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Improving Park Maintenance Efficiency Using a Mobile Application

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ABSTRACT

This article describes the construction and evaluation of a mobile application for use by park maintenance personnel that features an interactive map allowing for real time positioning of the user in relation to equipment locations, and the ability to create, view, and edit maintenance logs. The application was evaluated by the Park Services department of the City of Kelowna in Kelowna, British Columbia, Canada. The results of the study demonstrate that numerous tasks, especially locating equipment and logging maintenance, can be more efficient using mobile technology. Further, technicians are receptive to the introduction of technology in their work schedules and find it easy to integrate into their routines. An analysis of the time savings shows that the technology may save technicians 15 to 50 minutes daily which translates to thousands of dollars annually in savings per technician and increased productivity rates.

KEYWORDS

GPS, iPad, Irrigation Technician, Kelowna, Maintenance, Mapping, Mobile Technology, Park Infrastructure

INTRODUCTION

Technology has allowed for increased efficiency and productivity in many tasks. Although industrial technologies for irrigation management including wireless and programmable controllers have reduced the amount of manual work done by park maintenance personnel, there are many other daily maintenance tasks that may be more efficient to perform with the aid of technology. This article describes the construction and evaluation of a mobile application for use by park maintenance personnel. The application provides information about the parks, including the irrigated areas, historic and expected water usage, and the global positioning system (GPS)

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locations and layouts of equipment. The application also features an interactive map allowing for real time positioning of the user in relation to equipment locations, and the ability to create, view, and edit maintenance logs for each park. The usefulness of this iPad application to log maintenance, quickly find infrastructure in the field, and communicate with others was evaluated by the Park Services department of the City of Kelowna in Kelowna, British Columbia, Canada. With over 300 unique irrigation sites and a staff of six full-time irrigation technicians, the size of the department allowed for a comprehensive field study and data collection. In addition to determining the speed tasks were performed with and without the iPad technology, technicians were surveyed about their attitudes and capabilities of using technology for their work. The introduction of technology into a workplace must consider both efficiency and worker satisfaction to be effective. The results of the study demonstrate that numerous tasks, especially the locating of equipment and logging of maintenance, can be more efficient using mobile technology. Further, technicians are receptive to the introduction of technology in their work schedules and find it easy to integrate into their routines. An analysis of the time savings shows that the technology may save technicians 15 to 50 minutes daily which translates to thousands of dollars annually in savings per technician and increased productivity and satisfaction rates. The use of technology is especially beneficial for new technicians, which often occurs due to high turnover in these positions. The contributions of this work are the construction of a mobile park management application for field workers allowing for efficient discovery and maintenance of equipment in the field, and a field evaluation of the system with maintenance employees on realistic tasks related to their daily activities. To our knowledge, this is the first such evaluation of a mobile application for park maintenance personnel to determine if the introduction of technology is positive for their performance. The City of Kelowna has been using the Site Manager starting in 2015, and the technology would be useful for other cities, park maintenance organizations, and golf courses.

BACKGROUND

Commercial products by vendors such as Toro and Rainbird allow for controlling irrigation systems using wireless technologies. These systems when applied correctly can significantly reduce water consumption and manual technician intervention for irrigation activities. In (Fazackerley, Campbell, Trenholm, & Lawrence, 2012), the authors described an adaptive irrigation control system that uses wireless soil moisture sensors to measure water content in the soil and dynamically calculate the watering requirements based on those readings. The adaptive irrigation system reduced water usage by 50% when use in a city park which had a weather-based controller. In (Zhao, Bai, & Zhao, 2007), the authors describe an automated irrigation system that calculates and applies water to green spaces. The authors successfully tested the system in a green space located on the campus of Beijing Forestry University for six months.

In comparison to automating irrigation tasks, there has been considerably less research and commercial systems for improving the efficiency of maintenance workers for other on-site tasks. In (Fan, Xu, & Chen, 2013), the authors present an iPad application for road maintenance and management in China to allow managers and field workers to make better decisions and manage roads better, particularly in the more remote areas of China. In (Zhong-Xiao & Yimit, 2009), the authors developed a decision support system for sustainable irrigation water usage. The system features knowledge integration and machine learning analysis of weather, soil moisture, and water availability data from three environmental sensor databases to calculate suggested daily irrigation watering requirements for farming areas in Australia. (Kim, Park, Lim, & Kim, 2013) describes a system to help management and planning on construction sites, and (Kim, Lee, Lee, & Choi, 2013) demonstrates how augmented reality and mobile technology can be applied for construction sites.

Previous studies relate to using computer technology in the office but do not evaluate mobile technology for park maintenance workers. Specifically, despite many organizations collecting spatial and GPS data on infrastructure, this data is rarely conveniently used by field technicians. For example, GIS systems were used to collect information about parks in (Nedovic-Budic, Knapp, & Scheidecker, 1999) and (Nicholls, 2001), but the data collected was used for planning, not by technicians in the field.

CITY OF KELOWNA PARK SERVICES

The City of Kelowna Park Services department maintains over 300 unique irrigation sites including city parks, green spaces, beach accesses, sports fields, and road medians. The irrigation systems typically run from mid-April through the summer months until the end of September when the systems are shut down for the winter. The department has six full-time technicians, whose responsibilities include the management and maintenance of irrigation equipment. These employees have become very knowledgeable about the parks they regularly maintain, including layout of irrigation zones and equipment, the different types of equipment that works best for various landscapes and plants, any trends in water usage, and irregularities such as recurring wet or dry areas in the parks. However, since each employee can be responsible for up to 80 individual irrigation sites, it takes a significant amount of time for them to become knowledgeable about each of the parks they maintain, and they often know very little when it comes to the other parks outside of their regular responsibilities. Technicians may visit up to 20 parks during their workday to perform the routine maintenance activities required. Tasks that technicians perform include:

- Locating major pieces of equipment and irrigation lines;
- Identifying any problems or malfunctions with the irrigation system;
- Repairing or replacing damaged and worn-out equipment;

- Determining watering requirements for turf and plants;
- Ensuring new installations have minimal impact on equipment.

A challenge the Park Services department faces is a high turn-over rate of employees. New employees spend a significant portion of their time learning about each park they are responsible for, particularly during the first few months. Due to this frequent transition of new employees and a steep learning curve, years can go by before fundamental issues at a park are identified and properly addressed, such as modifying the irrigation zone layout at a park to provide better coverage and reduce unnecessary water waste. The costs of employee turn-over including replacement and training costs was studied by (McKinney, Bartlett, & Mulvaney, 2007), and these costs may be able to be reduced by leveraging technology.

Despite limited resources, the City of Kelowna and the Park Services department are committed to sustainability in city parks including reducing water consumption by deploying flow meters, weather stations, and adaptive irrigation controllers. The goal for introducing a mobile application is for field workers to have up-to-date info on parks, otherwise this results in delay in activities, less efficient work, and unnecessary water waste. Also, management needs accurate information on work performed and costs for planning purposes.

Site Manager – Mobile Management Application

A cloud-based mobile management application called Site Manager was developed for the Park Services department and its technicians. While the layout of the application was optimized for the Apple iPad, the application works on desktop computers and internet-capable mobile devices including smart phones. This allows for flexibility on the hardware used in the field. Site Manager is a web-based application that is accessible using any web browser. It was built using a MySQL database and an Apache web server running PHP. The user interface uses the Google Maps API, JavaScript, and dynamic, AJAX interactions with the server.

Park information and irrigation data were collected and integrated into the application, including the current, historic, and expected water usage for parks with irrigation meters and details for each park such as address, irrigated area, category classification, and water supplier. Over a year and half, the GPS locations of all equipment in the parks were collected by researchers and employees.

The key goals of the application were to aid field employees with maintenance activities and decisions in the parks and allow managers to generate dynamic reports and charts. The development was performed over a period of two years. System features include:

- Site searching, browsing, and details;
- Google Maps visualization of site equipment and features;
- Logging of site maintenance including text and images;
- Equipment inventory;

- User and role-based management and security;
- Data import and export for system interoperability;
- Customizable reporting.

When an employee is at or planning to visit a park, the employee is able to use the application to view site details including its location, installed equipment, and maintenance log. In Figure 1 is a screenshot showing park details. The technician can also log maintenance from this screen.

When logging maintenance (Figure 2), users can categorize the maintenance and include pictures and notes. This avoids paper logging processes and makes it easier to analyze trends on parks requiring more maintenance for planning purposes. Further, the maintenance log is available to all employees to help users understand past maintenance immediately when they are on site.

The equipment overlay map (Figure 3) is a key feature for field technicians. This map displays the location of all the equipment in the park and the user's current location as a blue compass icon that moves across the screen as the user moves the

Figure 1. Park detail view

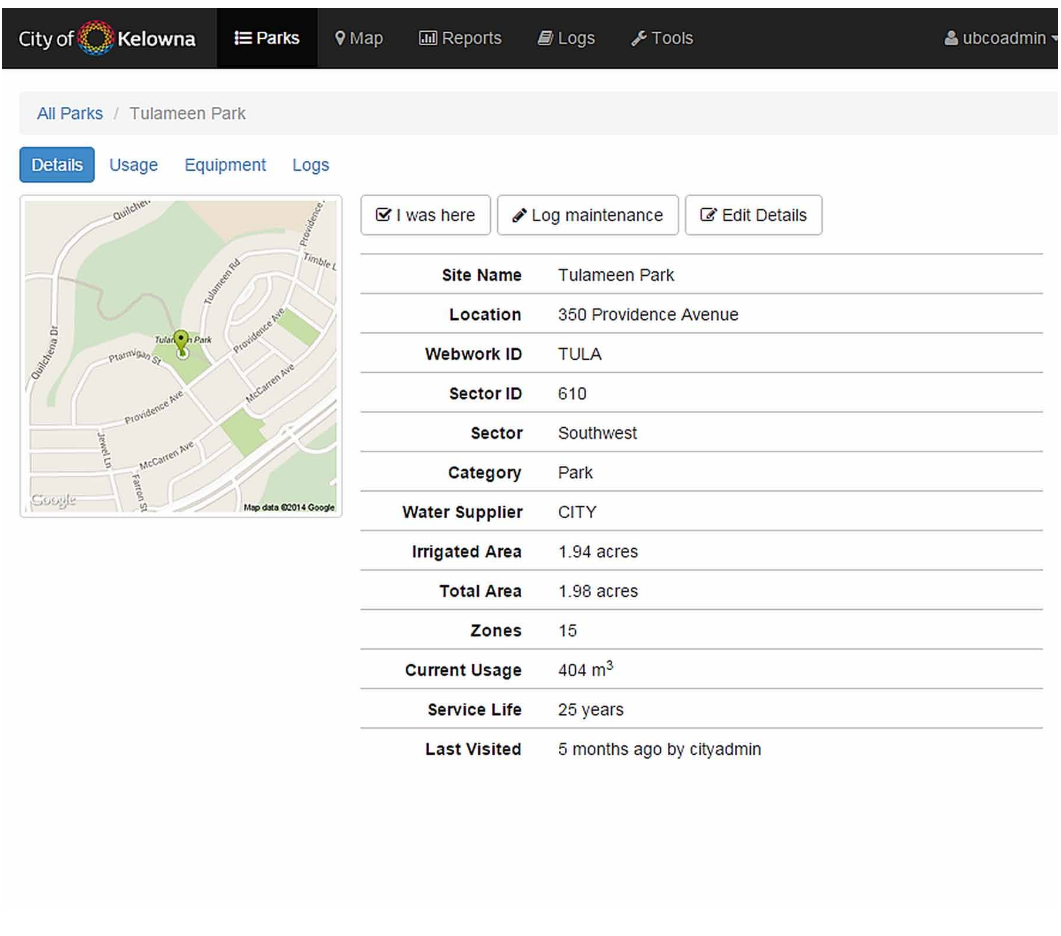
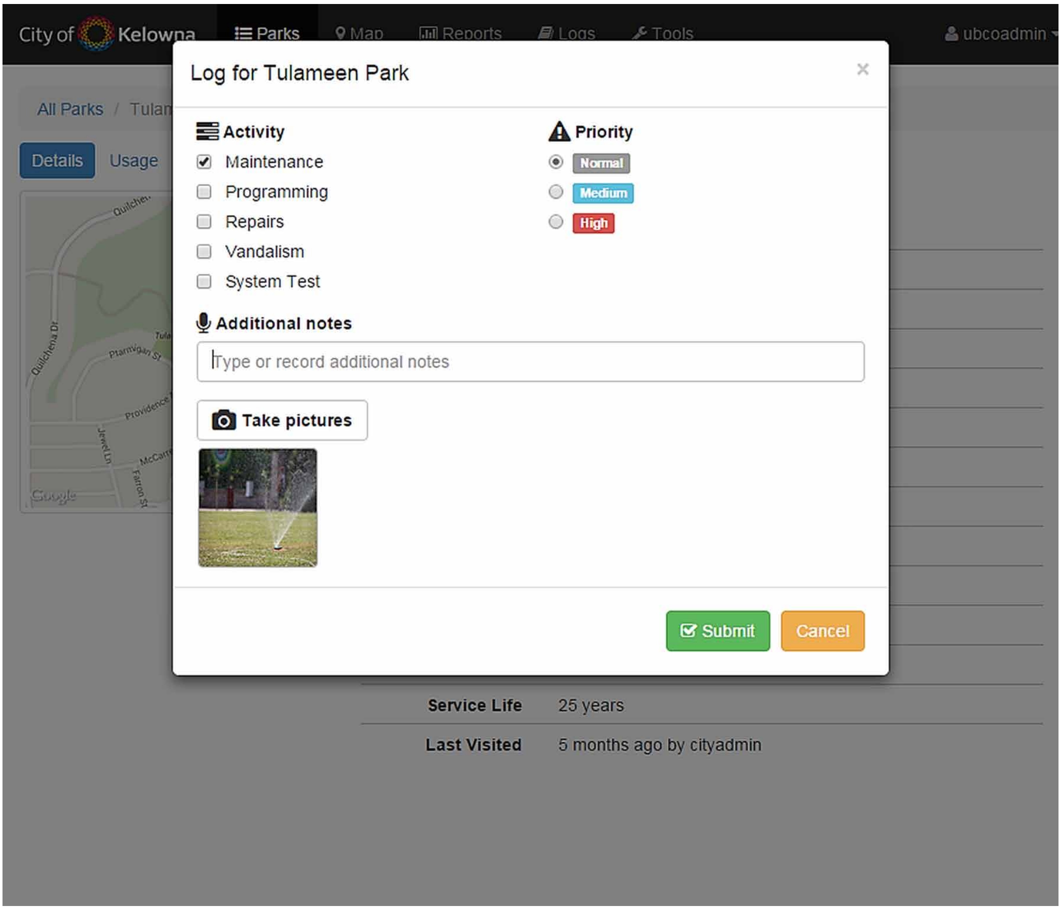


Figure 2. Logging maintenance



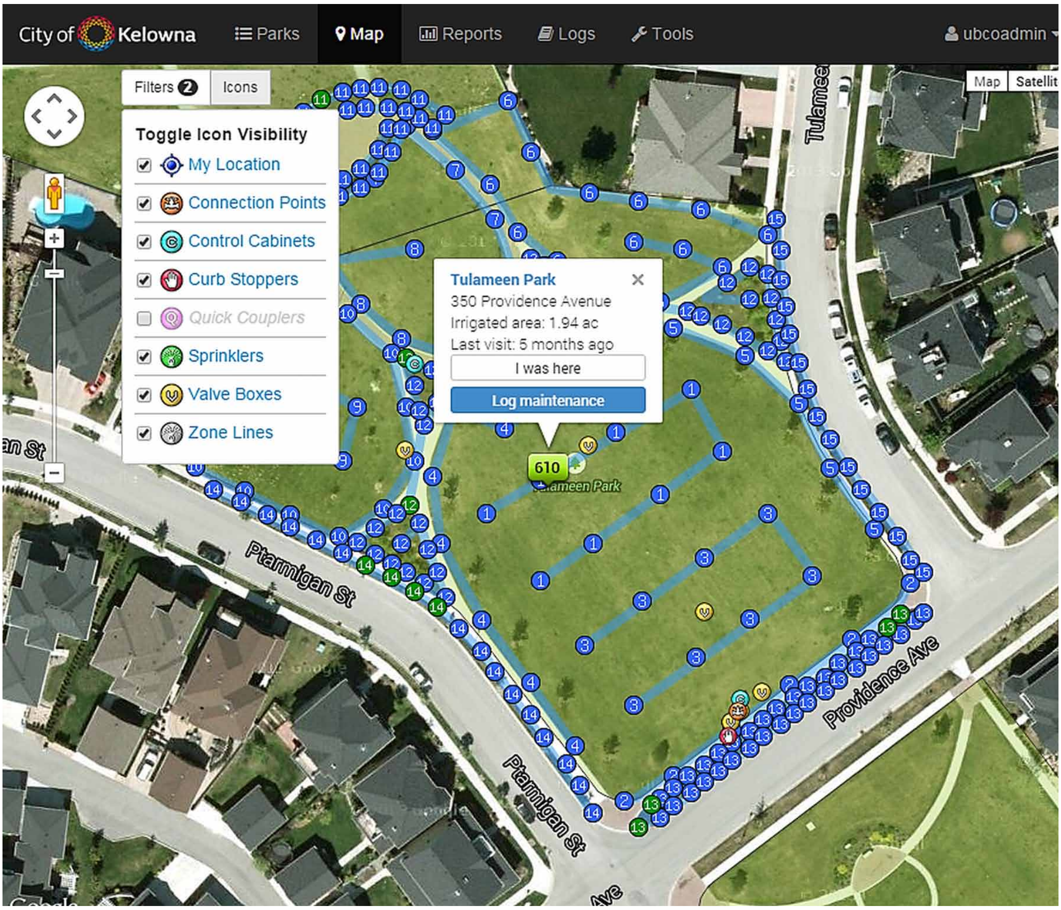
device around in the park. Finding and identifying equipment, which is often hidden or buried, is time-consuming for technicians, especially those unfamiliar with the park. This map view gives users an efficient way to identify equipment and irrigation features and zones. The user can change the visibility of icons for equipment at parks, including sprinklers, connection points, control cabinets and valve boxes. Sprinklers are displayed on the map using colored circle icons labelled with their zone number. Each icon for equipment can be clicked to bring up more information for that equipment.

For longer term irrigation efficiency planning, the usage screen displays an interactive chart of the water usage for the park. Usage for the current year can be compared to prior years and expected water usage as calculated based on weather data from various weather stations.

CASE STUDY: CITY OF KELOWNA

The primary motivations for developing the Site Manager application were the high water usage for city park irrigation during the summer and the time-consuming task

Figure 3. Equipment layout map view (digital as-built)



of maintaining those irrigation systems by technicians. The hypothesis was that the irrigation practices and maintenance activities at City of Kelowna parks could be significantly improved by providing field employees with information about the parks they manage through the use of a mobile application for the iPad. Having that information available out at the parks will help irrigation technicians manage their time and resources better, and that they will be better supported in making decisions regarding sustainable irrigation practices.

The study used questionnaires and scenario-based testing to measure the length of time to complete tasks (efficiency) and the perceptions of the participants (subjective satisfaction). Efficiency was determined by measuring the length of time to complete the assigned tasks. Subjective satisfaction was measured through pre-test and post-test questionnaires.

Study Participants

The participants for this study were the full-time irrigation technicians from the City of Kelowna Park Services department, whose responsibilities include the regular management and maintenance of irrigation equipment in parks. Four full-time irrigation technicians who were primarily responsible for city parks, two full-time irrigation technicians who were primarily responsible for sports fields, and one temporary irrigation technician were recruited, for a total of seven participants overall. Due to the small sample size and the closed environment of the Park Services department, no demographics were collected from the participants to ensure their privacy. None of the participants had any prior experience with the application before the study.

Participant Testing Conditions

Participants were asked to complete a series of tasks at the parks with and without the use of the iPad and Site Manager application. Participants were considered to be an ‘expert’ for parks which they regularly visited and maintained. For parks outside of their normal responsibilities, participants were considered to be a ‘novice’; however, ‘novice’ participants were still trained technicians from the Park Services department. Experts were used to provide a baseline of performance for comparison against the two novice conditions during the study: novices with the iPad and application, and novices without. This resulted in three testing conditions:

- Expert without the iPad as baseline of performance (E_0);
- Novice without the aid of the iPad and application (N_0);
- Novice with the iPad and application available (N_1).

Due to the small sample size of participants available, each participant was asked to repeat all test scenarios in as many of the testing conditions as possible at the selected parks.

Park Selection

Four test parks were selected that were the most representative of parks in Kelowna. Three criteria were used to select which parks would be most appropriate for this study; sites had to be regularly maintained by irrigation staff, be average in terms of irrigated area and zones, and needed to have recent GPS location data collected. The size of the park is important as many of the common tasks that irrigation technicians perform involve finding equipment and irrigation zones. Parks that are quite small make the completion of these tasks trivial, whereas parks that are very large require considerably more time to complete those same tasks. There is significant variation in the layout of equipment and irrigation zones among the different parks in Kelowna. Irrigated areas range from a minimum of 0.06 acres to a maximum of 31.79 acres, with an average irrigated area of 2.74 acres and standard deviation of 4.98 acres. The number of irrigation zones at parks range from a minimum of a single irrigation zone to upwards of 70 irrigation zones at larger parks. The average number of irrigation zones was 13.17 with a standard deviation of 10.27.

While several parks matched the above criteria, only four were deemed suitable for the study by the Kelowna Park Services management: Birkdale Park, Knowles

Heritage Park, Tulameen Park, and Whitman Glen Park. The irrigated areas and number of irrigation zones for each park is shown in Table 1. All parks were within one standard deviation of the mean in regards to both irrigated area and number of irrigation zones, had recent GPS location data collected for their equipment, and were considered representative of a typical park in Kelowna by management.

Pre-Test Survey

Participants completed a pre-test survey that measured their confidence and anxiety towards using technology and mobile devices. The questions were adapted from (Durndell & Haag, 2002).

Test Scenarios

Four test scenarios were developed to replicate the different types of tasks performed by technicians. Managers of the Park Services department were consulted to determine the list of tasks for each scenario, as well as the viability of testing those tasks in a reasonable time-frame given the limited availability of the irrigation staff during the summer season. The tasks for the test scenarios were designed to be representative of the daily routine at city parks, as well as other less common but still significant activities that may occur. Several of these tasks asked participants to locate areas of particular interest such as dry brown patches of grass, potential tree planting locations, and damaged sprinkler heads. These areas of interest were indicated in the parks using different colored flags to mimic the conditions for each task without actually causing any damage to city property or equipment.

As part of routine maintenance for a park, a technician needs to be able to locate all of the equipment at the park. Scenario 1 asks the technician to locate major items of equipment including the control cabinet housing the irrigation controller, the points of connection to the main water line, the curb stoppers for shut off and drainage of the main water line, and valve boxes for individual irrigation lines. Scenario 2 involves determining watering program alternations based on dry turf areas, which may be due to damaged equipment or inadequate water times. Scenario 3 involves identifying which irrigation zones may be affected by planting trees, and where it will be safe to install new features or plant trees to have minimal impact on the existing irrigation installation. Scenario 4 is repairing damaged sprinkler heads. Whenever sprinkler heads are damaged as a result of vandalism, accident, or general wear and tear, the

Table 1. Study parks

Park Name	Irrigated Area (Acres)	Number of Zones
Birkdale Park	1.42	23
Knowles Heritage Park	0.95	22
Tulameen Park	1.94	15
Whitman Glen Park	1.21	10

irrigation technicians must perform a series of tasks to resolve the issue. They must first identify which irrigation zones the damaged sprinklers are located in, determine the replacement parts that will be required, retrieve the replacement parts and make the repairs, and then finally make a report of the damage and repairs to their supervisors and management. The scenarios are listed in Table 2.

Observation and Data Recording

The test scenarios were performed individually by the participants at each of the selected parks throughout July and August of 2014. If a participant had enough familiarity to be considered an expert at a selected park, then the participant was asked to complete all the scenarios for that park without the use of the iPad and mobile application, in order to provide a baseline of expected performance at that park. Otherwise, the participants were randomly assigned as either novice with the iPad and mobile application available (N_1 condition), or as novice without the iPad and mobile application (N_0 condition). This led to a distribution of a single expert

Table 2. Performance of experts and novices in scenario tasks. Times are in seconds.

(Time in Seconds)	E_0		N_0		N_1		ANOVA
Scenario/Task	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**p-Value**
Scenario 1 Task 1: Find control cabinet	17.01	19.30	38.21	55.88	30.40	22.82	**0.00476**
Scenario 1 Task 2: Find point of connection	11.29	13.72	12.96	13.18	18.74	12.94	0.632
Scenario 1 Task 3: Find curb stopper	11.66	4.68	16.58	21.68	17.64	14.26	0.831
Scenario 1 Task 4: Find valve boxes	122.35	162.97	153.55	122.31	48.63	36.85	**0.00202**
Scenario 2 Task 1: Identify irrigation zone with dry patch	24.57	30.59	72.36	53.12	19.16	9.80	**0.00226**
Scenario 2 Task 2: Report watering time changes	N/A	N/A	N/A	N/A	45.32	28.92	N/A
Scenario 3 Task 1: Identify irrigation zones to plant trees	15.05	19.51	95.17	138.50	10.82	9.10	**0.000021**
Scenario 3 Task 2: Determine if safe to plant tree	5.93	3.62	13.07	15.28	6.56	6.56	**0.00926**
Scenario 4 Task 1: Identify zone with damaged sprinkler	7.52	7.33	57.75	57.36	5.68	5.09	**0.00476**
Scenario 4 Task 2: Determine replacement parts	5.48	3.92	13.03	12.92	4.48	3.84	0.0626
Scenario 4 Task 3: Report on repairs made	N/A	N/A	N/A	N/A	30.12	16.44	N/A

participant, three novice participants without the iPad or application, and three novice participants using the iPad and application at each of the selected parks. During all test scenarios, the participants were allowed to use any resources they would normally have available. Participants using the iPad and mobile application were asked to use the iPad first before resorting to other tactics. The length of time to complete each task for each scenario was recorded using a stop watch, and the observations of behavior, errors made, and verbal comments from the participant were written in a notebook.

Post-Test Survey

After the participants completed the test scenarios, the post-test survey asked about their perceptions for each test scenario as well as repeating the pre-test survey questions measuring their confidence and anxiety towards using technology and mobile devices.

RESULTS AND DISCUSSIONS

The time to complete tasks for the test scenarios at each park was recorded for each participant as either an Expert without the iPad for baseline performance (E_0 condition), Novice without the aid of the iPad and irrigation management application (N_0 condition), and Novice with the iPad and application (N_1 condition). An analysis of variance was run to determine if there were any differences between the groups and the p-value is reported. Pair-wise differences are discussed in the text. The results for each scenario and task are in Table 2.

Overall, the data shows that the use of technology does have a significant impact on technician performance for the tasks studied. Participants with the technology (N_1) were more efficient than those without the technology (N_0) in the majority of tasks. The tasks without statistically significant differences were Scenario 1 Tasks 2 and 3 and Scenario 4 Task 2. This improvement is valuable as it demonstrates how technology can be used as a substitute for experience and location familiarity, which allows for increased resilience to employee turnover and scheduling changes. The data also demonstrates the performance difference when technicians must perform the same duties but at locations they are not regularly working at. There were significant differences between N_0 and E_0 for 2 of the tasks (Scenario 2 Task 1, Scenario 3 Task 1) and 2 others had a p-value less than 0.07 (Scenario 1 Task 1, Scenario 4 Task 1).

Although the technology benefits technicians without location experience, there was some data that also demonstrated that technicians with location experience may benefit, specifically finding valve boxes (Scenario 1 Task 4 – p-value: 0.167). Novices using the iPad and application (N_1) were on average faster than novices without (N_0), and in many cases were faster than the experts (E_0) who are familiar with the parks. N_0 and E_0 participants on average took over two minutes to find the correct valve box for the indicated irrigation zone, while N_1 participants were typically able to complete the task in under a minute. One reason why this task has very different results in comparison to finding other equipment is that control cabinets, points of connection, and curb stoppers are typically easy to locate at parks, whereas valve boxes are a different matter. They are physically smaller, buried into the ground, and are often overgrown by turf grass or covered by dirt. As well, there are usually several valve boxes at each park, and each one may connect to one or more irrigation zones. Locating valve boxes for particular irrigation zones is a more labor-intensive task than the three previous ones. The irrigation management application greatly aided N_1 participants in locating the valve boxes and correctly identifying the associated irrigation zones.

In Scenario 2, N_1 consistently outperformed N_0. N_1 participants on average were able to complete the task in under 20 seconds, in comparison to over a minute for N_0. For most of the parks N_1 performed on par or even better than the baseline of performance E_0. To complete this task, most N_0 participants turned on each irrigation zone one by one until they could confirm which zone(s) were affected by the indicated problem area, which can be quite time consuming. Experts familiar with the park (E_0), on the other hand, simply had to recall the layout of the park if they could, whereas N_1 were able to use the irrigation management application to quickly determine the answer. Task 2 required reporting which irrigation zones had their watering time altered. During the course of the study, it was discovered that the irrigation technicians typically would not report any changes made to the water programs for the irrigation zones at the parks, so there is no comparable data when not using the iPad. N_1 participants were able to complete the task of creating a maintenance log to record alterations in the watering program for irrigation zones in an average of 45 seconds, which included the time required to take a photo of the problem area using the camera on the iPad, and the time to type the necessary information about which irrigation zones needed to have their watering programs changed. For Scenario 3, N_1 participants drastically outperformed N_0 participants, and had similar to the baseline of expected performance E_0.

In Scenario 4, participants were asked to perform activities associated with repairing damaged sprinklers. N_1 participants dramatically outperformed N_0 participants across all of the parks, and performed on par with, if not better than, E_0 participants for the majority of parks. The identification of the irrigation zones is a time-consuming task for participants not familiar with the layout of the park since they have to turn on each irrigation zone manually. The last task of Scenario 4 was to record the repairs made at the park. As with the second task of Scenario 2, irrigation technicians do not actively report their maintenance activities at the parks, so data for E_0 and N_0 could not be collected. Participants created maintenance logs with pictures and text in an average of 30 seconds. The decrease in time compared to the similar task from Scenario 2 could be that participants took fewer photos when creating the maintenance logs for this task in comparison to the previous task.

Summary of Task Performance

Table 3 compares the baseline performance of experts with the two novice conditions. A positive percentage in the table indicates that the task took longer to complete in comparison to the baseline of performance, while a negative percentage indicates the task took less time to complete. Tasks where users of the iPad were faster than experts are bolded in the table. The ability for the user to immediately determine

Table 3. Percent change in mean performance between the respective novice conditions in comparison to the baseline of performance from experts at all parks for each task

	Novice Without iPad App	Novice Using iPad App
Scenario 1 Task 1: Find control cabinet	+125%	+65%
Scenario 1 Task 2: Find point of connection	+15%	+66%
Scenario 1 Task 3: Find curb stopper	+42%	+51%
Scenario 1 Task 4: Find valve boxes	+26%	**-60%**
Scenario 2 Task 1: Identify zone with dry patch	+195%	**-22%**
Scenario 3 Task 1: Identify zones to plant trees	+532%	**-28%**
Scenario 3 Task 2: Determine if safe to plant tree	+120%	+11%
Scenario 4 Task 1: Identify zone with broken sprinkler	+668%	**-24%**
Scenario 4 Task 2: Determine replacement parts	+138%	**-18%**

locations of infrastructure equipment based on their current location and database of GPS locations has a dramatic productivity benefit in multiple tasks. Displaying and interacting with this information in real-time on a mobile device with a map-based interface is a significant advantage.

The results emphasize the significant improvement in maintenance efficiency that can be achieved when using the Site Manager application for novice technicians unfamiliar with the parks, as well as the potential benefit for expert technicians for certain maintenance activities.

The results from the pre-test and post-test surveys were analyzed to see if there were any changes in the anxiety and confidence of the participants, as well as to gather their perceptions of the test scenarios and of using the irrigation management application. While the small sample size of participants limits the analysis, the data shows that irrigation technicians are fairly confident about using mobile devices, willing to use them in their work activities, and their anxiety towards mobile technology was lower after using the iPad and Site Manager application. Participants consistently rated their experiences (Table 4) when using the Site Manager application as being faster and taking less time in the parks compared to when they did not have the application available. This pattern can be seen across both expert and novice experiences. When asked if there was any equipment that was easier to find in the parks when using the application, the feedback was nearly unanimous: points of connection, valve boxes, curb stoppers, irrigation zones, and individual sprinkler head locations. This perception is supported by the results for finding valve boxes and irrigation zones. Comments and feedback from the participants were overwhelmingly positive. Every participant stated that they recognized the potential of the irrigation management application to improve their maintenance practices. Overall, participants found the application to be very useful and would likely use it again in the future.

A key consideration in adopting new technology is return on investment for the improved efficiency. Using the results from the test scenarios, it is possible to estimate

Table 4. User feedback on usefulness of iPad and site manager application

#	Question	Mean	SD
1	Do you feel that you spent more time or less time overall in the parks when using the iPad and Site Manager application? (1 = significantly more time and 5 = significantly less time)	4.57	0.53
2	How useful was the interactive map showing the locations and descriptions of the equipment in parks? (1 = not useful at all and 5 = very useful)	4.86	0.38
3	How useful it was to have access to the park details?	4.29	0.49
4	How likely will you continue to use the log maintenance feature? (1 = highly unlikely and 5 = highly likely)	3.71	1.38
5	How useful was it to have the iPad out in the parks? (1 = not useful at all and 5 = very useful)	4.86	0.38
6	How difficult was it to carry the iPad around in the parks? (1 = significant difficulty and 5 = significantly easy)	3.86	0.90
7	How likely are you to use the iPad and irrigation management application again in the future? (1 = highly unlikely and 5 = highly likely)	4.86	0.38

a daily savings for irrigation maintenance tasks and translate that into a monetary savings. Irrigation technicians are responsible for numerous parks, and even experts are challenged to remember the layout of all equipment. Most maintenance tasks involve finding equipment locations including valve boxes (Scenario 1 Task 4) and irrigation zones (Scenario 2 Task 1, Scenario 4 Task 1). The time to find a valve box and irrigation zone was reduced by 30 to 60 seconds using the iPad application. These activities are the most frequent activities that may be repeated 30 to 50 times a day resulting in a time savings of 15 to 50 minutes daily that translates to $10-$40/day/technician or $2000 to $8000/technician/year. With the cost of the iPad and software less than $700, the system will have a ROI of less than one year and increase the efficiency and satisfaction of technicians as well as making it easier to onboard new workers. Although there is an upfront cost on collecting GPS locations for park infrastructure, that work can typically be completed in a few hours per park and requires minimal updates over time (as irrigation infrastructure rarely moves). A further benefit is increased visibility for managers understanding the time spent at each park by every technician and historical maintenance trends and relative costs of individual parks. This data can help predict and prevent emergency or disaster situations which are costly and hurt public reputation.

CONCLUSION

This work designed and evaluated a mobile application for park maintenance technicians to use in the field to improve their efficiency. The ability to rapidly find infrastructure in the field and log maintenance activities reduced wasted time searching and manual paperwork. The field study with the City of Kelowna Park Services department demonstrated that technicians are receptive to using the technology in their maintenance activities and many tasks can be more efficient when aided by technology. This is especially true for technicians, such as new or replacement employees, that have less familiarity with the park infrastructure. The time and monetary savings per technician may be several thousand dollars per year allowing a ROI of adopting the technology of less than one year. The City of Kelowna has the system in production since 2015. Future work will expand the application to have more reports and alerts related to water efficiency (e.g. inform of potential water leaks or need for preventative maintenance) and examine how logs of maintenance activities can be used by planners to identify infrastructure that is especially costly to maintain or due for replacement. The technology has applications to other cities, park management organizations, and golf courses which require efficient maintenance of infrastructure.

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