

MOTORWAY CRASH ANALYSIS USING GIS

A case study of St. Marys Bay, Auckland

Authors Details;

Joshua Aldridge, Graduand#
Phone: +6427 3866 153
Email: joshua.aldridge@gmail.com,

Ross Harper, Graduand#
Phone: +64 21 042 3099.
Email: ross.w.harper@gmail.com

Dr Douglas James Wilson, PhD, BE(Civil, Hons), NZCE, MIPENZ, PIARC
Senior Lecturer, Dept. of Civil and Environmental Engineering, University of Auckland
Phone: 64 9 373 7599 ext 87948
Email: dj.wilson@auckland.ac.nz

Associate Professor Roger Dunn, BE, BSc, MEngSc, DipTP, FITE, FIPENZ
Director of Transportation Engineering
Dept. of Civil and Environmental Engineering, University of Auckland
Phone: 64 9 373 7599 ext 87714
Email: rcm.dunn@auckland.ac.nz

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Abstract

This research paper undertaken at the University of Auckland investigates the potential for developing a raster geographical information system which is capable of analysing crashes on a lane by lane basis on multilane roads. A 1.2km section of motorway located in St Marys Bay, Auckland has been used as a case study to determine the feasibility of such a system. This project uses ArcGIS to combine crash data, road data and traffic characteristics as a raster GIS plot on an aerial photograph. ArcGIS also includes features which enable crash trends to be displayed based on the attributes of individual crashes.

It was found that a raster GIS can have significant benefits over the existing vector crash analysis system used in New Zealand as it can aid the visualisation of crash patterns on multilane roads such as motorways, arterials and intersections. Another advantage is that it can be easily incorporated with police GPS units for more accurate location of crashes. Also plotting data on an aerial photograph can help identify geometric and infrastructure features which may contribute to crashes.

1. Introduction

1.1. Background

The current New Zealand crash analysis system (CAS) has limitations when analysing crashes on multilane roads such as motorways. It uses a vector geographical information system (GIS) which is only capable of displaying crashes on a linear basis. As a result, little research has been done to analyse crashes on a lane by lane basis in New Zealand. This study uses the St Marys Bay section of the Auckland motorway as a case study to investigate the potential of using a raster GIS to analyse crashes spatially. This section of motorway was chosen due to its high crash rate in comparison to the Auckland motorway network average. It also has four relatively small radii reverse curves that geometrically have a marginal factor of safety for the speed environment. These curves have historical evidence of a high relative loss of control crash rate compared to the rest of the motorway network. The St Marys Bay section of motorway includes three of the top five black spots on Auckland City's state highways based on social costs within a 30 metre radius (NZTA, 2009a). The definition of social costs is provided in the Economic Evaluation Manual (NZTA, 2010).

1.2. Objectives and Aim

The objectives of this research undertaken at the University of Auckland as a final year BE (Civil) research project were as follows:

1. Identify crash rates on a lane by lane basis and movement type basis.
2. Investigate road and environment factors contributing to the crash trends.
3. Investigate the potential for using a geographical information system (GIS) to analyse crashes on multilane roads.

The overall aim of this project is to investigate the potential for the use of a GIS based system for crash analysis, while further investigating trends of crashes within the chosen case study area

1.3. Site Description

The St Marys Bay section of motorway extends from the Fanshawe Street interchange to the southern side of the Auckland Harbour Bridge as shown in Figure 1. The horizontal alignment includes four reverse curves connected by three short tangents while the vertical alignment is mostly level. Between 6-8% superelevation is provided through the central circular arc of each curve and the road surface is an open graded porous asphalt over the entire section. There have been no significant site infrastructure changes during the five year study period between 2005 and 2009.



Figure 1: Aerial photo of St Marys Bay, Auckland

Each direction of the study section was treated separately. The northbound and southbound directions were examined by Joshua Aldridge and Ross Harper respectively. This was possible as the two directions of the motorway are divided so there is little or no interaction between opposing traffic flows due to the physical separation by means of concrete central median barriers.

2. Literature Review

2.1. Introduction

There are a considerable number of published articles on how a wide range of factors can affect the crash rate on urban motorways. Almost all traffic crashes can be attributed to either one or a combination of three factors; road, driver and vehicle (Polus et al., 2005). Due to the unpredictable and complex nature of driver behaviour, most research is focused on factors relating to the design of roads which authorities are able to control (Abdel-Aty et al., 2006).

The main road and environment factors which have been found to affect the crash rate are; geometric and infrastructure characteristics, surface conditions, weather and lighting conditions, and traffic characteristics. As a result, many accident prediction models have been developed to determine the effects that these variables may have on traffic safety (Caliendo et al., 2007).

2.2. New Zealand Road Safety Research

The road toll in New Zealand has been on a steady decline since peaking at just above 800 fatalities in the early 1970's and again in the late 1980's. In 2008 there were 366 fatalities on NZ roads, of these, six were on motorways (IRTAD, 2009). There are currently 179.5 kilometres of motorway in New Zealand out of a total of approximately 94,000kms of roads, of this 114 kilometres are located in the Auckland region (NZTA, 2009b). Whilst only a small proportion of the total Auckland road network (0.12%), the Regional motorway network carries a very significant proportion of vehicle kilometres travelled. Also, Auckland's

Motorways are among NZ's safest roads on an accident rate basis with a 4-star rating (NZAA, 2010).

The Auckland Road Safety Report 2004-2008 provides extensive data on crashes in Auckland City for this five year period (NZTA, 2009a). It also gives comparisons to other similar urban areas in New Zealand and to New Zealand as a country. This report has estimated that the social cost of road crashes in New Zealand in 2008 was 4.3 billion dollars, 0.3 billion of this cost was a result of crashes on urban state highways. The social cost of road crashes includes; loss of life and quality of life, loss of output, medical costs, legal costs and property damage costs. A more detailed definition of social costs is provided in NZTA, 2010.

In Auckland City there are on average 90 crashes on motorways per 100 million vehicle-km travelled. The only New Zealand city with a higher crash rate is North Shore City with 145 crashes per 100 million vehicle-km travelled (NZTA, 2009a). The Auckland Road Safety Report also ranks crash black spots based on the highest social costs of crashes within a 30 metre radius for urban areas and a 250 metre radius for rural areas. Three of the top five black spots on Auckland City's state highways are included in the 1.2 kilometre St Marys Bay section of State Highway One. These three black spots were the Shelly Beach Road over bridge (ranked 2nd), the Fanshawe Street northbound on-ramp (ranked 4th) and the Shelly Beach Road southbound off-ramp (ranked 5th) (NZTA, 2009a).

Within Auckland City it was found that poor observation (a factor in 44% of crashes) and failing to give way or stop (a factor in 33% of crashes) were the major contributing factors on urban roads (NZTA, 2009a). On rural roads in Auckland, incorrect lane or position (a factor in 37% of crashes) and poor observation (a factor in 36% of crashes) were the major contributing factors. It is noted in the report that determining which factors have contributed to each crash is subjective and a single crash may have several contributing factors therefore the data must be interpreted with care (NZTA, 2009a).

2.3. Traffic Safety Applications of GIS

A geographical information system (GIS) is a method of storing and analysing spatial data. GIS comes in one of two forms; vector or raster. A vector type GIS is used to assign attributes to points, lines and polygons while a raster type GIS is used to assign attributes to an array of rows and columns. An example of a raster GIS is an aerial photograph. There have been a number of studies in recent times that have used a GIS to find trends in the occurrence of traffic accidents. In these cases, GIS has been an invaluable tool for visualisation of data and has helped researchers to see spatial patterns and black spots (areas of high crash occurrence) which would be difficult to find using statistical methods (Erdogan, 2009, Erdogan et al., 2008, Krishnakumar et al., 2005).

The primary objective in many studies concerned with accident prevention is the identification of black spots which helps authorities determine locations to direct funding for improvements (Erdogan et al., 2008). Montella (2010) compares seven different 'hotspot' (more commonly known as 'black spot' in New Zealand) identification methods, one of which is the crash frequency method where sites are ranked in descending order of crashes per year per kilometre. Another method is the crash rate method where the total number of crashes on a segment of road is divided by the volume of vehicle-km's travelled. This method is more common as it takes into account exposure to crashes measured as traffic volume (Montella, 2010).

Erdogan et al. (2008) uses a GIS to identify black spots on the road network in Afyonkarahisar, Turkey by analysing spatial phenomenon. This was done by converting

crash data into a tabular form where it could then be geo-referenced onto the road network. After identifying black spots, consideration was then given to the factors causing the accidents at these locations. A similar study used the city of Konya, Turkey as a case study for identifying black spots (Gundogdu, 2010).

In a study by Krishnakumar et al. (2005), a GIS was developed for crashes involving pedestrians in Las Vegas. This was done using data collected by local law enforcement which was displayed spatially on the street network. This tool was able to easily identify high pedestrian crash zones based on crash density and crash rate (Krishnakumar et al., 2005).

In another application of a GIS, spatial variability of weather related accidents was analysed for the state of Wisconsin, USA. In this study, only crashes caused by adverse weather (snow, rain and fog) were considered, the objective being to determine whether some areas have a higher risk than others due to adverse weather conditions (Khan et al., 2008).

In New Zealand, there is an existing system supported by NZTA called 'Crash Analysis System' (CAS). CAS has been linked to a geographical information system so that crashes can be displayed spatially. This tool is used for managing, analysing and mapping traffic crash data and it stores the details and reports of all crashes attended by a police officer since 1996. This system is used in New Zealand by NZTA to determine road safety funding allocations. A deficiency in this GIS is that crashes can only be mapped on a linear basis (or bilinear in the case of divided roads such as motorways).

CAS also has several useful output options for displaying crash data for a given road or area. The 'English language' report provides written details of each crash in tabular form. The 'coded crash' report shows the same information in a more compact form using letter codes and number codes for movements and factors respectively. The 'factor grid' report is useful grouping crashes by location and comparing details within groups. Finally the 'collision diagram' is useful for visualising crash distribution and movement types which are shown on a map of the road.

Each crash entered into CAS is assigned a two letter code which corresponds to a movement type. In total there are 71 listed movement types. NZTA has also developed a grouping system of factors contributing to crashes. This has significantly simplified crash analysis as it compresses several hundred contributing factors into eight 'factor groups' as listed below:

- Driver control
- Vehicle conflicts
- General driver
- General person
- Vehicles
- Pedestrians
- Miscellaneous

CAS also provides scanned copies of the original police traffic crash reports (TCR's) which include a diagram and a description of events.

3. Methodology

3.1. Crash Data Collection

From discussions with Andrew Stevens, the traffic safety manager of the Auckland Motorway Alliance, the St Marys Bay site was selected as an appropriate case study due to the sites high crash rate, interesting geometric features and lack of fundamental changes during the 5

year study period. Crash data was exported from the CAS database in an Excel format for the 1200 metre long section of motorway. This was done using the 'polygon' drawing tool to surround the study section. All crashes occurring during the five year period between 2005 and 2009 were extracted. This yielded a total of 360 crashes (181 northbound crashes and 179 southbound crashes). The CAS data included the following variables:

- Location (position along road and coordinates)
- Date, time of day and day of week
- Movement type
- Vehicles involved
- Crash severity
- Contributing factors
- Road, weather and light conditions

However, the exported data did not provide the lane of crash occurrence; as a result each traffic crash report (TCR) had to be examined individually to determine the lane of crash origin. This data was added manually as an additional column in the Excel spreadsheet. Throughout this process several crashes were eliminated from the analysis for varying reasons as summarised in Table 1.

Table 1: Crash Data Summary

Data Summary	<i>Northbound</i>	<i>Southbound</i>
Initial crashes from CAS	181	179
Unknown lane	5	8
Outside scope	1	8
Wrong direction	9	2
Remaining crashes	168	170

'Unknown lane' includes crashes where the lane of origin could not be determined from the TCR. This indicates that approximately 4% of police reports were not carried out to the minimum standards. 'Outside scope' includes crashes that were outside the scope of the study section or occurring on the on/off-ramps. 'Wrong direction' includes crashes that were wrongly entered into CAS. Nine southbound crashes were wrongly entered as northbound and two northbound crashes were wrongly entered as southbound. This accounts for over 3% of crashes and is partly due to police error in completing the TCR diagrams and partly due to incorrect entry of data into CAS. After making these adjustments, 168 northbound crashes and 170 southbound crashes remained.

3.2. RAMM data Collection

Additional data relating to the study section was collected from Road Assessment and Maintenance Management (RAMM) database, this included:

- Road geometry data including crossfall, grade, horizontal and vertical alignment.
- Skid resistance data including macrotexture, mean summer SCRIM¹ coefficients (MSSC²) and equilibrium SCRIM coefficients (ESC³).
- Hourly traffic flow data for each lane from 2005-2009.
- Resurfacing dates and materials used

¹Sideway force Coefficient Routine Investigatory Machine

²SCRIM coefficient corrected for variations across a summer period

³SCRIM coefficient corrected for annual summer variations across the previous 3 years

These additional variables were then assigned to each crash in the existing Excel spreadsheet as the crashes already had coordinates in the Transverse Mercator coordinate system attached to them unlike much of the RAMM data.

The RAMM data is gathered on an annual basis. After plotting the crossfall data against road chainage, it was observed that there was a horizontal shift in the data between some of the years. This indicates that the data collection did not begin at exactly the same point each year and/or 'rubber banding' of the distance recording occurred. As a result, some adjustment was required to ensure the RAMM data matched from year to year (discussed further in section 4.6).

A summary of the AADT data for each lane between 2005 and 2009 is provided in Table 2. This data was used to calculate crash rates on a lane by lane basis as described in section 3.3.

Table 2: AADT data summary

Northbound Lanes AADT					
Year	1	2	3	4	Total
2005	16196	22679	20611	11665	71151
2006	16501	22453	19984	11255	70193
2007	17106	22503	20637	12189	72435
2008	15144	21046	20691	13202	70083
2009	10581	19006	23892	18287	71766
Southbound Lanes AADT					
Year	1	2	3	4	Total
2005	4782	18608	16926	19464	68731
2006	4585	18028	16755	19963	68114
2007	4847	17606	17016	21288	70503
2008	4723	17521	16474	20474	68199
2009	4668	16938	17180	20737	68564

3.3. Objective 1 Methodology

The first objective was to determine the crash rate according to crash movement type for each lane. For this study, crashes were grouped into four general crash movement types; nose to tail, lane change, loss of control and other. These groups were chosen as they account for almost all crashes which occur on motorways. The definition of crash rate is the number of crashes on a section of road divided by the exposure as defined below from the EEM (NZTA, 2010).

$\text{Exposure} = \frac{L \times \text{AADT} \times 365}{10^8}$
<p>Where:</p> <p>L is the section length in kilometres.</p> <p>AADT is the annual average daily traffic.</p>

The remaining 168 northbound and 170 southbound crashes were grouped according to their lane and crash movement type. In cases where the crash took place in more than one lane, the lane where the crash was thought to have originated was used.

The exposure of each lane was calculated using the AADT for each lane multiplied by the length of the road section (1.219km) multiplied by the number of days in five years (1826).

The crash rate was then calculated by dividing the total number of crashes during the five year period by the exposure which is measured in 100 million vehicle-km's travelled (100MVKM).

3.4. Objective 2 Methodology

The second objective was to investigate road and environment factors potentially contributing to crashes on this section of motorway. The CAS data includes factors which have contributed to each crash which have been assigned using a reference system developed by NZTA. In total there are several hundred possible factors from codes 100-999. It was found that the 2007 to 2009 data was complete however prior to 2007, not all of the crashes have had contributing factors assigned to them. For the purposes of this study each TCR was examined that enabled the contributing factors to be checked for the 2007 to 2009 data and completed for the 2005-2006 data.

The focus was then directed towards crashes caused by road and environment factors (codes 800-899) so that they can be related back to geometric, surface and infrastructure conditions. From this data, conclusions could be drawn on what improvements were required. However, it was found that few crashes had been assigned these factors because there are usually more significant factors contributing to any crash which gets used instead. As a result, road and environment factors were analysed visually by examining spatial trends in GIS.

3.5. Objective 3 Methodology

The third objective was to investigate the potential of using a raster GIS to analyse crashes on multilane roads. To do this, the data was first plotted onto an aerial photograph using a program called 'ArcGIS' to aid visualisation of crash patterns. The New Zealand Transverse Mercator grid based coordinate system was used as this was compatible with the northings and eastings for each crash provided by CAS.

Because the crash coordinates originated from CAS, the plotted crash coordinates appeared in a single line between lane two and lane three. As a result, the points had to be manually offset into the correct lane based on information provided in the TCR's so the accuracy of the coordinates in CAS were limited to the accuracy of the information contained in the TCR. Features of ArcGIS were then utilised to aid visualisation of various crash patterns based on the crash variables outlined in section 3.1 and 3.2. Figure 2 shows the lane labelling system which is referred to in this report.

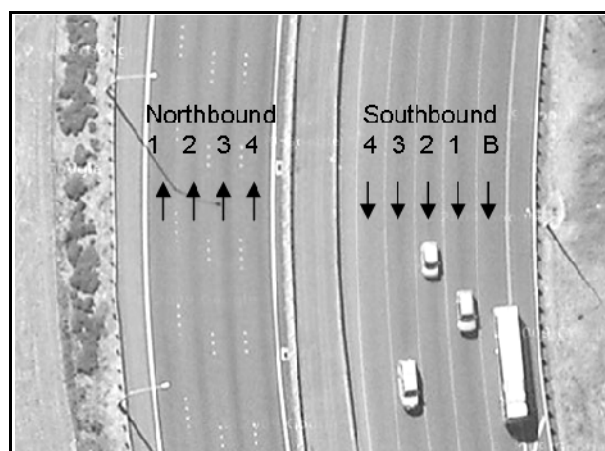


Figure 2: Lane labelling system used in this paper

4. Results and Discussion

4.1. Northbound Results and Discussion

Figure 3 is a graph displaying the crash rate per 100MVKM (million vehicle-km's) travelled on a lane by lane and movement type basis for the northbound direction. This shows a number of interesting trends. Firstly it is clear that the crash rate in lane three is significantly higher than any other lane (155 crashes per 100M vehicle-km's travelled). This is due to the relatively high proportion of lane change crashes compared with other lanes which is thought to be a result of the high interaction between lanes two, three and four. The crash rate in lane one is significantly lower (45 crashes per 100M vehicle-km's travelled). This is due to the relatively low proportion of nose to tail crashes occurring in this lane compared with other lanes which are a result of lower traffic volumes (only 21% between 2005 and 2009) and generally more conservative driving behaviour.

The most common type of crash in all four lanes was nose to tail. These crashes are generally caused by a combination of road, driver and traffic characteristics. They were found to occur most often at times where there was congestion resulting in a variation in traffic speeds. Also in wet conditions, skid resistance can fall significantly which increases the stopping distance for vehicles. The vehicle can also become a factor if tyre condition is not maintained. These factors combine with the main factor being driver inattention and distraction.

Lane change crashes also make up a significant proportion of total crashes especially in lane three as noted earlier. These crashes were more common in the centre lanes as there is potential for interaction from both sides. Lane change crashes were also found to be concentrated at either end of the study section near the on-ramps simply due to more lane change manoeuvres occurring in these areas. Vehicle and driver factors are the predominant causes of lane change crashes, the majority of crash reports suggest that poor driver observation, decision making and vehicle blind spots are responsible.

Loss of control (LOC) crashes were found to increase in rate per lane the closer the lane was to the median (eg. one, five, eleven and twelve LOC crashes in lanes one, two three and four respectively). This could be due to the higher speeds and possibly related to more reckless driver behaviour in lanes three and four. The majority of these crashes occurred on horizontal curves in wet conditions suggesting that the loss of lateral skid resistance and drivers failing to adjust speeds are the predominant contributing factors. Traffic characteristics also have an effect as all 'loss of control' crashes occurred when traffic was flowing freely therefore at higher operating speeds. There were five 'other' category crashes. These mostly involved vehicles striking objects, three of which were ladders dropped from other vehicles.

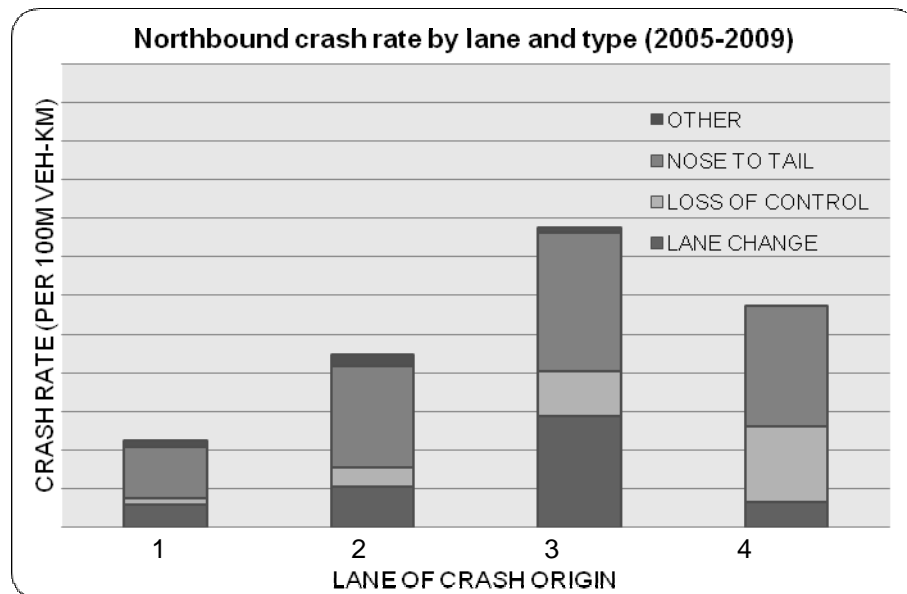


Figure 3: St Marys Bay motorway northbound crash rate by lane and crash type, 2005 to 2009

4.2. Southbound Results and Discussion

Figure 4 is a graph displaying the crash rate per 100M vehicle-km's travelled on a lane by lane and movement type basis for the southbound direction of the St Marys Bay motorway. This direction provides five lanes directly after the Auckland Harbour Bridge however the left lane becomes a bus lane shortly after the first left hand corner as shown in Figure 2. As a result, this lane has been omitted from the scope of the study due to the small number of crashes occurring in this lane.

Once again lane three has a significantly higher crash rate than any other lane (233 crashes per 100MVKM followed by lane one (149) followed by lane two (98) followed by lane four (78). However unlike the northbound direction, lane three's higher crash rate is mostly due to nose to tail crashes (75%) while this type of crash is similar between the other three lanes.

The crash rate for lane change crashes is significantly lower in lane four compared with the other three lanes. This is because vehicles wishing to travel south of Auckland are able to stay in lane four while there is much greater lane change activity in lanes one, two and three as vehicles attempt to position themselves for the dual lane Fanshawe Street off-ramp and subsequent central motorway junction. The relatively high 'lane change' crash rate in lane one and lane two is likely due to drivers who attempt to save time by pushing their way into the queue during the morning peak. During this time, lanes one and two are free flowing while lanes three and four are backed up from the Victoria Park viaduct. It is expected that the frequency of this type of crash will be significantly reduced once the Victoria Park tunnel (currently being constructed) that will provide additional capacity is completed.

There does not appear to be any obvious reason why loss of control crashes appear to be more common in lane one and lane three. However, as was seen with the northbound direction, loss of control crashes were more frequent on curves and in wet conditions for the same reasons.

There were three 'other' crashes which did not fit into any of the other predefined categories. All three occurred in lane four.

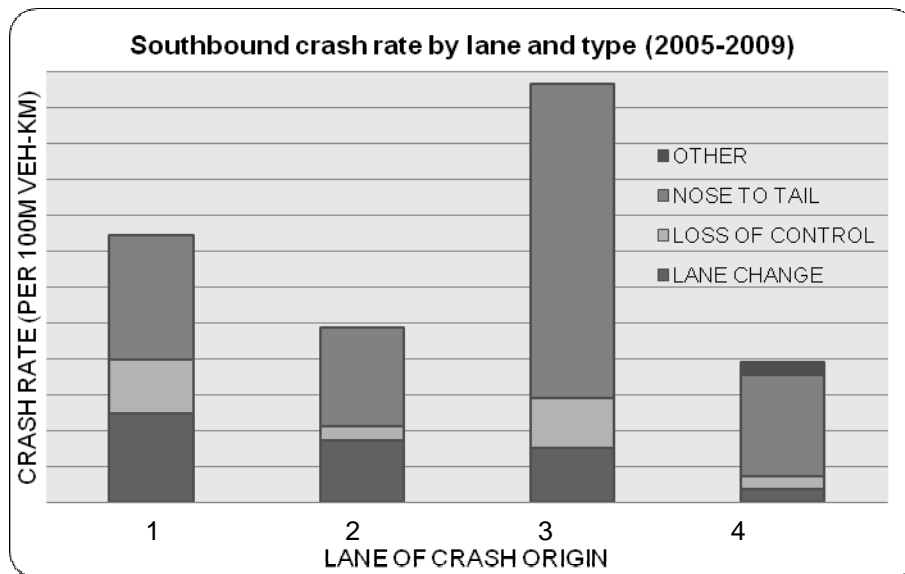


Figure 4: St Marys Bay motorway southbound crash rate by lane and crash type, 2005 to 2009

4.3. Road Surface Data Discussion

Plots of macrotexture, ESC and MSSC did not provide conclusive evidence that the crash rate is related to skid resistance for this section of motorway during the crash analysis period (2005 to 2009). This is believed to be a result of good asset management practices on behalf of NZTA as this section used to have a much higher loss of control crash rate in the wet due to the high friction demand. A regional policy was subsequently developed that utilised a surfacing aggregate with higher resistance to polishing on this section for the full period of crash analysis. This policy was tested using this 'after' crash analysis period using a colour coded plot of each of these variables. Plots of differential macrotexture, ESC, and MSCC (between right and left wheel paths) showed that for left hand curves, more wear occurred on the right wheel path and for right hand curves, more wear occurred on the left wheel path as would be expected. Skid resistance in wet conditions could still be a factor with over 20% of crashes occurring on a wet road.

4.4. Vector GIS Discussion

Figure 5 shows a screenshot from the existing CAS GIS package. This uses a vector system where each direction of the motorway is represented by a single line. In this image the crashes that have occurred between 2005 and 2009 are represented by points for the northbound direction. The position of these points is based on a distance along the motorway from a given intersection or landmark such as an on-ramp or an over-bridge. This system has several limitations as outlined in the following section.

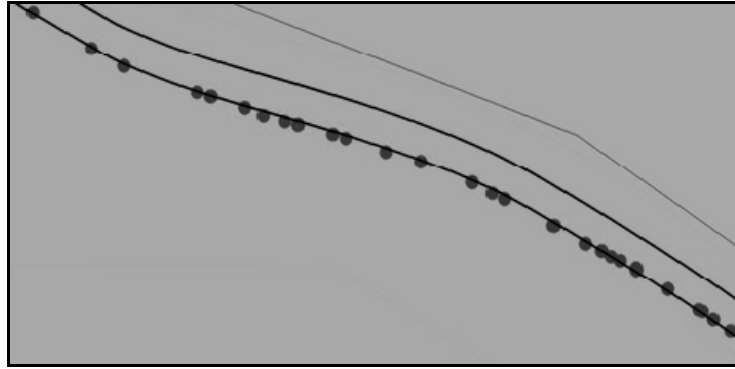


Figure 5: Screenshot from CAS

Firstly, the crashes are only displayed on a linear basis which is adequate for analysis of single lane roads but not appropriate for a four lane motorway as this case study highlights. At the very least CAS should have an additional variable named 'lane' assigned to each crash so that the crashes can be sorted and viewed on a lane by lane basis. CAS currently has the ability to do this for all other variables listed in section 3.1 so it would not be difficult to expand CAS in this way.

There is also an accuracy issue. The crash locations on the motorway are usually based on a distance from an on-ramp or off-ramp. This distance is taken from the police TCR and the level of accuracy between reports varies from 10m to 100m. In some instances, it is clear from the TCR that little or no effort has been made to accurately locate the crash and locations have been estimated.

Due to this issue, several crashes often appear in exactly the same location. For example, a number of crashes may be estimated to have occurred 100m north of an on-ramp. When displayed in CAS these will appear as one point and other outputs such as the collision diagram feature must be analysed to determine the number of crashes at that point.

4.5. Raster GIS Discussion

Figure 6 shows a screenshot from ArcGIS which is the program used in this study to plot crashes using a raster system. Each triangle represents a crash that has occurred in the northbound direction between 2005 and 2009. An aerial photograph was used as a base layer and the crashes were plotted based on northings and eastings using the Transverse Mercator coordinate projection system.



Figure 6: Screenshot from ArcGIS

The image shows that crashes can be displayed on a lane by lane basis which gives a clear idea of how crashes are distributed along the road and across each lane. The aerial

photograph layer enables road features to be viewed simultaneously so that these can be considered as contributing factors. For example, there is a cluster of nine 'nose to tail' crashes immediately following the visual message board shown in Figures 6 and 7 which suggests that this could be a possible distraction for drivers. It should be noted that in remote rural areas there may be an issue with aerial photograph quality. In addition some photographs may not be up-to-date therefore care must be taken during interpretation.



Figure 7: Visual message board from a driver's perspective (source: Google street view)

As with any GIS, the accuracy of the input data is critical to ensure meaningful results. Using this system, the accuracy issue can effectively be removed by eliminating the human element involved in crash location. As police vehicles are equipped with GPS units, the attending officer can simply save the coordinates on the device. This eliminates the need for officers to attempt to measure distances from intersections and landmarks. As a result, safety will be improved and more attention can be given to other tasks at the accident scene.

One issue which arises from determining crash locations is the difficulty in determining where the crash occurred rather than where the vehicle(s) came to a rest. For crash analysis applications the crash origin is of most interest. This is especially an issue in high speed situations such as motorways where crash origins may be up to 100m from the vehicles final position. Under the current system, the TCR's in CAS are not accurate enough for this to be an issue as the accuracy can vary up to 100m. If a more accurate coordinate based positioning system was used then standard procedures should be in place to determine the crash origin from the available information.

4.6. Further discussion and problems encountered

As with all systems, the quality of the output is related to the quality of the input data. Several problems were encountered throughout the course of this study. Measures taken to address each problem are described in this section.

The first source of error came from the data extracted from CAS. Several crash reports had minor errors due to incorrect data entry from the TCR's into the database. The most common source of error encountered was the incorrect entry of 'direction of travel'. Each TCR was examined to ensure the correct direction was entered into the spreadsheet.

Another source of error within the crash data originates from the accuracy of the crash location. The location is determined based on a longitudinal distance along the road section from a known landmark (usually an over-bridge or an on/off ramp in a motorway situation). However the accuracy can vary by up to 100 meters which is significant in road crash analysis. The attending police officer is required to complete the report onsite where he or she can accurately gather the appropriate data. However this can often be difficult due to

numerous external pressures including ensuring public safety, clearing traffic backlog and onsite weather conditions.

These crash positions are then converted into the Transverse Mercator coordinate system which enables them to be easily plotted into GIS programs. As a result of the inaccuracies in crash location, when the crash data is mapped using ArcGIS, the points indicating crash locations often appear in clusters at common intervals. All of the aforementioned problems can be rectified by using the global positioning system (GPS) unit which is installed in all patrol vehicles to directly reference the position of the crash. This will lead to increased accuracy as it removes the intermediate step of relating positions to nearby streets.

A second source of error found in the input data originated from the RAMM data. The high speed data that was gathered by a SCRIM+ truck was found to be slightly out of phase when comparing cross-fall data between different years as shown in Figure 8.

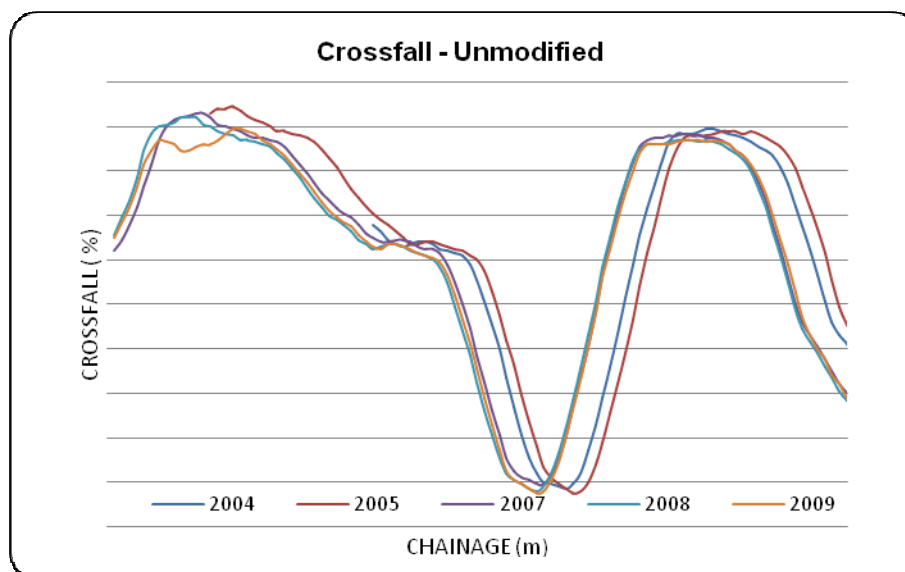


Figure 8: Graph of uncorrected lane 2 southbound cross fall against chainage showing variations from year to year

A horizontal phase shift was applied to the years previous to 2008, when a GPS unit was installed within the data collection truck. This ensured that all RAMM data including road macrottexture and ESC over the five year period are as accurate as possible. Figure 9 shows the improvement in the cross-fall data after adjustments have been made.

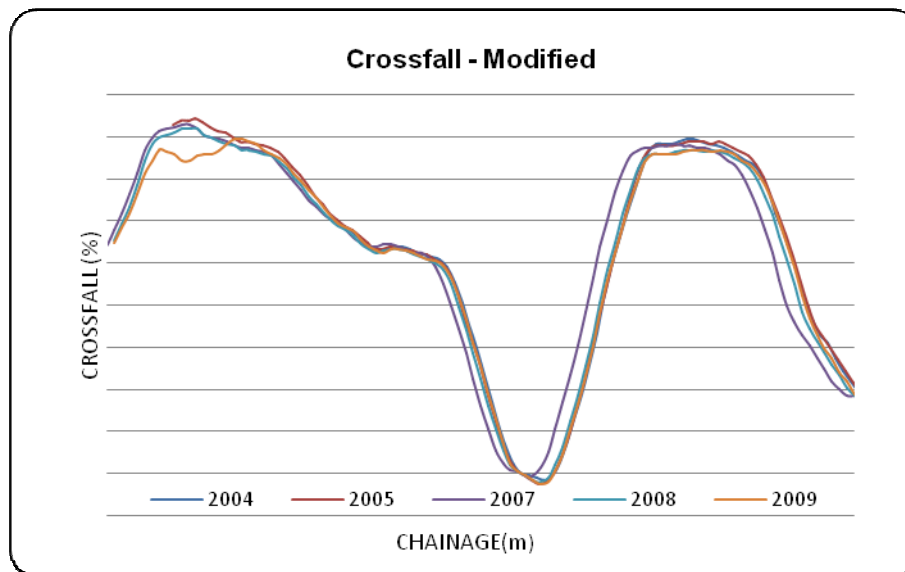


Figure 9: Graph of corrected lane 2 southbound cross fall with after data shift to minimise annual variation in other RAMM data.

For the purposes of this project, the relevant RAMM data was attached to each individual crash event because the crash data was already geo-referenced using the Transverse Mercator system. However, for large scale implementation, it would be much more efficient to create another layer within the ArcGIS which represents the RAMM data. By doing this it would enable future crashes to be added to the database without having to research the relevant road data for that point. The data for that crash could then be obtained within the ArcGIS, making the process much more efficient than the methodology used within the scope of this project. For this to be possible, the RAMM data must also be geo-referenced using the Transverse Mercator system.

The representation of the RAMM database within a GIS was an application not considered when initiating this project. However, as the project proceeded, it became clear that GIS provided clear visualisation of the road asset data in a form that was very visually appealing. The ability to time lapse the data also allows the user to view how the properties of the roadway are degrading over time and therefore aid in the planning of maintenance and rehabilitation works.

Traffic flow data obtained from the Auckland Motorway Alliance is obtained from dual loops located approximately 350 meters south of the northernmost point of the case study. This is the only flow data collection point within the study section, therefore all traffic volume calculations were based on this data. Within the scope of this project, it has been assumed that this data represents the entire length of the study section. However there is potential for movement between lanes throughout the section, particularly at the southern end of the section, closest to the on and off ramps. More research is required to more accurately assess volumes along the study section.

The traffic flow data provided in section 3.2 indicates that the traffic is not evenly distributed between the four lanes with 21%, 30%, 30% and 19% of vehicles using lanes one, two, three and four respectively in the northbound direction. The southbound direction has an even greater variation of flows between lanes. Lane one carries a lower volume as this becomes a bus lane south of the detection loops while lanes two, three and four carry similar volumes. The distribution of northbound traffic between each lane in 2009 differs from previous years. Upon further inspection of the data, there were periods of time (several days) where loops

did not detect any traffic for unknown reasons. As a result this data cannot be assumed to be totally reliable.

Due to the high profile nature of the study section, there is a large volume of data available and this is collected at regular intervals. Also as the study section was located within Auckland City, high resolution aerial photographs were available from many different sources. The availability of high resolution and up-to-date aerial photos decreases in more remote rural areas in New Zealand. Therefore the systems described in this paper may only be feasible in urban areas. In addition, the main advantages of a raster GIS are more applicable to multilane roads such as motorways, arterials and intersections. However the use of aerial photography to investigate potential road environment factors contributing to crashes is an advantage that is relevant to all areas, particularly rural areas where users may not be familiar with the site.

5. Conclusions and Recommendations

In conclusion, the implementation of a raster based GIS crash analysis system has the potential to overcome many of the limitations of the existing CAS programme which uses a vector GIS.

The major benefit is the ability to visualise crashes on a lane by lane basis which is a useful tool for crash reduction studies on multilane roads such as motorways, multi-lane arterials and intersections. It also has the potential to significantly increase the accuracy by eliminating some of the human element especially surrounding the location of crash sites. In addition the aerial photograph base layer offers the opportunity to better examine how surrounding road and environment features relate to crash occurrence.

This report has also highlighted inaccuracies in the current data provided by CAS and RAMM. CAS data was incomplete for some crashes while other data was entered incorrectly. RAMM road geometry data from year to year did not match up indicating inconsistent surveying techniques and hourly traffic flow data was incomplete leading to errors in AADT data.

In addition to crash analysis applications, this study can be applied to other databases such as Road Assessment and Maintenance Management (RAMM). This has the potential to be used as a visualisation tool for road surface data, geometry data and traffic flow data. Further research is required in order to fine tune the systems and processes required to implement this. Implementation of this system for a large network has the potential to be costly and time consuming. It will also take time for people to adapt to a new system which can lead to inefficiencies in the short term. With a lot of previous historical data to import into a new system, a long lead in time would be needed to implement a new system.

Due to the advantages of a raster GIS outlined in section 4.5, it is recommended that the Auckland Motorway Alliance consider combining the RAMM database with CAS in this way as the system could provide advantages in meeting their crash reduction targets.

It is also recommended that a study be conducted to investigate whether a similar raster GIS can provide advantages for multilane intersection crash analysis. If this was found to be successful then a raster GIS could be suitable for most urban areas throughout New Zealand where quality input data can be obtained.

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