Risk Mapping and a Physical-Attribute-Based Star Rating System for Road Safety Network Screening Purposes on Canadian Prairie Region Highways

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Abstract

Network screening for road safety can be based on either collision records or physical attribute data. This paper presents an exploratory analysis of methodologies developed by the International Road Assessment Program (iRAP) that apply these two general approaches to road safety network screening. There is interest in exploring the Road Assessment Program (RAP) through a case study in Manitoba to understand its usefulness and customization requirements for the specific needs within the Canadian Prairie Region. Risk mapping uses historical collision records while star rating mapping uses physical attribute data.

The research leading to this paper had four objectives: (1) synthesize strengths and weaknesses of the RAP according to a jurisdictional survey; (2) investigate constraints and availability of required data and resources in terms of information, level of effort, funding and equipment; (3) analyze the RAP methodology by applying it to part of the National Highway System (NHS) in Manitoba; and (4) explore the usefulness of the program for application in the Canadian Prairie Region, and possibly beyond.

The risk mapping methodology was found to be an effective road safety network screening process when required data is available; however, adaptations for the prairie context are necessary. Regarding the star rating aspect of the analysis, although it can be helpful, the aggregate nature of the results does not utilize the potential of the data collected. Details from the program developers on the technical rationale underlying the star rating methodology as well as processes to present results in a disaggregated form would enhance the usefulness of this approach.

INTRODUCTION

This research explores the suitability of the RAP in Manitoba. The program is applied to portions of the NHS in Manitoba in order to identify program methodology strengths, limitations, and modifications that are required to account for jurisdiction-specific traffic and infrastructure characteristics. These strengths, limitations, and modifications (and not the actual safety levels on Manitoba highways) are the subject of this paper. Therefore, the paper focuses on an exploratory analysis of the program methodology rather than on actual safety results derived from the application. The application to Manitoba highways followed, as closely as possible, the program methodology as described in the most recent available program reports. The application described in this paper does not represent an effort of the International Road Assessment Program (iRAP). Instead, the work represents the efforts of an independent university research group to reproduce, apply and explore the methodology.

The iRAP was developed to improve high risk roads around the world, with the goal of understanding and addressing the engineering aspects of the collision problem. The program aims to help jurisdictions develop road safety investment plans by ranking road safety levels and identifying problem areas based on the collision history and based on an assessment of physical roadway attributes. The program uses collision history information to develop *risk maps*, and an assessment of physical roadway attributes to develop *star rating maps*.

BACKGROUND

The iRAP is a not-for-profit organization that works in partnership with government and non-government organizations to "inspect high-risk roads and develop star ratings and safer road investment plans" (1). The program has been developed and is being implemented in more than 50 countries around the world to help understand and address the road collision problem, with a substantial concern for the engineering aspects of its root causes and consequences. The program involves ranking road safety levels from the perspectives of collision history and infrastructure safety assessments. The ranking results are used to develop road safety investment plans.

The program, which originated in Europe and subsequently was applied around the world in a range of developed and developing countries, aims to identify the potential to prevent deaths and serious injuries from road collisions. Other road assessment programs, including the European Road Assessment Program (EuroRAP), Australian Road Assessment Program (AusRAP), and United States Road Assessment Program (usRAP) have been developed under the umbrella of the iRAP organization with modifications to conform to the jurisdictions' unique characteristics.

Risk maps use historical collision data to identify more collision-prone road segments. These maps show collision densities, collision rates, collision rate ratios, and potential for casualty collision reduction. Risk maps are explained in detail in subsequent sections of this paper.

Star rating maps show a safety rating from one to five stars for the design features of road segments. They provide a simple measure of the level of nominal safety of road segments based on a formal evaluation of the road design and condition. The formal evaluation is based on a methodology for calculating Road Protection Scores (RPS), and the RPS are then converted to star ratings. The methodology first determines individual scores reflecting the risk of collision occurrence and severity for three collision types: head-on, run-off-road, and intersection. The scores are combined in a weighted average to determine an overall star rating for a segment.

INTERNATIONAL JURISDICTIONAL SURVEY

A jurisdictional survey of RAPs in other countries was conducted as part of this research to gain knowledge of experiences in implementing the program and how the results of the program have been applied. The number of jurisdictions selected for this survey was based on available resources and the jurisdictions' relevance to the application to Canadian rural highways. Because the usRAP methodology incorporates the experience of earlier RAPs, and United States (U.S.) rural highways share many similar characteristics with Canadian rural highways, all eight U.S. pilot program jurisdictions were selected for the survey (Florida, Illinois, Iowa, Kentucky, Michigan, New Jersey, New Mexico and Utah).

The survey also includes the original four iRAP pilot countries (Chile, Costa Rica, Malaysia and South Africa). Four additional developed countries were also selected for the jurisdictional survey as they were likely to be more comparable to the Canadian setting than developing countries (Australia, Ireland, Sweden and the United Kingdom). This results in a total of 16 jurisdictions that were contacted for the survey, nine of which responded. The jurisdictions that participated in the interviews are: Australia, Chile, Costa Rica, Malaysia, South Africa, Sweden, the United Kingdom, and the United States (New Mexico and New Jersey).

The research team attempted to contact the government department responsible for roads or road safety for each jurisdiction where the survey was conducted. In some cases it was not possible to contact the road or safety agency and the feedback on the questions was received from representatives of iRAP or a local automobile club that helped to arrange the study in the given jurisdiction. The rationale for contacting the highway agency in each jurisdiction was that road authorities would be able to give an objective opinion on the program – and this type of opinion was of greater interest to the research team than one from developers and promoters of the program itself. The topics discussed with those interviewed were:

1. Current status of the RAP in the given jurisdiction
2. Experience regarding effectiveness of RAP
3. Strengths and weaknesses of RAP
4. Lessons learned from RAP
5. Recommendations for future implementations of RAP in other jurisdictions
6. Effectiveness of knowledge transfer to local transportation staff
7. Resources and costs of implementation
8. Improvements for addressing vulnerable road user safety
9. The use of local collision modification factors versus default RAP methodology risk factors
10. Future plans for RAP

General themes emerging from the jurisdictional survey are:

- The jurisdictional survey was an effective way of learning about RAP experiences from other jurisdictions. Many key documents have been published by developers and promoters of the program, however, details on methodologies and analysis techniques have been limited for the public use. iRAP representatives indicated that they limit public access to the methodology because program results are sometimes used in efforts to support lending and investment decisions of multilateral agencies. iRAP wishes to control access to the methodology details in order to avoid applications by other parties who may wish to bias investment decisions towards a specific agenda.

- iRAP has recently developed a new methodology, which is proprietary and is not available to anyone without the commitment to a formal RAP requiring the collaboration of a government agency, an automobile association, and the iRAP umbrella organization.
- In general, agencies reported that using the RAP can be an effective, low cost, and consistent way of evaluating the safety performance of a road segment. However, some jurisdictions found limitations with the methodology and the results, particularly regarding factors such as traffic flow variability, the consideration of vulnerable road users, and the lack of consideration of mobility patterns.
- Survey participants identified a lack of correlation between star ratings and the actual collision experiences.
- Survey participants expressed that risk maps can be a tool for communicating with the general public. Attracting public attention can exert pressure on road agencies to act on high-collision locations. However, there is no consensus as to whether collision density or collision rate is the best method to use when providing results to the public.
- There is a lack of knowledge transfer between the RAP organizers and the local transportation staff, particularly in developing countries. This typically included limited access to the methodology, mainly because the analysis was completed by outside organizations.
- The international survey revealed some problems regarding buy-in, publicity and communication between engineers, politicians and program staff. Issues include understanding the rationale for the program and transparency of the methodology.

DATABASES USED IN THE ANALYSIS

This research used a variety of databases for analysis. The data required for risk mapping comprises: (1) geospatial data from a linear referencing system, (2) traffic volume data, (3) road inventory data, and (4) geo-referenced collision data. Although star rating mapping relies primarily on field data collection; geospatial data, road inventory data and geo-referenced collision data are also utilized. GPS-referenced photo-logs and Google Street View (Google, 2010) were also used as additional reference sources to confirm observations after the field visits. The databases are described below.

Geospatial and Traffic Volume Data

The geospatial and traffic volume data were obtained from the Manitoba Highway Traffic Information System (MHTIS). MHTIS is a partnership between Manitoba Infrastructure and Transportation (MIT) and the University of Manitoba Transport Information Group (UMTIG), which produces traffic flow estimates for Manitoba highways. MHTIS also developed the Manitoba highway linear referencing system (LRS) that is used in this research.

The Manitoba highway network is divided into road segments called control sections. The control sections provide a specific and systematic way to identify and analyze conditions and characteristics of the highway network for transportation engineering, planning, management, and traffic monitoring purposes. Control sections are based on continuity of pavement types, geometric design features, and functional classes. MHTIS's linear referencing system is further developed from MIT's network to capture the full extent of the Province's highway traffic monitoring program by dividing control sections into sequences based on the locations of counting stations, intersections, towns, and traffic generators/attractors. Figure 1 shows an example of a control section (top) that is further divided into control sequences (bottom).

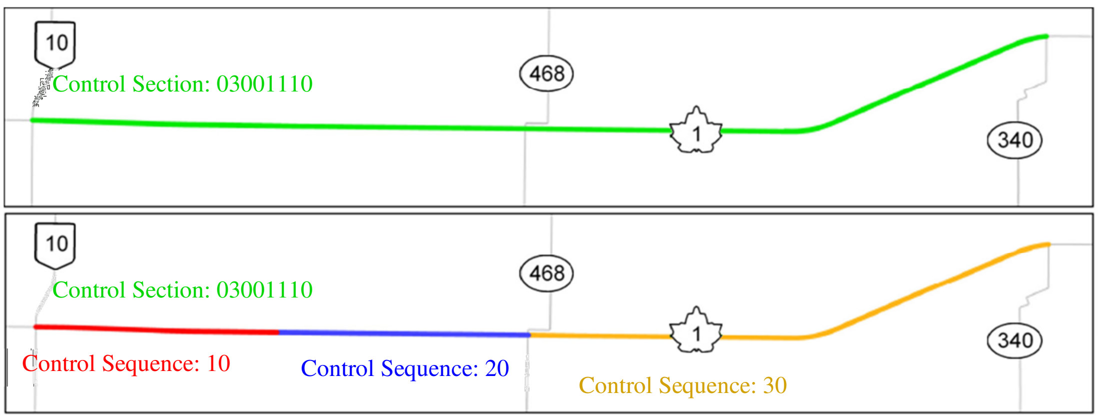


Figure 1: Control Section (Top) Versus Control Sequence (Bottom)

Road Inventory Data

Road inventory data for this research was obtained from MIT. The road inventory database is a continuously updated database maintained by MIT containing control section descriptions and characteristics (e.g., divided status, number of lanes, median type).

Collision Data

The collision database was provided by MIT and the data is obtained from the compilation of Traffic Accident Reports completed by municipal police or the Royal Canadian Mounted Police; the data includes self-reported collisions and collisions attended by a police officer.

The collision database identifies three types of collision severity: fatal, injury, and property damage only (PDO). A fatal collision in Manitoba is defined as a collision in which at least one death occurred as a result of the reported collision within 30 days of its occurrence (2). An injury collision is defined as any collision which resulted in at least one injury, but not death, within 30 days of the collision (2). In Manitoba, this is typically determined by a police member attending the scene of the collision (3). A PDO collision is defined as a collision resulting in over $1,000 in property damages without any fatalities or injuries. This research analyzes casualty collisions which comprise fatality and injury collisions. In subsequent sections, where the term 'collision' is used, it is referring to the sum of fatality and injury collisions.

Linearly referencing Manitoba's collision data is a resource-intensive process. The most recent complete year of traffic accident reports which have been linearly referenced and reviewed by MIT is 2006 (at the time of this research). Manitoba Infrastructure and Transportation re-segments highway control sections regularly, therefore collisions on these locations are identified and transferred to the MHTIS linear referencing system.

There are certain issues that affect the quality of the data. In the case of collision databases, it is common knowledge that inaccurate information may be entered as a result of the way in which data is collected by police officers in the field. There may also be coding errors or other quality control problems. In addition, the database only consists of data on reported collisions.

Field Data

Field investigations consisted of driving each segment in each direction to record data on both sides of the road as needed, and recording necessary attribute data every 100 metres. The distance along each highway was measured using the vehicle odometer. Distances were verified at milestones such as intersections. The field data collection was found to be resource-intensive and is described in greater detail in following sections.

Although manual field data collection was used in this research, technologies are available which can simplify this task. Programs carried out under the auspices of iRAP usually collect GPS referenced video from a moving vehicle. The video is subsequently analyzed in an office setting to make estimates of road attribute information for calculating RPSs. This can speed up the process, although the equipment is expensive and the subsequent analysis can only estimate parameters such as side-slope or clear zone distances. A mobile spatial imaging system is another technology that adds laser scanning to GPS-referenced image capture from a moving vehicle; the laser scanning enables precise measurements of road attributes.

Photo-logs and Google Street View

Photo-logs and Google Street View were used to collect intersection characteristics. The photo-logs were collected by the research team through pre-drives of the study segments which included photographing the roadway every few seconds using a camera with GPS capabilities. Every photograph was referenced with a location on the roadway segment.

ANALYSIS OF RAP METHODOLGIES

The Midwest Research Institute report *usRAP Feasibility Assessment and Pilot Program* (4) provided the basis for the methodologies used in this analysis with additional input from the report *Canadian Road Assessment Program (CanRAP) Feasibility Study* (5).The *usRAP Feasibility Assessment* methodology was developed from comparable EuroRAP criteria with adaptations for the U.S setting (4). A more recent methodology has been developed which is a proprietary methodology of iRAP and is not available for exploratory analysis purposes without formal partnership. Such a partnership was precluded by both the resources available for the project and the intent to carry out an independent exploratory analysis of the methodology.

The methodologies used in this analysis follow the *usRAP Feasibility Assessment* and any deviations from the methodology are noted throughout. Deviations from the methodology were necessary due to inadequacy in the provided information and where the methodology was unsuitable for the Canadian Prairie Region setting. In these cases, the research team interpreted the methodology by applying engineering judgement and proceeded in an appropriate manner for the Canadian Prairie Region application.

Risk Mapping

Risk maps were created for a subset of the NHS network in Manitoba including all of Provincial Trunk Highway (PTH) 1, PTH 101, PTH 100, PTH 75, PTH 16, and PTH 6. This subset represents 80 percent of the NHS in Manitoba by length and carries over 90 percent of NHS vehicle kilometres of travel (VKT) in Manitoba. The NHS subset comprises 1,648 centreline kilometres, which is approximately nine percent of the total centreline-kilometre highway network in the province. Analyzed sections can be seen in Figure 2. Collision data was analyzed for the years 2002 through 2006 for the creation of risk maps. During this time, 1,661 fatal and injury collisions were reported on the NHS subset, which represents approximately 22 percent of fatal and injury collisions on all Manitoba provincial highways for this period.

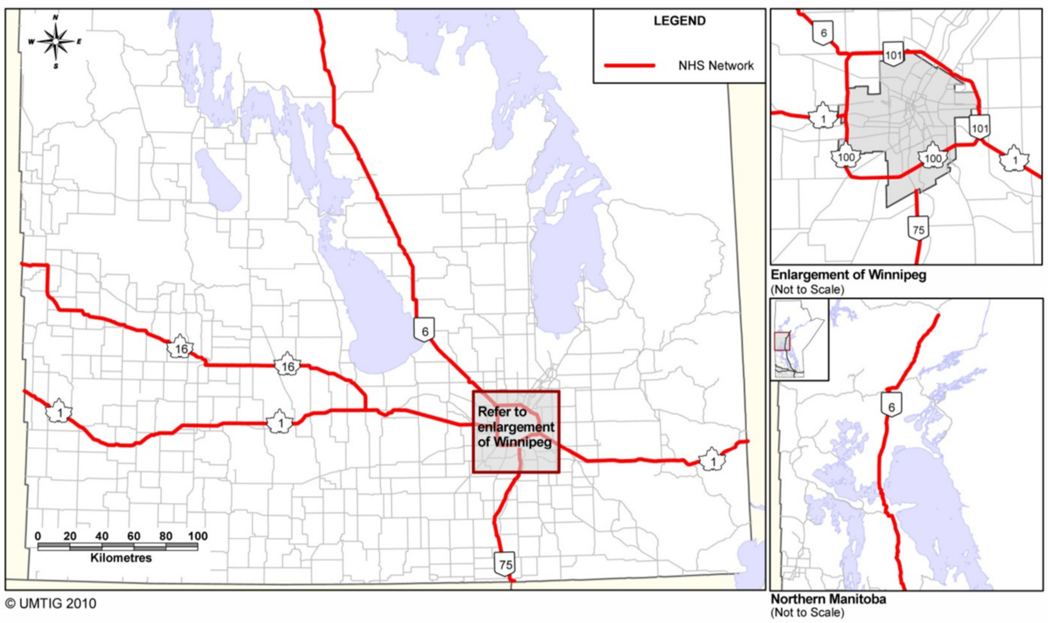


Figure 2: Analyzed Subset of National Highway System Network in Manitoba

Risk Mapping Methodology

This methodology involves four steps: (1) establishing the collision analysis period; (2) road classification; (3) road segmentation; and (4) development of risk categories. Each of these is described below.

1. Collision Analysis Period

The usRAP Feasibility Assessment and the CanRAP Feasibility Study recommend using five years of collision data (4),(5). The purpose of using multiple years of collision data is to allow for a greater number of collisions in the database to be able to produce more accurate results from the analysis. The most recent collision data which has been linearly referenced and reviewed by MIT, is for the year 2006 (at the time of this research). For this reason, this research considers data from 2002 to 2006.

2. Road Classification

Road type classification is based on access control, median type, number of lanes and highway functional classification. Roads in Manitoba can be classified into four road types based on easily identifiable road characteristics: freeway, multilane divided highways, multilane undivided highways, and two-lane highways. The defined network for this research comprises roadways in two of these groups: multilane divided highways and two-lane highways.

3. Road Segmentation

The road segmentation methodology outlined in the CanRAP Feasibility Study prescribes a four step approach (5). It recognizes that the appropriate segmentation is a critical component of the RAP methodology and that potential problems may occur associated with selecting road segments that are too short or too long. If the segments are too long, the analysis will not be useful for identifying specific sites requiring improvement. Because collisions are infrequent events that are partially influenced by random events, very short segments can show a distorted picture of actual safety levels. This can be understood by considering the collision rate at a collision site as the segment size approaches zero. The rate is determined by dividing the number of collisions by the exposure on the segment, typically in terms of vehicle kilometres travelled (VKT). Since the VKT of a segment approaches zero as the length of a segment approaches zero, the rate would approach infinity at the collision point – and zero everywhere else. At small segment sizes, collision rates can be highly unstable with respect to the segment length. Since road safety is not a function of segment size, the measurement of road safety should be independent of segment size selection – but at short segment lengths, it is not independent.

The main goal of the methodology in the CanRAP Feasibility Study is to meet three criteria for highway segmentation (5):

- Easily identifiable start and end locations for the road user
- Homogeneous geometric characteristics
- Homogeneous major traffic characteristics

Several practical limitations were encountered by the research team when applying this road segmentation process. The following discussion presents the experiences encountered in the application of the CanRAP method for road segmentation.

Step 1: Initial Segmentation

This first step identifies segments which have an easily identifiable start and end location for the road user. For this initial step, the highways were divided into segments of approximately 100 kilometre lengths using towns, cities, or major highway intersections as the nodes of the segments. Completing this step created 14 segments on the NHS subset, as shown in Table 1. This step was completed without encountering any practical limitations.

Table 1: Initial Segmentation Characteristics

Highway	Start of section	End of section	Length (km)
PTH 1	MB / SK border	PTH 10 (Brandon)	122
PTH 1	PTH 10 (Brandon)	PTH 1A (Portage)	117
PTH 1	PTH 1A (Portage)	PTH 101/PTH 100 (Winnipeg)	79
PTH 1	PTH 101/PTH 100 (Winnipeg)	MB / ON border	142
PTH 100	North Perimeter		40
PTH 101	South Perimeter		50
PTH 16	MB / SK border	PTH 10 (Minnedosa)	151
PTH 16	PTH 10 (Minnedosa)	PTH 1	116
PTH 75	Canada/U.S. border	St. Norbert	91
PTH 6	PTH 101 (Winnipeg)	PR 229	90
PTH 6	PR 229	PR 239	104
PTH 6	PR 239	PTH 60	186
PTH 6	PTH 60	PTH 39	208
PTH 6	PTH 39	PR 280 (Thompson)	152
		Total	**1648**

Step 2: Review Segment Characteristics

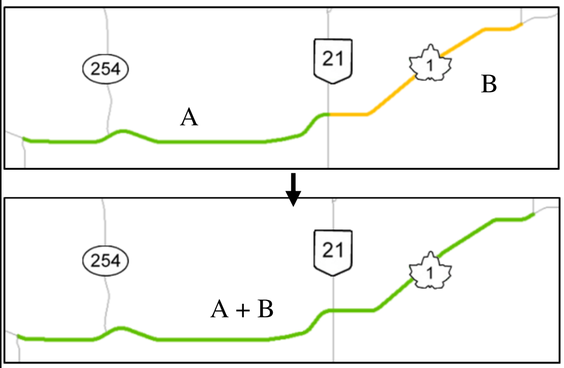
This step requires reviewing the necessary attribute data (e.g., geometric characteristics, posted speeds, traffic volumes) for the entire network. After reviewing this attribute data, it is necessary to create analysis segments in a LRS and be able to assign collision data to this new LRS. Creating new segments is a resource-intensive process. Many road authorities already have an LRS with the necessary attribute data and collisions already assigned. For example, MHTIS has an existing LRS with control sections based on homogeneous geometric characteristics and functional characteristics, and control sequences based on homogeneous traffic patterns. For this reason, it was not necessary to complete this step for Manitoba.

Step 3: Check Collision Frequency

This step checks that the collision frequency threshold is met on each segment. The purpose of this step is to avoid the problems discussed above related to segments that are too short. The casualty collision frequency threshold for avoiding short segment instability is defined as one collision per kilometre per five years of collected data (4). When a segment does not meet this frequency it is recommended that the segment be joined with adjacent segments of similar characteristics. If the adjacent segments are not of similar character, the segment can be allowed to have less than the minimum collision frequency threshold.

The casualty collision frequency threshold (one collision per kilometre per five years) was not possible to meet for many long sections of the NHS subset in Manitoba. Of the 14 initial segments produced, eight had a collision frequency of less than one collision per kilometre per five years. Combining these segments would produce very long segments and reduce the usefulness of the risk maps. In fact, the NHS subset analyzed in this research experiences almost exactly one collision per kilometre per five years (1,659 collisions in five years on 1,648 kilometres), however, many of these collisions are concentrated on high volume sections of the network such as PTH 101 and PTH 100 (Winnipeg's perimeter highway) and adjacent portions of PTH 1 and PTH 75. If this approach were to be applied to the entire highway network in Manitoba (not just the NHS) it is expected that many roads would not meet this frequency threshold due to extremely low collision frequencies.

This step of the methodology also creates a concern when considering year-to-year comparisons. One identified use for risk maps is performance tracking. To track the performance of a segment it is ideal to have consistent segment definitions across time periods. If the collision frequency of a segment is a criterion for defining segments this means that with varying collision data, varying segment definitions will occur, rendering comparisons difficult. Figure 3 illustrates an example of this using roadway segments on the Manitoba NHS subset and collision data from 2002 through 2006.



Segment A

Length = 18.9 km
Collisions in 5 years = 18
Collision Density* = 0.95

Segment B

Length = 13.3 km
Collisions in 5 years = 16
Collision Density* = 1.20

Segment A + B

Length = 32.2 km
Collisions = 34 (5 years)
Collision Density* = 1.06

Figure 3: Collision Density Segmentation
** Collision density is shown as collisions/km/5 years*

As can be seen from Figure 3, the two segments, A and B, would be combined into one segment if the approach was strictly applied. If data from a different time period was available, Segment A could have greater than 18 collisions. Due to the partially random nature of collision frequencies, this is entirely possible. Following the approach with this different data from another time period could keep A and B as two separate segments, or in another case require both A and B to be joined with a third segment. Different segmentation for different time periods would make performance tracking difficult.

Step 4: Search for "Shorter Segments"

The purpose of this step is to search for "shorter segments" within each segment that would exhibit a higher level of safety risk if they were identified as separate from the existing segment. The CanRAP Feasibility Study describes that "...a short segment should have a minimum length of 10 kilometres because this is a length that could likely be easily recognizable to a road user"(5).

Generally, the location of rural towns surrounding portions of the NHS subset cause segments to have a higher level of risk than the adjacent highway segments. Many rural towns are located on the NHS subset, and their geometric and operational characteristics are quite different from the adjacent highway segments. Examples of these differences include shoulder type (paved versus gravel or partially paved), right-of-way, posted speed limit, traffic volumes (segments around towns usually have increased volumes from local traffic), and temporal traffic characteristics.

The usRAP Feasibility Assessment states that “it does not appear to be feasible to have a formal guideline for the minimum length of roadway segments for usRAP. Rather, the best guideline for usRAP appears to be that each analysis section should be as long as possible consistent with maintaining the internal homogeneity of the section” (4).

Due to identified practical limitations regarding the road segmentation approach, the control sections created by MHTIS were used as the “analysis sections” in this research. As previously stated in this report, control sections are created based on homogeneous geometric and functional characteristics. The network as a whole experiences approximately one collision per kilometre per five years. However, there are many long sections that are much less than this required criterion, therefore the minimum criteria of one collision per kilometre per five years was not used as part of the segmentation process for the application to Manitoba highways.

4. Risk Categories

The last step in this methodology is to develop risk categories. The risk category definition was selected to be consistent with usRAP which uses a relative ranking system. These risk categories were developed in the U.S. to help meet the requirements of the Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This legislation requires states to submit an annual report describing the five percent of locations in their road network with the most severe safety needs to be able to obtain Federal funds. The risk categories and the colours that represent them are as follows:

Table 2: Risk Categories

Risk Level	Percent of Roadway Length
Dark Green (Low)	40
Light Green (Medium / Low)	25
Yellow (Medium)	20
Red (Medium / High)	10
Black (High)	5

Source:Midwest Research Institute (2006)

Developing Risk Maps

1. Collision Density Map

A collision density (CD) risk map shows the number of collisions per unit length of highway for a given segment and thereby identifies locations where the greatest volumes of collisions occur. The collision density was calculated as follows:

$$\text{collision density (CD)} = \frac{\sum_i^N C_i}{L * N}$$

Where: C_i = number of collisions in year i
L = length of the segment
N = number of years of collision data

2. Collision Rate Map

A collision rate (CR) risk map incorporates traffic exposure by showing the number of collisions occurring per million vehicle-kilometres of travel (MVKT) on a given segment. The collision rate was calculated as follows:

$$\text{collision rate (CR)} = \frac{\sum_i^N C_i * 10\text{^}6}{L * \sum_i^N AADT_i * 365}$$

Where: C_i = number of collisions in year i
L = length of the segment
N = number of years
$AADT_i$ = AADT estimate for year i (vehicles per day)

3. Collision Rate Ratio Map

A collision rate ratio (CRR) map shows the ratio of the collision rate for a given analysis section to the average collision rate for similar roads for a given area. A CRR greater than one indicates that the analysis road segment experiences a higher collision rate than the average collision rate for roads with similar characteristics. The CRR map provides a useful tool to identify whether the collision rate for an individual road segment is higher than what might be expected for a similar road segment. The collision rate ratio was calculated as follows:

$$\text{collision rate ratio (CRR)} = \frac{CR}{ACR}$$

Where: CR = collision rate
ACR = average collision rate for similar road types $= \sum_i^N CR \,/\, N$
N = number of segments

4. Potential for Casualty Collision Reduction

A potential for casualty collision reduction (PCCR) map shows the number of collisions that could be avoided on a yearly basis if road segments with above average collision rates were improved so that the collision rates was brought down to the jurisdiction average for similar road types. The collision rate for a segment of road was compared to the average collision rate of all roads of the same classification and the difference was used to calculate the PCCR value. Negative values were calculated for sections that perform better than average and therefore no potential reduction in casualty collisions is expected. The PCCR value can be thought of as the excess rate of collisions on a segment multiplied by the exposure.

$$PCCR = (CR - ACR) * \boxed{\frac{L * \sum_i^N AADT_i * 365}{N * 10\text{^}6}}$$

This can be thought of as the average vehicle exposure per year

Where: CR = collision rate
ACR = average collision rate (for similar road types)
L = length of the segment
N = number of years
$AADT_i$ = Average Annual Daily Traffic estimate for year i (vehicles per day)

The above equations were used to determine risk categories for each of the four risk maps. The thresholds can be seen in Table 3. The ranges of risk measures for specific maps are determined by assigning the calculated Manitoba data to fit the target percentage of each risk category.

Table 3: Risk Category Thresholds

		Range of Risk Measures for Specific Maps			
		Map 1	**Map 2**	**Map 3**	**Map 4**
Risk Category	Target Percentage of Road Network Length	Collision Density (Collisions / km / yr)	Collision Rate (Collisions per MVKT)	Ratio of Collision Rate to rate on Similar Roads	Potential for Casualty Collision Reduction
Low	40	< 0.09	< 0.14	< 0.76	< 0
Low-Medium	25	0.09 - 0.20	0.14 - 0.18	0.76 - 1.00	< 0
Medium	20	0.20 - 0.33	0.18 - 0.23	1.00 - 1.20	0.00-0.65
Medium-High	10	0.33 - 0.58	0.23 - 0.32	1.20 - 1.66	0.65-1.19
High	5	> 0.58	> 0.32	> 1.66	> 1.19

Notes: The target percentage of road network length for each risk category is assigned based on usRAP methodology (4).

Practical Limitations and Considerations Associated with Risk Mapping

Segmentation Issues

By applying the methodology shown in the CanRAP Feasibility Study to this research, describing risk mapping, several practical limitations and concerns were identified (5). These are:

- Creating new segments or a new linear referencing system can be labour-intensive.
- The casualty collision density of one collision per kilometre per five years is not a practical application for Manitoba highways given the low collision frequency. This limitation would also be present in any highway network that experiences similar collision frequencies.
- Using collision density as a segmentation criterion raises questions concerning reproducibility of the segmentation process for performance tracking.
- It is difficult to both avoid short segments and maintain homogenous geometric and traffic characteristics.

For these reasons, the existing 2005 LRS map created by the MHTIS was used to develop risk maps. This LRS system includes many short segments and a concern is that a small volume of collisions may be large enough on a very short segment to make this segment appear as one of the highest risk segments. This issue was also a concern in the usRAP Feasibility Report, which states that “as an interim solution to this issue, a decision was made in the Iowa and Michigan pilot studies to require that a roadway section experience more than two fatal and major injury crashes in five years before it could be placed in the medium-high (red) or high (black) risk categories (for all risk maps). Roadway sections with low crash counts or traffic volumes so low as to have a high risk measure for any of the maps were placed in the medium (yellow) risk category" (4).

No explanation was provided for the choice of two collisions as the threshold to not allow a segment to be ranked in the high (black) or medium-high (red) risk categories. No minimum collision threshold was used in the development of risk maps for this research but if existing LRS networks are to be used the appropriate collision threshold for inclusion in high risk categories should be explored.

There are several shorter segments either adjacent to or through communities that have high collision rates. These collision rates may be overestimated as the method to calculate AADTs may underestimate traffic volumes in towns. Traffic on the highways going through a small town is usually higher than on adjacent highway sections due to internal trip-making, but the AADT estimates for the town segments are based on the same counts as adjacent highway segments (there is a practical limit to the amount of count data that can be obtained). An underestimate of AADT represents an underestimate of the exposure (denominator) in the rate, meaning that the collision rates can be overestimated. In addition to traffic volume estimate issues, other characteristics of highway segments through towns which may affect collision rates include greater intersection density, increased pedestrian traffic, and changes in speed, and changes in geometric design.

The treatment of towns should be carefully considered in any revisions to the risk mapping methodology, as well as the analysis of any risk maps. If town segments are included without modification, the resulting maps could overemphasize safety needs in the towns relative to the other segments, and the resulting maps could also suggest misleading comparisons of safety performance between very different road segments. If the town segments are excluded from the maps, the resulting analysis would lack the ability to draw any conclusions or recommendations about road safety within the towns – which may very well be an important issue. Since the methodology already includes provisions for grouping highways into similar types (for example rural two lane, rural multilane divided), it may be wise to add a category for highways passing through towns.

The segmentation process described in the CanRAP Feasibility Study proves to be complex and contextually dependant for each jurisdiction developing risk maps (5). Shorter segments must be analyzed carefully to understand their geometric design and operating characteristics and how they may differ from the adjacent road segments. There is a need to develop an approach to better address the collision rates in towns where they may be over representative based on a combination of potentially higher collision rates and underestimated AADTs.

National Benchmarks

National benchmarks for risk categories would be beneficial to compare travel risk on different roads across the country. EuroRAP and AusRAP have both fixed thresholds for the different risk levels shown on their risk maps. The CanRAP Feasibility Study and the usRAP Phase III Pilot Program have discussed concerns with creating a national benchmark (5), (6).

The reporting of and definition of injury collisions can vary across jurisdictions. To have accurate meaningful results at a national level this definition would need to be standardized. Differences in topography, weather conditions, traffic composition, typical geometries, traffic control measures, and driver behaviour can cause safety performance variations. This makes it difficult to compare and interpret the meaning of risk categories across the country.

The CanRAP Feasibility Study produced risk maps for 144 kilometres of road on a section of PTH 1, located in eastern British Columbia between the east boundary of Revelstoke National Park and the west boundary of Yoho National Park (5). Table 4 shows the percentage of the 144 kilometre network that would be assigned to the different risk category ranges if these segments were in Manitoba. The table illustrates that if the road segments studied in British Columbia were assigned to the risk map categories developed in Manitoba they would be assigned to higher risk categories. Although this is just a sample of the British Columbia NHS network it does show how creating national benchmarks may have difficulties associated with a loss of local detail in risk category gradation.

Table 4: Comparison of Manitoba and British Columbia Network Assignment to Risk Categories

	Collision Density			Collision Rate		
Risk Category	Range (collisions/ km/yr)	Percentage of Manitoba Network	Percentage of BC Network	Range (collisions per MVKT)	Percentage of Manitoba Network	Percentage of BC Network
Low	< 0.09	40	0	< 0.14	40	0
Low-Medium	0.09 - 0.20	25	0	0.14 - 0.18	25	0
Medium	0.20 - 0.33	20	0	0.18 - 0.23	20	16
Medium-High	0.33 - 0.58	10	68	0.23 - 0.32	10	51
High	> 0.58	5	32	> 0.32	5	32
Network Length (km)		1648	144		1648	144

Note: This table shows the percentage of Manitoba and British Columbia risk mapped networks assigned to risk category ranges developed in Manitoba. This table is not intended to compare safety on BC and Manitoba Highways – any comparison lacks meaning due to the limited nature of the sample and the differences in climate, topography, and trip characteristics. The purpose of the table is to illustrate the loss of local resolution associated with establishing risk categories based on national benchmarks.
Some columns may not sum to 100 due to rounding.

Star Rating Mapping

Five sections of approximately 80 kilometres each (40 kilometres in each direction) of the Manitoba NHS network were analyzed in this part of the research. The objectives considered during this analysis were to: (1) include a broad range of rural NHS highways in Manitoba; (2) avoid highway sections with active construction; (3) avoid population centres; and (4) maintain the use of resources within a reasonable level. The five segments included in the analysis are along the following NHS highways: PTH 1 East of Winnipeg, PTH 1 West of Winnipeg, PTH 16, PTH 6, and PTH 75. Figure 4 shows the location of the control sections that comprise the five study segments in the NHS.

The star rating segments defined for this task use the same control sections as those in the risk mapping component to maintain consistency and more easily allow for comparison between risk categories and star ratings for the same segment of roadway. While risk maps were created for a large subset of the NHS in Manitoba, star rating maps were created for segments on a smaller subset due to the resource constraints.

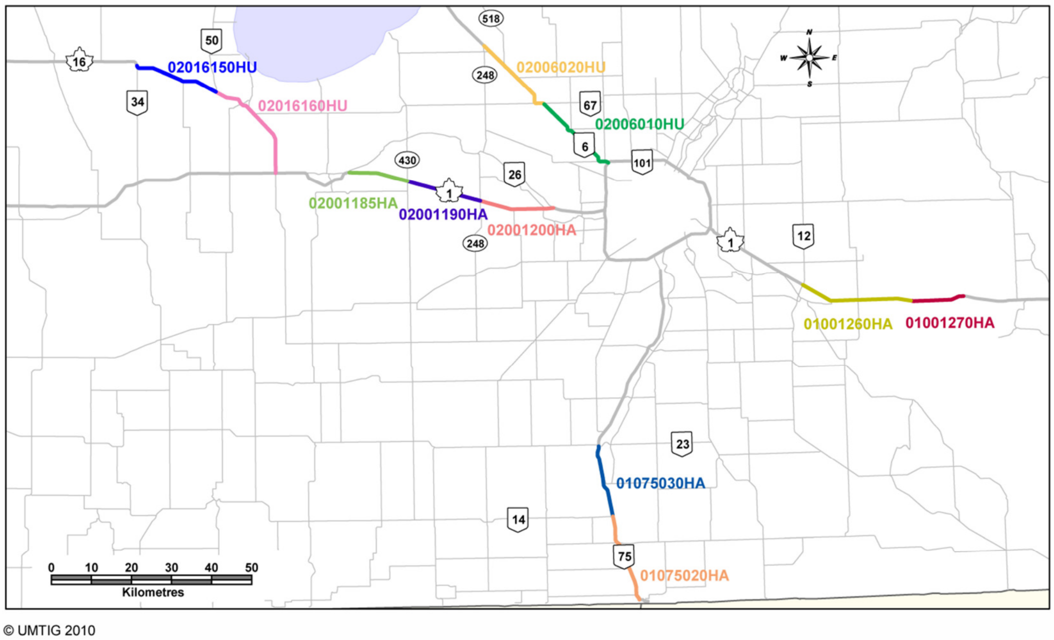


Figure 4: Control Section and Segment Locations

Star Rating Mapping Methodology

The star rating methodology used in this exploratory analysis includes four components: (1) collection of roadway attribute data; (2) calculation of Road Protection Scores (RPSs) based on roadway attribute data; (3) conversion of RPSs to star ratings; and (4) calculation of overall star rating.

1. Road Attribute Data Collection

Based on the available usRAP methodology, the following roadway data is required to determine RPS: 85th percentile or posted speed, median treatment, clear zone width, roadside slope, lane width, shoulder type, shoulder width and intersection characteristics.

The data collected for the Manitoba application comprises: (1) field data; (2) inventory data; and (3) photo logs and Google Street View. Field investigations were the primary method of roadway attribute data collection and were used to collect 85th percentile or posted speed, median treatment, clear zone width, and roadside slope. Manitoba Infrastructure and Transportation provided inventory data for a number of roadway attributes including lane width, shoulder type, and shoulder width. Photo-logs and Google Street View were used to collect intersection characteristics.

2. Road Protection Score Calculation for Collision Types

The Midwest Research Institute provides criteria for road protection scores for the three most common collision types: (1) head-on, (2) run-off road, and (3) intersection (4).

Head-on Collisions

The RPS for head-on collisions is based solely on median treatment and posted speed. The RPS was determined for every 100 metres.

Run-off Road Collisions

The RPS for run-off road collisions is based on clear zone width, roadside slope, lane width, shoulder width, shoulder type and posted speed. The initial score is based on clear zone width, roadside slope and posted speed. Adjustment factors for lane width, shoulder width and shoulder type are then applied. The RPS was determined every 100 metres for each direction and the two directions were averaged for a final RPS over the 100 metre section.

Intersection Collisions

The calculation of the RPS for intersection collisions involves summing RPSs for all intersections found within a segment and dividing by the length of the overall segment. The calculation of the RPS for intersection collisions followed a different process than for head-on or run-off road collisions. As intersections are not located in 100-metre increments, the RPS cannot be calculated for the 100 metre sections. The RPS for intersection collisions was calculated as a total for an entire segment, in this analysis for every control section. The intersection collision RPS is not calculated by direction as an intersection typically applies to both directions.

3. Conversion of RPS to Star Rating

The Midwest Research Institute uses a four-star rating system in the star rating methodology (4). The four-star rating system was converted to a five-star rating system for this research. The conversion consisted of adjusting RPS ranges into equally smaller ranges for the five-star rating system.

4. Overall Star Rating

The overall star rating is based on the relative collision frequency of the three types of collisions. For this analysis, casualty collision data from MIT for the years 2002-2006 inclusive were utilized to determine the weights of the three collision types.

For the purposes of this research, head-on collisions are collisions entered in the database as head-on collisions; run-off road collisions include off-road (left) and off-road (right); and intersection collisions include intersection 90 degrees, left turn (across), left turn (opposing), left turn (same direction), right turn (opposing) and right turn (same direction). All other collisions were excluded when determining collision weights.

It is likely that collisions recorded as “rear end” may be located at intersections and those collisions recorded as “fixed object” may be run-off road collisions although this was not assumed in this research. Table 5 shows the total number of collisions and the corresponding proportion (or weight) for each of the three collision types.

Table 5: Collision Proportions by Type

Collision Type	Total Casualty Collisions On MB NHS Highways	Weight (%)
Head-on	175	5
Run-off road	2386	61
Intersection	1335	34
Total	**3896**	**100**

The overall star rating is determined by averaging the star ratings for the 100-metre sections across the entire segment for each of the three collision types. The final star rating is then calculated based on the weights (or relative proportions) for the three collision types. The star rating outcome is rounded to the nearest integer. All control sections analyzed in this research were found to range between four and five stars.

Practical Limitations and Considerations Associated with Star Rating Maps

Roadway Attribute Data Collection Limitations

Issues which exist for the collection of roadway attribute data are the resources associated with collecting the necessary data and the accuracy of the data. Although much of the required data was provided in the inventory database, field investigations were necessary to collect the remaining data and confirm existing information.

Collecting the desired level of accuracy for slope data is resource-intensive in terms of time and staff. Similar experiences were identified by the Midwest Research Institute and G. Ho Engineering Consultants (4),(5). The Midwest Research Institute collected slope data using videologs, and found accuracy to be an issue as slopes could not be measured from a videolog and only estimated visually. For this analysis, the research team conducted slope measurements in the field. However, due to limited resources it was not possible to take a physical measurement of the slope every 100 metres. For this reason, the slope was measured initially in the field and only measured again when a change in slope was observed. Although measurements were taken periodically, the observed changes in slope prompting measurements were based solely on visual estimates.

Due to the prairie landscape in Manitoba, many roadway attributes remained consistent throughout segments. In most cases, the roadway attributes exceeded the highest possible RPS range. This may not be true for other jurisdictions having a more diverse landscape in which case data collection may be more labour-intensive.

Roadway attribute data was collected every 100 metres and in some cases the data was inconsistent throughout the 100-metre section. In cases when the value of the data in question applied to more than half of the 100-metre section, it was considered to apply to the entire 100-metre section. In the case of clear zones, the minimum clear zone distance to a fixed object within a 100-metre section governed the score for the entire 100-metre section.

RPS and Star Rating Calculation Criteria

A key issue with the methodology provided by the Midwest Research Institute is the origin and detail of specific RPS and star rating criteria (4). These details include the development of roadway attribute data ranges corresponding to RPS and the development of the RPS values. Without these details it is difficult to determine the appropriateness of the methodology for the Manitoba application (or for its application to any other jurisdiction). The RPS and star rating calculations are straightforward and simple to use, however, the origin of the criteria is not clear from the methodology presented in the report.

Interpretation of Results

The overall star rating of a segment is heavily impacted by the weights of the three collision types on Manitoba highways. For example, a roadway segment may have a low star rating for head-on collisions, but the weight of head-on collisions on Manitoba highways is only five percent. The low head-on star rating may have only a small impact on the resulting overall star rating of the segment. This suggests that weighting the scores based on province-wide collision type frequencies may require reconsideration in the methodology.

Two methodological adaptations are possible in order to avoid the loss of potentially useful information that occurs when averaging the ratings across collision types and across 100 metre sections within the segment. First, supplementary maps can provide star ratings for each collision type. Second, the star rating maps could, in addition to showing the average star rating for the set of 100 metre sections in a segment, also show maximum, minimum, and standard deviation of star ratings on the segment. This information could help analysts understand if there are smaller sections within the segment that need attention.

Comparison of Star Ratings to Risk Categories

A direct comparison of the level of safety resulting from a star rating or a risk level determined for risk mapping is difficult to make due to the unique characteristics of each method. Since the categories for star ratings are an absolute category ranking system and the categories for risk maps are a relative ranking system, it is difficult to make conclusions or comparisons between the two. Although direct comparisons are difficult to make, it may be possible to recognize sections that may stand out in both categories and warrant further investigation into the roadway condition at that location. Due to the high star ratings found on all road segments for this research no sections stand out as being poor in both the star rating and risk mapping categories. A ranking system that rates all roads as four or five stars is useful to provide information that the roads are above a certain threshold, but not very useful for focusing attention on the most serious areas. For this reason, the star rating categories could be revised such that the full range of categories from one to five stars was utilized on Manitoba highways.

Star rating maps may also help to identify locations where collisions have not occurred, but which may pose a higher risk to road users. A road section could have unsafe features, but if most users are aware of this and adjust their driving behaviour accordingly, or traffic volumes are relatively low, there may be no collisions at the site. In this case, the star ratings may identify potential improvements that would not be identified by risk maps alone.

CONCLUSION

This paper presents the result of research which explored the suitability of the RAP in Manitoba. The program methodology was applied to portions of the NHS in the province in order to identify methodology strengths, limitations, and modifications that are required to account for jurisdiction-specific traffic and infrastructure characteristics.

The following limitations were found with the applicability of the RAP methodology as it pertains to risk mapping:

- The RAP provides criteria to segment the network for mapping and analysis purposes. However, creating new segments or a new LRS to comply with the RAP criteria can be labour-intensive, and many jurisdictions including Manitoba have already segmented their networks for other purposes. Consideration should be given to using existing segmentation schemes to facilitate the required integration of traffic volume, physical attribute, and collision data.

- The casualty collision density of one collision per kilometre per five years as a segmentation criterion is not practical for application to Manitoba highways because of low collision frequencies; this criterion should be updated before any full scale implementation. Furthermore, using collision density as a segmentation criterion raises questions concerning reproducibility of the segmentation process for performance tracking, because the segmentation resulting from this criterion would change from year to year as collision densities change.

- The criteria to segment the network require both avoiding short segments and maintaining homogenous geometric and traffic characteristics on the segments; these criteria are sometimes impractical or in conflict with one another.

- There is a tendency to have high collision rates on shorter road segments adjacent to or through communities. These rates may be high from potentially underestimated AADTs, greater intersection density, increased pedestrian volumes, or changes in speed.

- Due to the wide traffic characteristics, geometric features, topography, weather, and collisions rates across Canada, it is difficult to establish national benchmarks for risk mapping categories without losing resolution at the local level.

The following limitations were found with the applicability of the RAP methodology as it pertains to star ratings:

- The road protection scores are determined based on visual observations of the roadway attributes and can require extensive resources.

- The origin of the RPS and star rating criteria is not transparent or reproducible from the provided methodology alone. This makes it difficult to determine the appropriateness of the methodology for the Manitoba application.

- The overall star rating for a segment is sensitive to the weighted relative collision frequency of the three collision types (head-on, run-off road and intersection) over the entire segment and therefore does not provide sufficient information on the nature of the safety problem or the specific location of concern.

- It is difficult to make conclusions on comparisons between star rating maps and risk maps as the categories for star rating maps are an absolute category ranking system and the categories for risk maps are a relative ranking system.

Overall, numerous limitations and required modifications were found in applying the RAP to portions of the NHS network in Manitoba as well as through the experiences of other jurisdictions. The development of the star rating maps requires extensive resources and may not accurately represent the level of safety of a roadway segment due to the weighting of the collision types. The risk maps can provide a consistent method to identify risk areas and could act as an initial step or be used in conjunction with existing road safety programs by jurisdictions. The limitations and required modifications identified in this research should be addressed before a potential future full scale application of the program in jurisdictions similar to Manitoba.

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