An Innovative Footpath Pavement Management System for Auckland Transport

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Abstract: Traditionally footpath inspections are done either on foot which is slow and labour intensive, or from a vehicle driving on the carriageway. Both often give inconsistent and inaccurate results. A mobile footpath inspection vehicle, consisting of a 50cc scooter and an on-board data capture system, has been developed for inspecting and collecting footpath condition data for Auckland Transport. Voice recognition technology is utilised so that the inspector can record type and severity of faults hands-free. All location information (route position, road id#, footpath id#, street address) is captured automatically through GPS tracking technology. The system also automatically calculates the condition grade of each footpath section based on fault types, quantity and severity. This mobile inspection system greatly enhances the efficiency, accuracy and consistency of collecting and managing footpath condition data. Three years of inspections have been completed for over 6,800 km of footpath managed by Auckland Transport. Optimized 3-year and 10-year footpath renewal programmes have been developed based on the footpath condition data collected, helping Auckland Transport make more informed decisions for better management of their footpath assets.

Key Words: Footpath Inspections, GPS Positioning, Data Capture, Voice Recognition, Asset Management

INTRODUCTION

In 2011 the Auckland Transport along with the Maintenance Contractor identified that current methods of footpath inspections were ineffective and were not delivering the level of detail required in an efficient manner.

Previously in Auckland, footpaths were inspected via two separate methods, each delivering a separate data set for different purposes.

1) Condition Rating. The objective of condition rating is to assign each footpath section a 1 to 5 grade to assess its "point in time" condition over its expected lifecycle. This data is used by asset managers to project Forward Works budgets over 3 and 10 years. This inspection is usually done by a large number of people of different skill levels on foot and "all at once" over summer. The only fault information collected is a lineal measurement of each type of fault over each section (regardless of severity) and limited location information. Data is collected either by clipboard or touch screen devices. The section is then given a calibrated but subjective grade by the inspector. An inspector using this methodology averages 12-15km of footpath inspected per day. This approach leads to inconsistent results due to the large number of people completing the inspections and a data set of little immediate use to maintenance contractors. The raw data usually takes a long time to be sorted, input and analysed.

2) Maintenance Inspections. These inspections are performed as part of a boundary to boundary inspection across all road asset types. Only maintenance level faults are recorded i.e. faults in need of repair in the short to medium term. Typically these inspections are done from a car. Individual fault locations and details are recorded but not faults to the level of detail required by the Condition Rating inspections.

Scooter Initial Design Process

After discussion with asset managers and maintenance managers an ideal solution was envisaged. One trained operator able to perform inspections actually on the footpath and able to cover good distances each day with minimal physical effort (current average is 20km inspected per day). Cost would have to be comparative to the Condition Rating inspection but significantly cheaper than the combination of Condition Rating and Maintenance inspections as the data collected satisfied both requirements.

For these reasons a 50cc scooter was developed as the tool to deliver accurate and efficient footpath inspections. The scooter is highly visible and can be driven legally on the footpath with a maximum speed of 10km/hr. A canopy provides some weather protection and mounting areas for equipment. The scooter has a small storage area for hardware and power supplies.

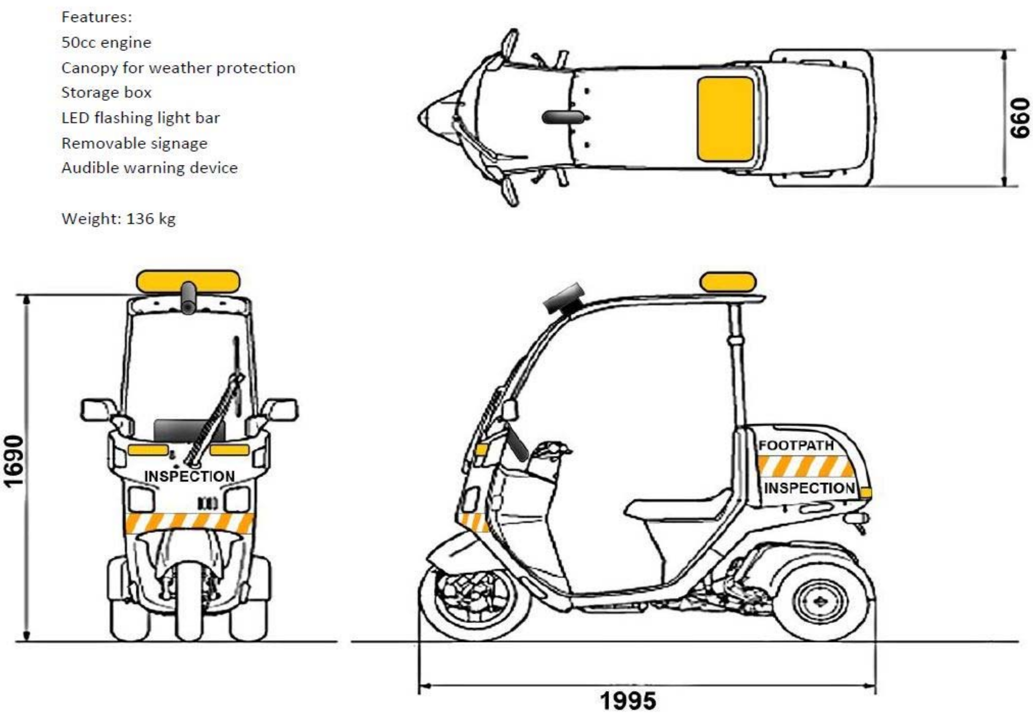

FIGURE 1 Scooter diagram

The safety features include high mounted LED orange flashing lights and reflectorized "Footpath Inspection" sign writing visible from all angles. The operator wears orange overalls, safety boots and a helmet.

FIGURE 2 Scooter and Operator

The selected hardware specific to the data collection is a Windows compatible rugged tablet, GMouse GPS receiver, microphone/speakers attached to a helmet and a video camera. A 22ah Lithium-Ion battery located in the scooters storage compartment provides the daily power needs of the system, (computer and hazard warning lighting). The original tests using a cheaper Lead-Acid battery prompted the change due to weight, capacity and duty cycle issues.

Custom brackets were required for mounting the tablet and other equipment.

FIGURE 3 Data collection device and mounting brackets

The scooter also has a video capture camera mounted to record the worst sections of footpath allowing the client to review these from the desktop.

The development of Voice Recognition and GPS tracking software.

The use of Voice Recognition (VR) was chosen as the most efficient way of data entry. This required significant testing and development to get acceptable results. Windows native voice recognition software was found to be suitable. A customised Grammar was developed so that VR could be used in “command” mode rather than “dictation” mode to input data into database fields. Dictation mode is used to add additional notes occasionally. To keep data input requirements minimal, fault, cause, grade, and priority fields are automated or have default (most common) values assigned. The operator is able to override these as necessary. Typically the operator only has to enter the fault and its size. On average 5.5 words per fault are spoken with 43% requiring 4 words only and 85% needing 7 words or less.

All location data is determined automatically via the GPS Auto Tracking (GAT) system.

The challenges with VR were to achieve it in a non-office environment. In an outdoors urban setting the noise cancelling has to deal with wind, vehicle and power tool noise and seasonal loud insects. With these conditions VR may either not understand the operator’s entries or the noises could trigger false data inputs.
A noise cancelling microphone from the aeronautical industry has reduced these issues significantly. At the time of writing initial investigations have begun into microphones and noise cancelling systems from the motorsport field that may provide better results.

Overall, despite these issues VR error rates are relatively low. Recently software to track and analyse VR accuracy has been introduced. On a typical day the operator logging more than 1000 new faults will need to change approximately 5% but many of these are due to either reassessment of faults or from an ill formed sentence. The number of entries resulting from unwanted VR is thought to be less than 1% emanating from severe background noise (wind, machinery, or insects), almost all of which don't create a false positive but are filtered out because they fail to match a valid input rule as defined by the grammar. The system "reads back" each valid input stream for feedback to the inspector who can easily alter any undesired field value.

Log retention of GPS trail, plus all VR communication and responses add sufficient redundancy so disaster recovery is possible in case of equipment failure. This also provides monitoring of performance. Optionally all VR streams can be retained for later playback and trouble shooting.

With the advancements in GPS technology and the Transport Authorities road asset data spatially mapped, GAT has enabled location data of faults to be recorded automatically, drastically improving field data entry efficiency over old methods. However the accuracy depends on the precision of Transport Authorities footpath GIS data. Footpath mapping has generally been secondary to road mapping. Largely footpaths are mapped as mirrors of road centrelines, which do not reflect reality as footpaths don't always parallel adjoining roads. The GAT system requires the mapped centreline to be very close to the actual footpath the inspector will drive. Pre-inspection the Transport Authorities footpath data is downloaded and then checked for duplications and omissions. This data is remapped by cross referencing Google Earth and Google Maps and the footpath centre lines are manually adjusted to align with the actual layout.

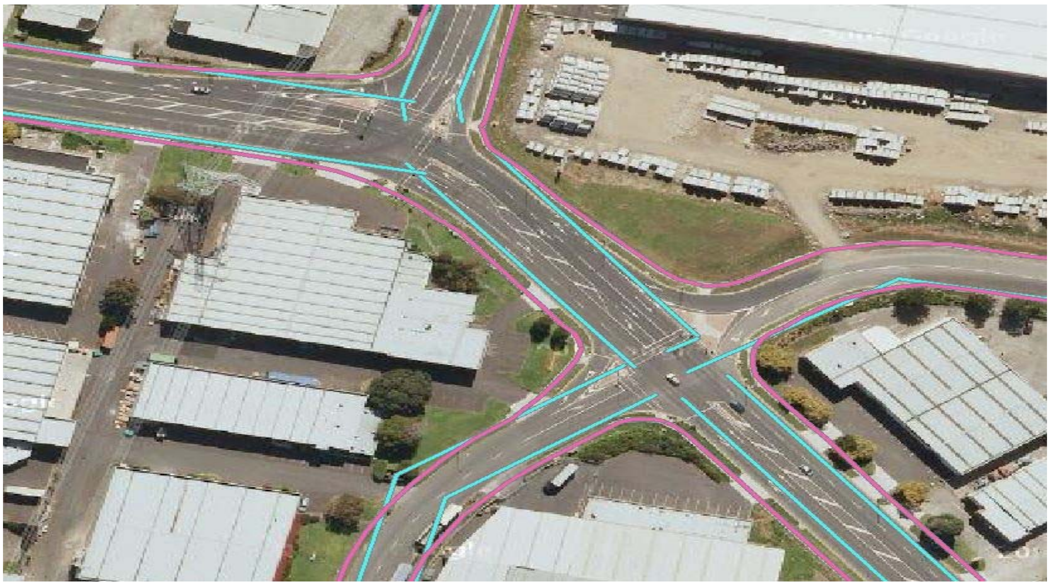

FIGURE 4 Blue lines are pre mapping, Pink lines post mapping.

Smoothing the footpath centre lines facilitates attaching the GPS location of faults to a centreline to pick up the locality precisely.

THE CURRENT FIELD DATA COLLECTED

All fault types recorded are matched to a cause and given a size, priority and grade. The inspector uses a simple set of fault words. However due to the difference in terminology between data users (Maintenance vs. Condition Rating) the system (when generating the reports) converts the raw data into the specific terminology required by both parties.

Footpath Fault Analysis — November 2012 ONSITE Version 5

Asset	Zone	Type (Surface Material)	Fault	Beca/RAMM	Cause	Priority	Condition Grade	Inventory
F Footpath	U Urban	C Concrete	T Trip Hazard <35mm	Bump	V Vehicles	U Urgent	1 Excellent	M Incorrect SM
K Kerb & Channel	C Comm/Shopping Centre	A Asphalt	L Trip Lip >35mm	Bump	T Trees	M Maintenance	2 Good	L Incorrect DL
C Carriageway	I Industrial	P Brick Pavers	D Displacement	Settlement	U Utility Contractor	R Renewal	3 Fair	N Not in DB
B Berm	R Rural	T Tiles	H Crack/Hole	Crack/Pothole	A Age	O Other Priority	4 Poor	D Non Existing
S Signs	W Walkway	W Wood	B Broken	Crack	W Water/Stormwater		5 Bad/Very Poor	C New/Construction
L Lighting	O Other Zone	L Loose Metal	K Kerb & Channel	-	C Workmanship		0 No Footpath	O Other
O Other Asset		O Other Type	V Vege Encroachment	Vege Encroachment	M Material			
V Vehicle Crossing			U Un - Even	Depression/Ponding	S Service Cover			
P Pram Crossing			R Trench Sunken	Settlement	D Design			
			S Slippery	-	P Plant Growth			
			G Gradient/Slope	-	G Ground Movement			
			O Other	-	O Other			
			C Scabbing	Scabbing	N Sub. Development			
		B Blue Stone	P Patch	Patch	R Road Works			
Beca only			Beca only		Beca only			

Defaults

Asset	Zone	Type (Surface Material)	Fault	Beca/RAMM	UOM	Cause	Default Priority	Condition Grade (Rating): Urgent	Condition Grade (Rating): Maintenance
F Footpath	U Urban	C Concrete	T Trip Hazard <35mm	Bump	EA	Trees	Urgent	4 (10-35mm)	
			L Trip Lip >35mm	Bump	EA	Trees	Urgent	5	
			D Displacement	Settlement	M2	Trees	Urgent	4	3
			H Crack/Hole	Crack/Pothole	M2	Vehicles	Maintenance	4	2
			B Broken	Crack	M2	Vehicles	Urgent	4	3
			K Kerb & Channel	-	M2	Vehicles	Urgent		
			V Vege Encroachment	Vege Encroachment	LM	Plant Growth	Maintenance		6
			U Uneven	Depression/Ponding	M2	Age	Maintenance	4 (>10mm)	3 (<10mm)
			R Trench Sunken	Settlement	M2	Utility Contractor	Maintenance	4	3
			S Slippery	-	M2	Water	Urgent		
			G Gradient/Slope	-	M2	Design	Maintenance		
			O Other Fault	-	EA	Other/Unknown Cause	Maintenance		
			C Scabbing	Scabbing	M2	Age	Maintenance	4	2
			P Patch	Patch	M2	Utility Contractor	Maintenance		

FIGURE 5 Table of data collected for each fault and their default values.

The different values for each fault collected are:

Asset: The different types of assets faults are recorded against. For instance the Transport Authority requires separate fault data on vehicle crossings and on pram crossings located at each carriage way crossing.

Zone: The different areas. These zones have design implications and foot traffic volume considerations.

Type: The construction materials used.

Fault: The various types of faults. The “Fault” column is used by maintenance. The “Beca/RAMM” column is the different terminology of the same fault used by condition rating. “Kerb and channel” as a fault type means broken or missing kerb blocks and channel.

Cause: The suspected cause of each fault. This can be useful in the renewal design phase. An example is one area had a large amount of faults caused by trees. This was attributed to a species of tree with large roots planted by the Local Authority near the footpath causing significant slab displacement as the trees matured.

Priority: The severity of each fault. As with Fault Type, there are different priorities for Maintenance and Condition Rating purposes.

The lower table details the system default fields for each type of fault based on the most likely attributes. Default fields for Fault-Cause-Priority are appropriate 95% of the time as described in the statistics mentioned on pg5. Any variations between inspectors has not been discovered yet as only one inspector has performed this work to date. The Footpath Fault Analysis (Fig 5) lends itself to consistent assessments. The inspector is audited by an independent validator repeating 5% of the footpaths for any given area and the results compared.

Previously the footpath section was given a subjective overall grade by the inspector. By using a software based formula results are more objective, consistent and repeatable. The formula is based on the percentage of "clean" footpath weighed against the percentage of faults and their individual lengths and grades:

- If there are 10% or higher Grade 5 faults then the section is graded 5.
- If there are 10% or higher combination of Grade 5 and Grade 4 faults then the section is graded 4.
- If there are 10% or higher faults at Grade 5, Grade 4, and Grade 3 combined then the section is graded 3.
- If there are 9% or higher at Grade 5, Grade 4, Grade 3, and Grade 2 combined then the section is graded 3.
- If there is 6% or higher at Grade 2 or (1% or higher of Grade 5, Grade 4, and Grade 3 combined) then the grade of that footpath becomes a 2.
- Otherwise the grade of the footpath becomes a 1, meaning there is up to 5% Grade 2 faults with no Grade 3 or 4 or 5 faults)

THE REPORTS GENERATED POST INSPECTION.

Once an inspection is completed the software generates the reports required. This includes spreadsheets for the Condition Rating and Maintenance requirements.

This is the spreadsheet for Condition Rating, in a format able to bulk upload to the Transport Authorities database.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Footpath	Road Name	Road	Sta	En	Si	Position	Surface r	.eng	Settleme	Bum	Depressio	Crack	Scabbi	Patch	Pothol	Extra
2	49122	Acmena Lane	50665	0	151	Right	Middle	Concrete	151	0	0	0	1	0	0	0	150
3	49123	Acmena Lane	50665	0	151	Right	Kerb	Concrete	151	0	0	0	1	0	0	0	150
4	49124	Acmena Lane	50665	0	151	Right	Middle	Concrete	151	0	0	0	4	0	0	0	148
5	49122	Acmena Lane	50665	0	151	Right	Middle	Concrete	151	0	0	0	1	0	0	0	150
6	49123	Acmena Lane	50665	0	151	Right	Kerb	Concrete	151	0	1	0	0	0	0	0	150
7	49124	Acmena Lane	50665	0	151	Right	Middle	Concrete	151	0	1	0	0	0	0	0	150

FIGURE 6 Footpath Section Condition Rating data

This spreadsheet is delivered to the Maintenance Contractor and allows the identification of urgent safety issues for immediate repair and identification of moderate issues to generate a maintenance program. The maintenance program is cross referenced with the Transport Authorities renewal programme to ensure faults aren't repaired individually when the whole section is going to be renewed within the year.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Footpath	Road Name	Road	Area	Maint	Dis	Positio	ER	Si	Asset	Zone	Type	Fault	Cause	Priority	Siz	Len	Wid	Grad
2	49122	Acmena Lane	50665	Pakuranga	2a1zaM	M	1	25	R	Kerb & Channel	Urban	Concrete	Kerb and Channel	Vehicles	Maintenance	1x1	1	1.4	3
3	49122	Acmena Lane	50665	Pakuranga	1a1caM	M	1	25	R	Footpath	Urban	Concrete	Crack	Vehicles	Maintenance	1x1	1	1.4	2
4	49122	Acmena Lane	50665	Pakuranga	1a1ccM	M	1	25	R	Footpath	Urban	Concrete	Crack	Utility Contractor	Maintenance	1x1	1	1.4	2
5	49123	Acmena Lane	50665	Pakuranga	1a1caM	K	1	39	R	Footpath	Urban	Concrete	Crack	Vehicles	Maintenance	1x1	1	1.4	2
6	49123	Acmena Lane	50665	Pakuranga	1a1bbM	K	1	48	R	Footpath	Urban	Concrete	Trip Lip	Trees	Maintenance	1x1	1	1.4	3
7	49124	Acmena Lane	50665	Pakuranga	1a1cbM	M	Opp6	53	R	Footpath	Urban	Concrete	Crack	Trees	Maintenance	1x1	1	1.4	2
8	49124	Acmena Lane	50665	Pakuranga	1a1bbM	M	3	60	R	Footpath	Urban	Concrete	Trip Lip	Trees	Maintenance	1x1	1	1.4	3
9	49124	Acmena Lane	50665	Pakuranga	1a1caM	M	7	97	R	Footpath	Urban	Concrete	Crack	Vehicles	Maintenance	1x1	1	1.4	2
10	49124	Acmena Lane	50665	Pakuranga	1a1cbM	M	9	105	R	Footpath	Urban	Concrete	Crack	Trees	Maintenance	1x1	1	1.4	2

FIGURE 7 Individual Fault spreadsheet

With the availability of Google Earth, reports containing the spatial data have been implemented. The flexibility and acceptable accuracy of the Google Earth format enable engineers to sort and sift faults, allowing spatial analysis of fault types, causes, priorities and grades. Because each individual fault has the various attributes logged against it the data can be manipulated in numerous ways. The Condition Rating data is also included in Google Earth files for the same purpose.

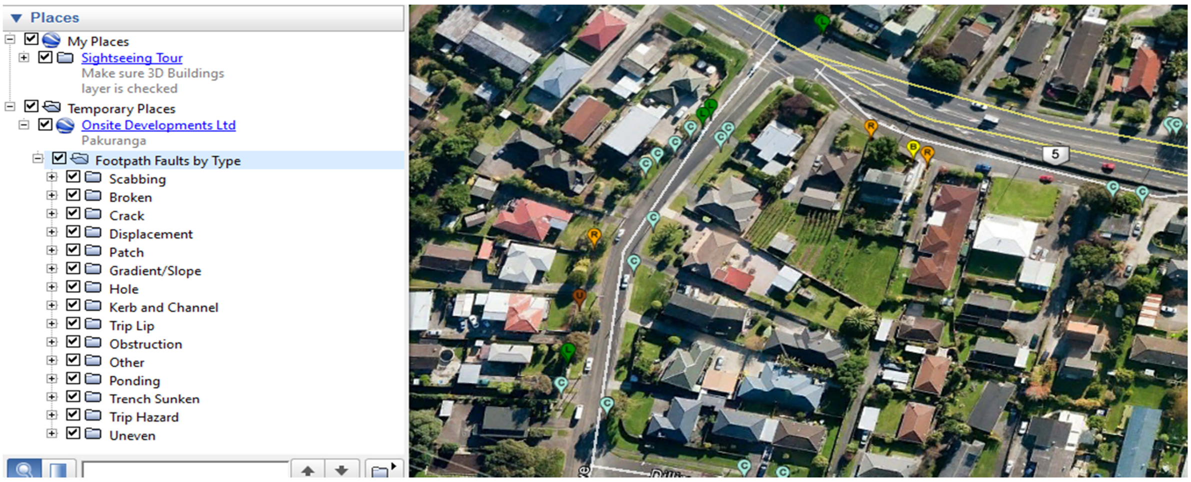

FIGURE 8 Google Earth file Faults By Type

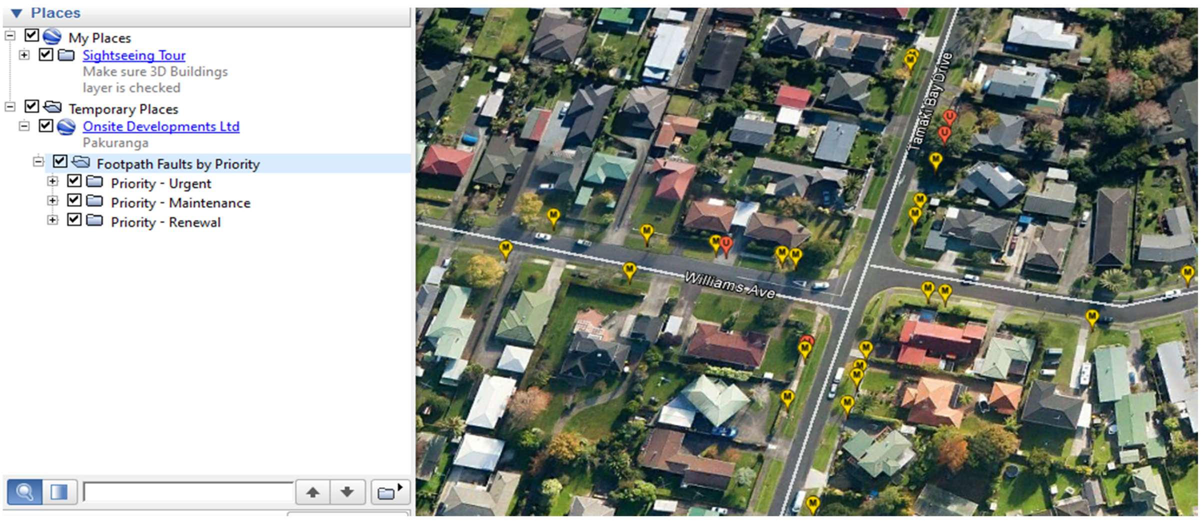

FIGURE 9 Google Earth file Faults by Priority

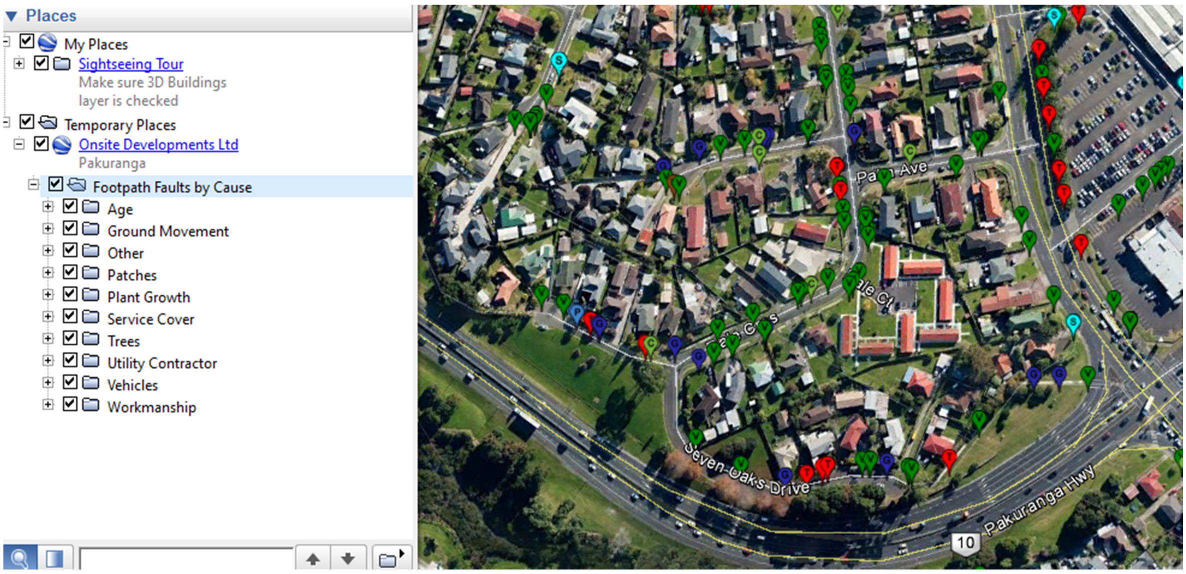

FIGURE 10 Google Earth file Faults by Cause

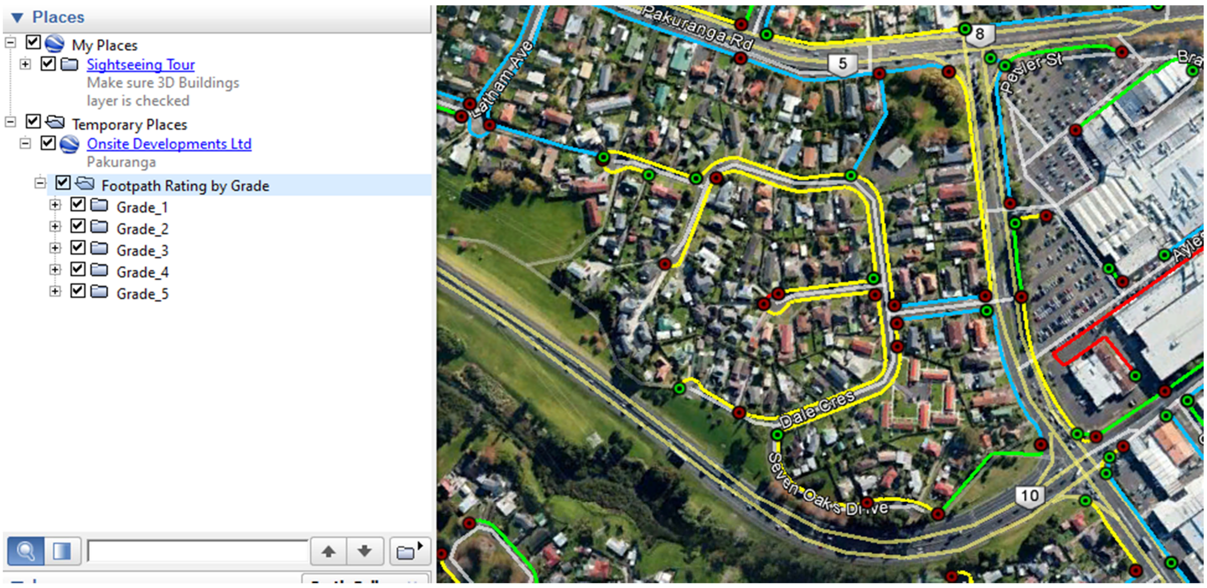

FIGURE 11 Google Earth file Footpath Sections by Condition Grade

DEVELOPMENT OF FOOTPATH FORWARD WORK PROGRAMME (FWP) FROM FAULT INSPECTION DATA

Footpath renewals are allowed for in an allocated annual budget of $3.0m for the Northern area of Auckland with an allowance of $0.5m for kerb and channel renewals.

Source condition data for footpaths was obtained from 2012/13 field surveys. This data measured faults on footpaths and includes:

- 67,000 faults on

- 12,000 footpath lengths (sections) covering
- Nearly 1,500 km of total footpath length

The source condition data for footpaths was further filtered and analysed to give the following for each section length:

- the combined measured square metre area for all faults
- faults such as vegetation encroachment and slippery surfaces were eliminated from the list because they were not covered under the renewals budget
- calculated renewals length by applying an empirical factor of 1.0 to convert fault area to renewals area, but with a maximum renewal area not exceeding the total area of the section
- renewals cost estimate; based on a unit rate of \$110/m2 for concrete footpaths and \$50/m2 for asphalt footpaths. These rates may be impacted by the new Road Corridor Maintenance physical works contracts which will come into effect for the 2014/15 year.
- renewals length estimate; based on an average width of 1.5m (which for practical reasons is less than the standard 1.7m for new footpaths and more than the average existing width of approximately 1.2m)

The initial (1st level) desktop prioritisation of the footpath 10-year FWP was by the concentration of faults as a proportion of section area. Renewals years for footpath were assessed by prioritised sites that accumulate to \$3.0m per annum, starting with year 1 as the sites with the highest concentration of faults. Higher priority and geographically dispersed sites were selected for drive-over checking. The FWPs were amended as required with results of the drive-over checking. The FWP has also been adapted by coordinating with pavement renewal works, utility works and other capital works.

Figure 13 below is a summary of 10-year footpath FWPs developed by suburbs and proposed renewals year.

FWP Year	Footpath Renew ($)	Footpath Fault Length (m)	K&C Renew ($)	K&C Fault Length (m)	Roads with Footpath Renewal (no.)
Year 1 (part Yr0)	**4,878,060**	**25,318**	**75,000**	**500**	**218**
Devonport-Takapuna	976,022	6,095	10,500	70	34
E.C.Bays	758,479	3,628	11,250	75	34
Hibiscus Coast	321,822	1,894	5,250	35	14
Kaipatiki	1,943,826	8,595	45,000	300	91
North Rural	177,698	1,394	150	1	9
Upper Harbour	700,213	3,713	2,850	19	36
Year 2	**2,767,748**	**16,185**	**94,200**	**628**	**233**
Devonport-Takapuna	298,644	1,847	12,600	84	36
E.C.Bays	187,737	1,112	5,100	34	25
Hibiscus Coast	250,310	1,391	3,750	25	29
Kaipatiki	1,560,087	9,242	66,600	444	102
North Rural	211,348	1,161	1,350	9	13
Upper Harbour	259,622	1,432	4,800	32	28
Year 3	**2,896,767**	**17,626**	**105,300**	**702**	**277**
Devonport-Takapuna	473,904	3,025	15,600	104	43
E.C.Bays	312,796	1,990	9,000	60	36
Hibiscus Coast	240,786	1,489	6,150	41	39
Kaipatiki	1,211,002	7,225	65,400	436	83
North Rural	184,900	1,131	1,800	12	25
Upper Harbour	473,379	2,766	7,350	49	51
Year 4	**2,791,879**	**17,207**	**94,800**	**632**	**224**
Devonport-Takapuna	417,066	2,643	19,650	131	47
E.C.Bays	624,619	3,992	18,150	121	46
Hibiscus Coast	568,065	3,477	13,650	91	34
Kaipatiki	775,608	4,738	40,500	270	52
North Rural	106,254	667	450	3	16
Upper Harbour	300,267	1,690	2,400	16	29
Year 5	**2,862,768**	**18,388**	**105,300**	**702**	**455**
Devonport-Takapuna	649,458	4,128	38,550	257	98
E.C.Bays	451,518	2,994	18,450	123	70
Hibiscus Coast	425,938	2,855	10,200	68	70
Kaipatiki	630,003	3,949	25,800	172	91
North Rural	173,474	1,104	5,100	34	36
Upper Harbour	532,377	3,358	7,200	48	90
Year 6 to 10	**2,569,111**	**17,135**	**103,500**	**690**	**1,112**
Devonport-Takapuna	570,880	4,064	36,600	244	176
E.C.Bays	267,636	1,820	14,250	95	96
Hibiscus Coast	411,682	2,743	11,700	78	203
Kaipatiki	380,653	2,434	19,200	128	119
North Rural	308,264	2,088	5,700	38	226
Upper Harbour	629,996	3,986	16,050	107	292
Total	**18,766,333**	**111,859**	**578,100**	**3,854**	**2,519**

FIGURE 12 Summary of 10-Year Footpath FWP

CONCLUSION

After three years of development this system of footpath inspections has successfully delivered to the local Transport Authority a data set previously collected by two separate inspections. By combining Voice Recognition as a data entry tool with GPS technology giving all required locality information, an experienced inspector is able to record an average of 1000 faults per day over 20 kilometers of footpath. The end data delivers urgent individual faults to maintenance contactors and an overall point in time asset condition assessment.

Going forward, the remaining challenges with this system are to improve Voice Recognition in high noise environments and to improve GPS accuracy in situations where reception is poor such as high rise urban environments, poor weather and low satellite count. This system could be adapted to other tasks such as asset recording (footpath lengths, widths, surface material, 3-D profiling etc). The fault analysis can be extended or modified also as needed.

REFERENCES

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