The role of a National Motor Vehicle Crash Causation Study-style data set in rollover data analysis

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Abstract - On 1 January 2005, The National Highway Traffic Safety Administration, an agency of the United States Department of Transportation, implemented a new data collection strategy designed to assess crash avoidance technologies and report associated behavioral inputs and outcomes. The original goal was a six-year program, however, during the shortened data collection period; it proved a valuable resource for understanding a precrash environment previously obscured by forensic case investigation. Another unintended consequence was an overlap with infrastructure, roadway geometry, and design with the occupant and vehicle outcomes, by virtue of well-defined attributes. External to the collected data, supplementary information was extrapolated, by using manuals published in the United States, by the American Association of State Highway Transportation Officials and selected State Departments of Transportation, in conjunction with the National Motor Vehicle Crash Causation Study (NMVCCS). This provided a backdrop to the infrastructure framework of the rollover problem within which the occupant and vehicle outcomes were studied. If a NMVCCS-style data collection were to be implemented elsewhere, then complementary manuals produced by federal transportation officials might be consulted producing similar relationships.

The current study uses NMVCCS data to describe vehicles travelling through diverse design geometries and the outcome for occupants involved in crashes within that system. Codified and extrapolated data form the basis for assessing NMVCCS and its value to the transportation safety community, as the protocols are applicable universally. The benefit in continuing a NMVCCS-style study is noted, as the interaction of roadway infrastructure and occupant protection agencies might find paths to better work together in solving the complex rollover problem using a common data-driven approach.

INTRODUCTION

A common problem in highway safety research is the lack of data to fully describe the physical and traffic environment in which the crash occurred, the behavior of persons and vehicle or hardware systems involved, and the specific outcomes. Police accident reports (PAR) have traditionally been the source of basic data that a crash event occurred, but these records provide insufficient data to determine crash causation and evaluate the performance of measures intended to mitigate the adverse effects of crashes. In absence of comprehensive crash data, most safety research has been forced to rely on other established data sets. These data sets might be part of a research program specifically addressing an issue or more generalized data sets created for other purposes. Generally, the latter approach is used despite the limits imposed, as it is more cost-effective.

In an environment of scarce research resources, alternative sources of data and methods of acquisition must be exploited. With this in mind, a review of data gathered under the National Motor Vehicle Crash Causation Study (NMVCCS) was undertaken to supplement the understanding of the role of roadway design factors relative to roadway departure problems, specifically rollovers. NMVCCS data was compiled by investigators sent to the crash scenes between January 1, 2005 and December 31, 2007, by NHTSA, leading to recording 6,949 light passenger vehicle crashes. Benefit existed with the freshness of the crash scene and the memory of interviewees, as well as willingness to speak prior to legal consultation. Although, the data set, in its current form, is inadequate for roadway and roadside safety problem definition and solution set creation. Opportunities for supplementing the data exist through methods for synthesis and data supplementation.

The specific objectives of the effort reported here were:

1. Review NMVCCS elements relevant to the roadway and roadside community.
2. Assess NMVCCS data relative to rollover crashes, with amplifying resources.
3. Identify external sources that might amplify NMVCCS reporting power.

The goal of this study was to determine the best potential uses of this data from a highway safety design perspective.

RESEARCH APPROACH

The study was undertaken via a two-step approach. First, the NMVCCS data set was queried with regard to the variables that might provide insight into the role of roadway design elements. With this in mind, the crashes were disaggregated into single event and multiple event crash configurations. Subsequently, a series of representative rollover crashes were reviewed owing to vehicle interaction with a barrier. Infrastructure results have been highlighted but other results will be reserved for the poster presentation and subsequent publications, as this paper was prepared to present applications of the data and relationships with other data sets.

Nomenclature

This document adhered to NMVCCS definitions and, based upon these definitions, created several user-defined terms to describe crash population by type and configuration. Judgments akin to defect or deficiency were attributes of NMVCCS variables and not necessarily in harmony with roadway designer usage.

Table 1: Nomenclature for Selected NMVCCS Data Elements

User-defined, Augmented Element	NMVCCS Variable	Attribute	Description
Vehicle Attitude, Crash Type	rollturns	Planar	zero vehicle quarter turns (rollturns)
		Rollover	rollover about the longitudinal axis, with quantified or unknown number of vehicle quarter turns (rollturns)
Crash Configuration	accseq	Single Event (SE)	one crash event (number of crash events, accseq)
		Multiple Event (ME)	two or more crash events (number of crash events, accseq)
all			All NMVCCS Crash events
1stroll	accseq tdd	first event rollover	NMVCCS first event with rollover type of damage distribution (tdd)
1stplanar	accseq tdd	first event nonrollover	NMVCCS first event with nonrollover damage distribution (tdd)
rigid	surtype	concrete	Pavement descriptions, high surface type
flexible	surtype	Bituminous (asphalt)	Pavement descriptions, high surface type
intermediate	surtype	brick, stone	Pavement descriptions, expected road travel just below high surface type, not susceptible to weather
low	surtype	Slag, gravel, stone, or dirt	Pavement description, lower cost, lower volume traffic, may be susceptible to weather
	KABCO		Observational Injury Severity Scale: killed (K), incapcitating (A), non-incapacitating (B), possible injury (C), no injury (O)

Source: NHTSA (2008) and FHWA (2009)

Case Selection and Data Extraction

The entire NMVCCS crash data base was queried, using Statistical Analysis Software (SAS) by filtering on crash type with respect to vehicle attitude. In order to better understand variable interactions in the data subset, crash type was replaced with crash configuration, with respect to the number of crash events. The crash configurations included: ***all***, ***1stroll***, and ***1stplanar***. It should be noted that ***1stplanar*** crashes may have had a subsequent rollover event of lesser or equivalent severity. Similarly ***1stroll*** may have a subsequent planar event of lesser or equivalent severity. Rollover tdd was selected in deference to the NASS CDS assessment of most severe rollover event; however, this principle was not operative in NMVCCS. Instead, it ensured retention of crashes deemed to have experienced pervasive rollover damage for the selected event.

National estimates were produced using the case weighting factors applicable to each case. This disallowed cases without weighting factors, retained in NMVCCS as anecdotal data. Cases carrying a weighting factor of zero were those that were collected as the sampling plan was being formulated and would have been inappropriate to include in the weighting scheme. Rather than sacrifice important observations found during the testing period of data collection, these cases were retained in the database as a supplement. As the weighting factors must applied for analysis, only cases carrying non-zero weighting factors were reflected in this study.

Variables were selected based upon their applicability to roadway design and to their improved information provision, as compared with similar National Automotive Sampling System Crashworthiness Data System (NASS CDS) variables. The selected variables included: posted speed limit, roadway deficiency, surface type, relation to junction, rollover object contacted, and location of rollover initiation. Special emphasis was given to surface type as a candidate for repurposing.

Table 2: Possible Relationships of Selected NMVCCS Variables to External Data and Issues

Selected Variables		AASHTO	FHWA	Other
Roadway Crash Environment	Posted Speed Limit	**functional class**		*test speeds*
	Roadway Deficiency	**qualitative relationship to design issues such as radius of curvature**		*roadway design*
	Surface Type	*Skid resistance*	**public roadway inventory**	
	Relation to Junction			*roadway design*
Rollover Specific	Object	*Manual for Assessing Safety Hardware, pending rollover criteria*		*Roadway design roadside environment*
	Location	*Roadside Design Guide, pending rollover criteria*		*roadside environment*

Note: **Those relationships contemplated in this study denoted in bold**. *Prospective relationships for future study in Italics.*

Rollover Barrier Case Review

In previous data sets, the uncertain time passing from crash to investigation was an obstacle to obtaining the most accurate roadway data for the period of the crash event. This was not lack of effort of the researcher, as case selection was dependent upon weekly visits to a police jurisdiction. For the NMVCCS researchers, reaching a crash broadcast over a police scanner was a function of distance of the researcher to the crash and ability to find the crash location. The rollover object contacted was queried to identify crashes with vehicle contact with a barrier concurrent with or preceding the rollover event. The freshness of the crash scene ensured that the barrier would not have been repaired or replaced. Pictorial evidence including the paint transfers or compromised sections were used to provide some clues.

SUMMARIZED RESULTS

Nearly 3.9 million crashes were estimated during the NMVCCS collection period with nearly 12 percent resulting in rollover. These crashes were disaggregated into units called events, which shaped the subpopulation selection. By restricting tdd to rollover damage, 25 percent of SE crashes and 61 percent of ME crashes qualified.

As a basic indicator of roadway classification, a general equivalence was drawn between posted speeds and the ranges of posted speeds appropriate for functional classes of roadways. This was prepared for ***all***, ***1stroll***, and ***1stplanar*** crashes, with accompanying graphics that will be published in a separate report owing to space constraints. It should be noted that ***all*** was a count of NMVCCS crash event records, therefore a case vehicle may be counted more than once. ***1stroll*** and ***1stplanar*** were first event counts for the specified conditions; therefore they are distinct vehicle counts

For the selected roadway crash environment and rollover-specific elements, results were filtered by ***all*** crash events, ***1stroll***, and ***1stplanar***, for their respective crash configurations. There were clear distinctions between planar and rollover areas of concern and planning considerations. For instance, there seemed to be a relationship for single event rollover crashes with higher speed facility. Further, where there was excessive curvature noted, by the NMVCCS data attribute but outside of the roadway designer vernacular, there were more single planar event crashes. The surface type on which crashes occurred was overwhelmingly asphalt; however, this was not consistent with roadway pavement inventories maintained by public agencies, and pavement type descriptors did not reflect factors of pavement condition, overlay presence, Annual Average Daily Traffic (AADT) or friction numbers.

Posted Speed Limit

Basic roadway conditions might be used to provide context for the NMVCCS crashes. Posted roadway speed, a surrogate for travel speed, was one such measure. Posted speeds for the entire NMVCCS event population were examined, drawing a rough relationship range for the speed limits of the facilities on which crashes occurred. Most of the crashes occurred between 48 through 80 kph, which might be associated with main arterial streets.

Table 3: Resolution of NMVCCS Speed Limits, in kilometers per hour, to Facility Type

Posted Speed Limit	Facility Type
24-48	Neighborhood
48-80	Main Arterial
89-105	Moderate Highway Speeds
113+	Higher Highway Speeds

Roadway Deficiency and Supporting Measurements

Only one percent of estimated crashes have some road deficiency noted. These were based upon the observation of the NMVCCS researcher. As with other data sets, indications of road deficiency or defect were not necessarily made by technical experts. Further, this should not be seen as an inconsequential issue. Instead, roadway deficiency might not be captured in such a detailed fashion or identified easily. This database was designed primarily for vehicle safety purposes; therefore, any repurposing of this data item would sacrifice cell size and resolution.

Another means of ascertaining the proper design of the roadway was an observational assessment made by the researcher. In tandem, a concern for roadway designers has been the percentage of crown and superelevation, as they interacted with the roadway geometry. Although the assessment was made by the NASS researcher, it should be noted that rudimentary measurement guidelines and formulae have been provided for this enterprise. With that, in just over two percent of crashes, was any deficiency noted. In this small subset of crashes, the deficiencies were overwhelming for the absence of shoulder or breakdown lane. The non-descript other, also subsumed many of these crashes. Interestingly, for the rollover subpopulation, the multiple vehicle crash configurations was well-defined and potentially over-stated by higher weighting, unlike most rollover crashes, which have been noted to be single vehicle encounters with better understood progression. For the planar configuration, single vehicle crashes owing to excessive curvature were also noted; however, absence of shoulder and other deficiencies, in multiple vehicle crash configurations were also present.

Pre-Crash Facility Description

The chosen descriptors attempted to eliminate the subjectivity of the relationship with vehicle and occupant outcomes. Instead, those elements that might have less direct effect on the occupant outcome were considered and these included: traffic flow, roadway surface type, horizontal

alignment, vertical profile, crash location with relationship to roadway junction, and presence of rumble strips.

For traffic flow, less than one percent of vehicle involvements were missing. The traffic flow recorded the facility type and divisions of traffic along the facility.

It was possible that a researcher inexperienced in distinguishing among the various types of road finish recorded inexactly or simply the sample of crashes was drawn from a fairly homogenous inventory of roadways.

In an attempt to resolve the surface types reported in the NMVCCS with those highways, under the FHWA purview, terminology was harmonized. This was an attempt to determine whether there was some correspondence with a larger, surrogate population of the roadway system. The ratios, however, when compared to the 2008 FHWA data did not yield similar representation. This might indicate that there were greater risks associated with asphalt surfaces or simply, that this data set was not collected to determine such a specific crash element. The crashes were used as a numerator of incidence and the kilometers of roadway, as a denominator. Also, AADT may important for increasing percentage of crashes, especially if the asphalt roads experienced higher AADTs than other roadway surface types.

Table 4: Incidence of NMVCCS Crash Events, by Number of Crash Events and Public Roadway Surface Type Inventory Incidence by Kilometers of Public Roadway

SURTYPE(Type of road surface)	***all***			***1stroll***			***1stplanar***		
	S.E.	M.E.	Total	S.E.	M.E.	Total	S.E.	M.E.	Total
Missing									
Concrete, Rigid, High	2.1324	6.5182	8.6506	0.0541	0.0173	0.0714	1.9168	2.8625	4.7793
Bituminous (asphalt), Flexible, High	2.0143	4.2647	6.2790	1.8589	1.7958	3.6547	1.8589	1.7958	3.6547
Brick or block, Intermediate	0.0020	0.0050	0.0070	0.0000	1.0000	2.0000	0.0020	0.0028	0.0048
Slag, gravel, stone, or dirt, Low	0.0050	0.0175	0.0225	0.0013	0.0003	0.0016	0.0029	0.0081	0.0110
Other, Unknown	0.0011	0.0009	0.0020	0.0000	1.0000	2.0000	0.0011	0.0004	0.0015
Total			1.7101			0.0259			0.9840

For the horizontal roadway alignment, very little new was learned regarding the crash composition. In vertical roadway profile data, as with straight horizontal alignment, the level attribute comprised most of the entries.

For rollover and planar crashes, non-junction and intersection crashes predominated, however, their relative contributions varied.

Rumble strips are another device applied to the roadway to alert the driver of impending roadway or lane departure. Approximately 80 percent of crashes occurred on roadways with no rumble strips.

Travel Lane, Rollover Object Contacted, Rollover Initiation Location

In the progression of determining where on the roadway the crash started, regardless of vehicle attitude, and, then extending the understanding to vehicle attitude, with its related contacts and initiation points, the crash countermeasures might better be understood.

The travel lane provided the vehicle location at the initiation of the sequence of crash events. Travel in the rightmost lane was supported by the many vehicles that depart the roadway, as part of the rollover crash.

Rollover object contacted identified the collision or force-related incident precipitating the event. An attribute existed for all crashes including planar crashes, indicating the absence of rollover. Further, the location of rollover initiation has also been codified for all crashes. This value has meaning only for rollover crashes.

For supplementary review, photography suggested points of impact via paint transfer. In this case, the vehicle color was reported as dark green. Review of relevant collision deformation classification values might allow more precision with regard to angle of impact. Further, type of guardrail and extent of damage might also be appreciated. Analysis of this type will be reported more fully in a subsequent publication.

Figure 1: 2005-012-102

Figure 2: 2005-13-038

DISCUSSION

Crashworthiness studies have made great strides in recent years. This may be attributed to the foresight of the analysts and data set architects. Underlying facilitations included the advances in computing power and vehicle instrumentation. A culminating factor was the ambitious development of a real-time crash reporting system. With the advent of NMVCCS, the relationship cultivated over a 30-year history with states, police officers, and local jurisdiction was supplemented with a relationship being developed with emergency medical personnel.

Underlying the human networking required in the NMVCCS data collection effort, a highly complex system of case selection and eventually weighting to a national estimate was developed through the cooperation of engineers, data set framers, and statisticians.

As most organizations do not have a data collection infrastructure, NHTSA has been called upon to perform special studies in convergent areas of highway safety. During the infancy of NASS CDS, a Longitudinal Barrier Special Study was conducted, in cooperation with FHWA. Later, in cooperation with Federal Motor Carrier Safety Administration, the Large Truck Crash Causation Study was developed to estimate the incidence of fatal and injury-producing heavy truck crashes and the underlying associated factors. Similarly, the Tire Pressure Monitoring System Special Study reported on the direct and indirect systems, allowing for assessment and proposal of a subsequently adopted system, as reported by Thiriez (2003). In these three examples, two external organizations with seemingly disparate goals in data collection and an internal study seeking greater understanding of an emerging technology were able to make use of the infrastructure deployed for crashworthiness studies supporting NHTSA research, rulemaking, and compliance.

As resources become scarcer, means of optimization of existing data must be explored. NMVCCS has augmented the road side data collection found in CDS. It was argued by those specialized in roadway planning that this data was insufficient to provide the sole support for any FHWA guidance, however, its value in determining the national estimates of crash incidence in the roadside, as well as its interconnectivity with existing highway design guidance might be established. In the NMVCCS structure, privacy issues precluded location identification; however, improvements in photography protocols, data compilation, and paint transfer coded elements to be compared with the photographs

provide the strongest indication that has been available to the highway community, when repurposing data sets.

The preceding analysis took known elements of highway geometry and supplemented two of the variables with FHWA-adopted guidance or terminology. Further, proposition of strengthening these estimates was also suggested. The focus has been on the first event of crashes, which allowed for a purer sense of the precipitating actions leading to the crash and took into account the technologies, which have been shown currently to be first event technologies. For example, upon deployment, the rollover stability control sensors might be disabled in the first event, in the absence of the rollover, and could be deemed a failure of the system. This, however, is an erroneous use of the data, as it ignored technological limitations of the systems. Further, the first event might have been benign, in comparison with the remaining crash events. For this reason, one subpopulation considered crashes, in which, the first event had rollover damage distribution type, as assessed by the NMVCCS researcher. Similarly, the second subpopulation aggregated nonrollover first events assessed by the NMVCCS researcher retaining the rollover attributes reported at crash level rather than event level.

Another means of ascertaining the proper design of the roadway was an observational assessment made by the researcher. Although the motivation has been laudable, the derived information might be on the order of the observational injury severity offered by police officers, in the form of a KABCO scale rating. Most crash researchers will have very general parameters by which to assess the roadway and its design. Another example was the experience-based, researcher assessment of proper belt usage, which was eliminated from the NASS CDS data set in 2003. These variables might be used to guide review of photographs and scene diagrams rather than to directly assess the condition of the roadway design.

Broad areas for greater analysis might be derived based upon the data presented in preceding section. First, data definitions must be harmonized to enhance comparability, as seen in the roadway surface type. Next, more precise definition might be useful in the case of barrier objects contacted, which could be aggregated by data users to increase cell sizes, when needed. Additionally, an accepted standard, beyond the generalization based upon ranges of posted speed and functional classes, to better understand where crashes have been occurring.

Posted Speed Limit - The posted speed limit variable was one collected from the official records and transferred to NMVCCS. Generally, reliance on the PAR existed for this value. The corresponding ranges were obtained by consulting design guides prepared by a number of jurisdictions but ultimately conforming to AASHTO guidance. The disaggregation by number of events allowed for the speed related issues on different facility types to be noted.

Roadway Deficiency - In the case of the roadway deficiency, the ***all*** events subsumed the absence of deficiency attribute, which comprised nearly 98 percent of ***all*** vehicles. When considering those vehicles operating on deficient roadway segments, single event ***all*** and ***1stplanar*** crash events, were associated with excessive curvature. This was linked to the radius of curvature measurements also reported in NMVCCS.

In the case of design assessments, it was noted that expertise of a roadway designer was needed. The researchers compiling the crash statistics operated under a finite set of general assessment parameters. This was an area where supplementation might have been useful with added information such as state highway inventories of maintenance, crash state statistics, by potential deficiency to supplement this variable. Areas noted, anecdotally, to possess such attributes might be flagged for a case study to better understand these deficiencies.

Surface Type - In a very rough attempt to harmonize FHWA definitions, with NMVCCS surface type attributes, to the extent possible, the surfaces were resolved by material properties. There may have been some additional resolution of the bituminous materials that were subsumed within the NMVCCS definition. Similarly, intermediate surface type was harmonized with brick and block, as reported in

NMVCCS. Finally, the low surface type, owing to its durability, was projected to be composed of slag, gravel, stone, or dirt. The resolution of intermediate and low were subject to interpretation and the lexicon offered was one for a reasonable grouping of data rather than adherent to the strictest pavement definitions, in the opinion of the author. In another data extension and synthesis effort with repurposed data, Amjadi (2010) undertook a pavement study in which state crash data files with associated pavement data file, including details on pavement type, condition index, age, other important pavement details, have been combined for statistical analysis. Now, pavement safety performance can be evaluated with objective measures, to study the relationship between safety and pavement type, age, condition index, and other characteristics, when available in data. Five Evaluation of Low Cost Safety Improvement Pooled Fund Study (ELCSI-PFS) member states have volunteered their crash data and pavement files for further research on this subject.

Overwhelmingly, bituminous surface described also as flexible pavement was associated with the greatest proportion of crashes. This was not to say that there was greater risk for this pavement type. Instead, this surface type was one used on the higher speed facilities, as supported by the posted speeds but confounding factors might include higher AADTs or road conditions, relevant to weather or maintenance. In an attempt to suggest a denominator, an FHWA Public Roads inventory was consulted. As NMVCCS represented tow-away crashes on public roadways occurring in the United States, the denominator offered by the Public Roads inventory was proffered as viable. Although the translations were a rough attempt to harmonize the NMVCCS data set with national denominators of roadway type, it should be noted that the crashes collected were small in number and adherent to the crash scanner protocols rather than obtaining a representation of crashes on specified roadway type.

Relation to the Junction - The relation to the junction indicated the segment of roadway on which the crash occurred, at grade, grade-separated, or nonjunction. For the ***all*** and ***1stplanar***, intersection crashes were the most prevalent. In contrast, non-junction crashes were most prevalent under ***1stroll*** circumstances. These findings were consistent with other national data sets prepared by NHTSA but were reported as part of general results but did not form part of the relevant variables.

Rollover Object - Effectively the tripping object, the rollover object suggested the influence of tripping object or other forces on the vehicle precipitating the rollover. Further, no rollover was an active attribute; the variable must have an assigned attribute, even in the case of a planar crash. For ***all***, ***1stplanar***, and multiple event ***1stroll***, the ground contact was the most frequent contact prior to a rollover event. Only in the case of single event ***1stroll*** did vehicle contact barely edge out lateral axis rollover and ground attributes as rollover object.

These might be important findings to the roadway designer. Unfortunately the presence of barriers was not a larger, better defined component of the data set, however, in the instances that these were reported, photography protocols allowed for a substantial improvement in analysis value over NASS CDS photography.

Rollover Initiation Location - When considering only the rollover crashes as part of total crashes, roadside crashes predominated in ***all***, ***1stroll***, and ***1stplanar***. The rollover incidence tended to be off-road, providing clues to those designing the roadside. The on-road crashes, however, especially, unfolding over multiple events became more difficult to assess. For this reason, the first events, without regard for severity, were selected for study.

The six relevant variables and their respective attributes were chosen owing to their harmonization with the extant FHWA inventory and AASHTO guidance materials. Further, qualitative assessment, based upon values collected from official records supplemented the understanding of the roadway design and potential deficiencies. Although, up to 98 percent of attributes might have indicated no issue or missing data, it must be noted that those collecting the data were generalists reliant upon public records compiled by parties outside of roadway design. For this reason, the data should be seen as an opportunity for synthesis with relevant data sets and a supplement to understanding using photographic evidence.

Although other attributes exist, relevant to roadway design, these provided data shown through previous NASS CDS relevant to the inventory of public roadways in United States on which tow-away crashes were occurring. The novelty of this data set was the freshness of the data and improvement in photography protocols. Other roadway design variables, disaggregated by number of crash events, were referenced as a supplement to the selected variables.

CONCLUSIONS

The purpose of this study was neither a comprehensive roadway design analysis nor a critique of NMVCCS practices. Instead, the goal was to determine the potential uses of this data from the perspective of highway design practitioners through review of basic crash proportions and suggestion of basic synthesis. The table below summarized the variables under consideration. Other variables existed; however, those were of a subjective nature, as they were generated by impressions of interviewees and researcher observation of the roadway, as this was, primarily, a behavioral study. The on-scene nature of the investigations made this appealing to any practitioner owing to the unsullied condition of the crash scene, especially important in reconstructing a rollover crash scene absent of roadside repairs or accumulated meteorological disturbance, and the access to law enforcement and emergency personnel.

In the absence of small cell sizes, an exhaustive study of the interactions among the roadway design elements, vehicle design, and occupant outcomes would be very useful. This might be a consideration to those who would resurrect this study in the United States or framers of such a study in other countries. Table 1 provided an overview of those variables considered, however, these would vary for the purpose of the study and were deemed appropriate, in this instance, by the author. Finally, the recommendations for external supplementation were taken from United States data compilation efforts but local data collection of similar content might be substituted for these.

Table 5. .Synopsis of NMVCCS Variable and their Potential Applicability in Roadway Studies								
NMVCCS Data Elements		%age Known Data	Data Set Assessment				Possible Supplementation	
			Strength	Weakness	Possible Improvement	Reconstruction Value	Photographic	External
Official Record	Posted Speed	98%	surrogate value for travel speed	absence of edr, unknown energy transfers	none	limited	paint color of vehicle allows for roadside hardware to be identified by transfers	Highway Performance Monitoring System (HPMS) Functional classification, by generalized roadway design speeds
Roadway	Roadway Design Deficiency	2%	captures design elements	data collected by researchers, who are not roadway designers	synthesis of state data systems, using geographical location	limited	dependent upon quality of photograph but problem must be egregious	Interactive Highway Safety Design Model (IHSDM) state data maintenance data sets
	Traffic Flow	100%	minimal knowledge of roadway design required	nomenclature may not conform or translate readily to FHWA lexicon	synthesis of state data systems, using geographical location	moderate	good photography might strengthen argument of roadway design issues	roadway design guides
	Surface Type	99%	captures general roadway materials	nomenclature may not conform or translate readily to FHWA lexicon	synthesis of state data systems, using geographical location, naming conformity with national standard	moderate	good photography might confirm but this is dependent on an experienced paving eye	Performance Monitoring System (PMS) state data maintenance data sets providing possible denominator
	Roadway Horizontal Alignment	10%	basic design element	limited practical information	synthesis of state data systems, using geographical location, naming conformity with national standard	moderate	good photography might confirm but this is dependent on an experienced alignment eye	Digital Highway Monitoring System (DHMS) state data maintenance data sets providing possible denominator
	Roadway Vertical Profile	99%	basic design element	limited practical information	synthesis of state data systems, using geographical location, naming conformity with national standard	moderate	good photography might confirm but this is dependent on an experienced alignment eye	DHMS state data maintenance data sets providing possible denominator
	Relation to Junction	100%	vulnerable roadway components might be exposed	unclear conformity to design standards	synthesis of state data systems, using geographical location	moderate	good photography might confirm but this is dependent on an experienced roadway designer	design guides for treatment solutions
	Rumble Strip Present	99%	role in mitigating crashes	Of the known values, nearly 90 percent had no rumble strip reported making assessments of usefulness limited	none	limited	none	design guides for treatment solutions

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NMVCCS Data Elements		%age Known Data	Data Set Assessment				Possible Supplementation	
			Strength	Weakness	Possible Improvement	Reconstruction Value	Photographic	External
Pre-Crash	Travel Lane	97%	identification of roadway location prior to crash	in multiple event crashes, its usefulness might decline	none	high	good photography might aid in confirming trajectory in roadside departure crashes	design guides for treatment solutions
Rollover	Location of Rollover Initiation	100%	excellent means of supplementing roadway departure understanding	Although a unique occurrence and comprising one percent of the population, end-over-end is not deemed to be a location of rollover initiation, yet it forms part of the attribute set	none	high	photographs, especially in the presence of paint transfer skid marks but limited by anti-lock brakes	design guides for treatment solutions
	Object Contacted, Rollover	98%	identification of roadside objects directly associated with rollover crash event	may not be most severe crash event and multiple event crashes might have complex damage patterns	Finer roadside furniture detail, per FHWA lexicon	limited	paint color of vehicle allows for roadside hardware to be identified by transfers	design guides for treatment solutions
Measurements	Radius of Curvature	17%	basic design element	only 17 percent of the radii of curvature are known	synthesis of state data systems, using geographical location	limited	none	Functional classification of superelevation facilities, by generalized roadway design speeds
	Super-elevation	15%	basic design element	only 15 percent of superelevation values are reported	synthesis of state data systems, using geographical location	limited	none	Generalization may be possible, however, this requires interaction of other elements

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