). A Mathematical Model of the Finding of Usability Problems. In *Proceedings of the INTERACT '93 and CHI '93 Conference on Human Factors in Computing Systems (CHI '93)* (pp. 206-213). New York, NY, USA: ACM. DOI: https://doi.org/10.1145/169059.169166

REEP Green Solutions Adopt a Storm Drain Map. (2017) Retrieved from http://rainmaps.ca/reep.html

Snow Moles. (n.d.) Retrieved from https://coaottawa.ca/snowmoles/

Sauer, J., & Sonderegger, A. (2008). The influence of prototype fidelity and aesthetics of design in usability tests: Effects on user behavior, subjective evaluation and emotion. *Applied Ergonomics*, 40(2009), 670-677.

Sim, G., Horton, M., & McKnight, L. (2016). *iPad vs Paper Prototypes: Does Form Factor Affect Children's Ratings of a Game Concept*? Paper presented at the 15th International Conference on Interaction Design and Children (IDC '16) (pp. 190-195). New York, NY: ACM. https://doi.org/10.1145/2930674.2930720

Soute, I., Lagerstrom, S., & Markopoulos, P. (2013). *Rapid Prototyping of Outdoor Games for Children in an Iterative Design Process*. Paper presented at the 12th International Conference on Interaction Design and Children (IDC '13) (pp. 74-83). New York, NY: ACM. http://dx.doi.org/10.1145/2485760.2485779

Spool, J.M., Snyder, C., & Robinson, M. (1996). Smarter Usability Testing: Practical Techniques for Developing Products. In Michael J. Tauber, paper in Conference Companion on Human Factors in Computing Systems (CHI '96) (pp. 365-366). New York, NY: ACM. http://dx.doi.org/10.1145/257089.257375

Sellen, K.M., Massimi, M.A., Lottridge, D.M., Truong, K.N., & Bittle, S.A. (2009). *The people-prototype problem: understanding the interaction between prototype format and user group*. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '09) (pp. 635-638). New York, NY: ACM. https://doi.org/10.1145/1518701.1518799

Tidwell, J. (2011). *Designing Interfaces, Second Edition*. Sebastopol, CA: O'Reilly Media Inc.