

National Highway Traffic Safety Administration



Redesign of the National Automotive Sampling System



NCSA/NHTSA/DOT

Webinar Guidelines

- 60 minutes presentation on NASS Redesign (Listen-Only Mode)
- 30 minutes to answer questions posed into Webinar
 - Questions can be typed into Webinar 'Notes' during session
 - Host will pick questions to be answered
 - Answers to remaining questions will be posted on www.nhtsa.gov
- Presenters from the National Center for Statistics and Analysis
 - Terry Shelton, Associate Administrator for NCSA
 - Chou-Lin Chen, Director, Office of Traffic Records and Analysis
 - Fan Zhang, Mathematical Statistician, Mathematical Analysis Division
 - Eun Noh, Mathematical Statistician, Mathematical Analysis Division
 - Rajesh Subramanian, Chief, Mathematical Analysis Division

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Welcome to NHTSA's public webinar of the redesign of its NASS. This webinar is to provide information and updates on the redesign of NHTSA's National Automotive Sampling System. We will mostly go over the survey redesign aspect of NASS. The presentation of slides prepared by NHTSA will last approximately 60 minutes. NHTSA requests that questions be typed into the webinar window where it will be reviewed by the Webinar host. We will have 30 minutes after the slide presentation to go over questions. NHTSA will post answers to all questions posed on its website.

Today, Terry Shelton, AA for the National Center for Statistics and Analysis will provide opening remarks. Chou-Lin Chen, the Office Director for the Office of Traffic Records and Analysis will brief us on the outline, overview of the NASS systems, the need to modernize NASS, MAP-21 mandates and NHTSA's efforts to assess and review data needs.

Fan Zhang, a mathematical statistician will then go over the redesign of NASS/CDS

Eun Noh, a mathematical statistician will go over the redesign of NASS/GES

Raj Subramanian, Chief of the Mathematical Analysis Division will provide some information on the benefits to be realized from the re-design and also discuss ongoing and remaining work which will then lead us to the Q&A.

With that, Terry will provide some opening remarks.

Outline

- NHTSA's NASS Data Systems
- Why Modernize NASS?
- Data Modernization
- Current NASS Sample Designs
- Framework for the Redesign
- The Sample Redesign of NASS-CDS
- The Sample Redesign of NASS-GES
- Improvements from the Redesign
- Additional Design Activities
- Implementation Plan
- Questions

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NHTSA's Data Systems

- NHTSA collects crash data to support its mission to reduce motor vehicle crashes, injury, and deaths on our nation's highway.
- National Automotive Sampling System (NASS)
 - One of NHTSA's major crash data systems
 - Crashworthiness Data System (CDS)
 - General Estimates System (GES)

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NHTSA executes its mission of reducing motor vehicle crashes, injuries and deaths on our highways through a data-driven approach. Crash data, such as those collected through its NASS system form the underpinnings of its vehicle regulations and behavioral programs and policy.

The NASS is a sample of the estimated 6 million Police Reported Crashes in the US. It comprises of two systems, namely the CDS – a sample of crashes involving at least one towed passenger vehicle that relies on a investigation based approach and the GES – a sample of all police-reported crashes in the U.S. that relies on a records (police accident report) based approach.

Why Modernize NASS

- The current NASS designs date back to the 1980's
- Need to address significant changes over time
 - Population growth and shifts
 - Vehicle fleet and driver behavior
 - Crash mechanisms
- Need to make estimates more efficient and consistent
 - Align designs with major data needs
 - Take advantage of strides in survey methodology
 - Strategies to reduce potential bias

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NASS has been in operation for more than 30 years and based on a sample that was designed in the 1980s. Although it still produces valid and useful national representative information, we know there is a long-standing need to modernize NASS. Because there have been significant changes in the U.S. highway safety area. The population has grown and shifted, the vehicle fleet has undergone significant technological advances and driver behavior has changes.

Primarily, the design needs to be aligned with current data needs. In addition, the science of survey sampling has had advances as computational power has increased. It is essential to take advantage of these advances to make the estimates from NASS more efficient and less biased.

Moving Ahead for Progress in the 21st Century Act (MAP-21)

- Congress – MAP 21
 - Examine the deficiencies in NASS
 - Assess data needs
 - Report to Congress
 - Plan and design a modernized and comprehensive data system

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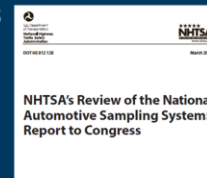
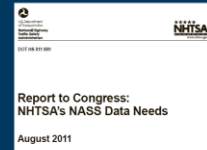


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Bearing all these issues in mind, Congress authorized NHTSA to conduct a comprehensive assessment of not its own internal data needs but also those of the general highway safety community. After asking NHTSA to document these needs, it instructed NHTSA to set out planning and designing a new data system that was better aligned with the data needs of its users.

Comprehensive Review of Data Needs

- NHTSA's review of Agency Data Needs [2009]
 - In-depth assessment of Agency needs for vehicle safety and behavioral program research and regulatory activities
 - 2011 Report to Congress published
- Assessment of External Data Needs
 - 2012 Federal Register Notice
 - Over 20 organizations provided 300+ comments
- Findings:
 - Existing data systems are important and relevant
 - Data on crash avoidance and behavioral measures
 - Expand scope (motorcycles, pedestrians, etc.)
 - Increase sample size
 - Provide easier access to data



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NHTSA conducted two major studies to assess the data needs. The first study was conducted in 2009 and reported to congress in 2011, which involved assessing the upcoming data needs for its vehicle and behavioral programs. Numerous technical and management personnel were interviewed to assess data needs.

The second study was conducted in 2012 in response to the MAP-21 mandate. A Federal Register Notice was published in 2012 to request the public's comments on their needs. Over 20 major organizations provided 300+ comments on a wide variety of topics ranging from sample size, design, data elements, scope and access to data.

NHTSA summarized these comments in its report to Congress (March 2015).

The main findings are:

- Existing data systems are important and relevant
- Data on crash avoidance and behavioral measures
- Expand scope (motorcycles, pedestrians, etc.)
- Increase sample size
- Provide easier access to data

Crash Avoidance: CISS will be collecting 8 Pre-crash elements that describe what the vehicle was doing just prior to the crash. These are especially useful in determining scenarios where crash avoidance technologies could have been beneficial.

Distraction, critical event, crash type, pre first harmful event maneuver sequence, Etc..
Sources are scene inspection, vehicle inspection, and interview.

CISS will also be collecting information on the presence and activation of 5 crash avoidance technologies.

- FCW without auto braking
- FCW with auto braking
- LDW without lane keeping
- LDW with lane keeping
- Blind spot detection

Sources are vehicle inspection and interview.

Data Modernization

- Focus Three Areas
 - Sample redesign
 - Information technology
 - Data collection protocols and technology
- Upgrade NASS
 - Crash Investigation Sampling System (CISS) replaces CDS
 - Crash Report Sampling System (CRSS) replaces GES

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With the Congressional Mandate and its assessment of internal and external needs, NHTSA embarked on the Data Modernization project. It identified three major focus areas for the Data Modernization project.

- The survey sample underlying the NASS had to be re-designed to better align with data needs as well as the changes in the underlying populations.
- The information technology platform on which the data systems reside would have to be modernized to leverage the significant changes in IT (mobile platforms, tablets, server technology, etc.)
- The data collection protocols (handheld data collection tablets with embedded forms) and modernized measurement and scene documentation (Total Station) had to be incorporated.

The rest of this webinar will focus solely on how NHTSA modernized the first aspect of Data Modernization, namely, how the data and statistical aspects of the redesign of the survey (Survey Modernization).

Current NASS Sample Designs

- Three-stages
- Primary Sampling Unit (County or Group of Counties)
 - 1,195 PSUs
 - 12 strata
 - Probability proportional to size - PPS
 - 60 sampled PSUs for GES
 - 24 PSUs subsampled for CDS
- Secondary Sampling Unit (Police Jurisdictions or PJs)
 - PPS Sampling
 - Average 7 sampled PJs per PSU

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Before we introduce the new survey sample designs, we first briefly describe the current GES and CDS sample designs so we can make a comparison later.

Both GES and CDS have a three stage sample design. The first stage sampling unit is also called the primary sampling unit, or PSU. GES and CDS use the same PSU frame and the same PSU sample design. In GES and CDS, a PSU is a county or a group of adjacent counties. There are total 1,195 PSUs in the frame formed from 3,000+ counties in the country. PSUs were stratified into 12 strata by 4 census regions and 3 urbanization levels. The PSU selection probability is proportional to a size variable called measure of size or MOS. In our case, this MOS is the PSU fatal and injury crash counts. So more fatal and injury crashes, the better chance the PSU was selected.

60 PSUs were selected for GES data collection.

From the 60 GES PSUs, 24 PSUs were subsampled for CDS data collection. Therefore, CDS is nested in GES.

GES and CDS also have the same second stage sample design. The secondary sampling unit, or SSU, is police jurisdiction (PJ). From each selected PSU, average 7 PJs were selected using PPS, again fatal and injury counts were used as the measure of size for PJ sample selection.

Current NASS Sample Designs

- GES Third Stage Sampling Unit (PARs)
 - Stratified into 6 PAR strata
 - Systematic sampling
 - ~50,000 sampled PARs

	GES PAR Strata
1	No Truck + Fatal + Towed
2	No Truck + Injury + Towed
3	No Truck + No Transported Injury + Towed
4	Truck + (Tow or Injury)
5	No Truck + Injury
6	No Injury

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For both GES and CDS, the third stage sampling unit is police crash report, or PAR. But GES and CDS have different PAR sample designs.

In GES, in each selected PJ, PARs were stratified into 6 PAR strata defined by truck or no-truck, injury severity, and Tow status. Defining these PAR strata allow us to control PAR sample sizes for each stratum. So this allows us to address the data needs.

After PARs are stratified in each selected PJ, a systematic PAR sample is selected from each PAR stratum.

Approximately 50,000 PARs are selected every year.

Current NASS Sample Designs

- CDS Third Stage Sampling Unit - PAR
- 10 PAR Domains - ~3,400 – 5,600 cases selected by PPS

	GES PAR Strata
1	LMY + Fatal
2	NLMY + Fatal
3	LMY + Incapacitated + Transported + Hospitalized
4	NLMY + Incapacitated + Transported + Hospitalized
5	LMY + Incapacitated + Transported
6	NLMY + Incapacitated + Transported
7	LMY + Transported
8	NLMY + Transported
9	LMY
10	NLMY

LMY: Crash Year – Model Year <=3

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The CDS third stage sampling unit is also PAR. But CDS has a different PAR selection method.

CDS data collection is conducted weekly because CDS data are time sensitive. Every week, technicians visit selected PJs and list all the PARs accumulated since last visit. The listed PARs are classified into 10 PAR domains, defined by vehicle model year, injury severity, transportation status, and hospitalization status.

These 10 domains are not used as PAR strata because we can't afford to select at least one PAR per stratum. Instead, these 10 domains are used to assign different MOS to PARs in different domains so high interest cases can be selected with higher probabilities.

PPS method is used to oversample the high interest cases.

Number of cases selected ranges from 3,400 to 5,600 per year in the past decade

Framework for Re-design

1. Two new independent samples:
 - Crash Report Sampling System (CRSS) to replace GES
 - Crash Investigation Sampling System (CISS) to replace CDS
2. Scope of the new surveys and their relationship
3. Select scalable probability samples
4. Align analytic domains (strata) with data needs
5. Find optimum sample allocation
6. Use auxiliary information to improve estimates
7. Consolidate estimates among the surveys

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The framework of the redesign – these are the major components or major considerations of the new system.

1. NHTSA's and public's data needs indicated both record based and investigation based data collections are important and relevant. Therefore, a new survey – Crash Report Sampling System (CRSS) will replace GES as a record based survey and another new survey – Crash Investigation Sampling System (CISS) will replace CDS as an investigation based survey.

2. So we need to redefine the scope of new surveys and reconsider the relationship of the new surveys.

3. We need to select scalable probability samples at all stages to handle budgetary fluctuation, PJ frame changes and improve data quality.

4. In the new surveys, we need to revise PAR strata and PAR domains to better meet the data needs.

5. For multistage sampling, optimum sample allocation means the optimum combination of sample sizes of all stages. We need to find optimum sample allocation for CRSS and CISS.

6. After sample selected, the use of auxiliary information such as crash counts and population counts may further reduce the variance of the estimates and keep the PJ frame updated. Therefore, we'll consider advanced weight adjustments to improve the estimates at weighting stage.

7. Some estimates can be made from different surveys. In the new system, we'll consolidate these estimates to make them consistent to each other.

Scope of CISS

- Crash Investigation Sampling System (CISS) – Replacing CDS
 - In-depth investigation
 - Crashes involving at least one towed passenger vehicle
 - Crashworthiness and avoidance (e.g., Forward Collision Avoidance)
 - Revised analysis domains
 - All injury levels
 - Probability sample for valid statistical analysis
 - CISS target population
 - Police reported motor vehicle crashes on a traffic way involving a passenger vehicle and in which a passenger vehicle is towed from the scene for any reason
 - CISS scope is slightly wider than CDS

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Scope of CISS

As CDS, CISS data collection will continue to be in-depth crash investigation. And the crash must involve at least one towed passenger vehicle. In addition to crash worthiness data, CISS will also focus on crash avoidance data collection. Data items to be collected are being reconsidered and revised in NHTSA's DataMod project. For example, CISS will be collecting 8 pre-crash elements that describe what the vehicle was doing just prior to the crash. CISS will also be collecting information on the presence and activation of 5 crash avoidance technologies.

CISS will have different PAR domains to better address NHTSA's and public data needs.

NHTSA will continue oversample severe crashes and new vehicle crashes in CISS. But non-severe crashes are still necessary for NHTSA's data needs. NHTSA needs in-depth data for a crash database that is representative of the real-world crash population.

CISS sample will continue to be a probability sample so it can be used for valid statistical analysis.

CISS target population:

Police reported motor vehicle crashes on a traffic way involving a passenger vehicle and in which a passenger vehicle is towed from the scene for any reason.

Compared with CDS, the only difference is in CDS, the vehicle is towed due to the damage while in CISS the vehicle is towed for any reason. So CISS scope is slightly wider than CDS. The reason for the change is determining whether the vehicle is towed due to the damage or not from the PAR can be very difficult sometimes. So this change will reduce the number of misclassified PARs and speed up the PAR listing process.

Crash Avoidance: CISS will be collecting 8 pre-crash elements that describe what the vehicle was doing just prior to the crash. These are especially useful in determining scenarios where crash avoidance technologies could have been beneficial.

Distraction, critical event, crash type, pre first harmful event maneuver sequence, Etc..

Sources are scene inspection, vehicle inspection, and interview.

CISS will also be collecting information on the presence and activation of 5 crash avoidance technologies.

FCW without auto braking, FCW with auto braking, LDW without lane keeping, LDW with lane keeping, Blind spot detection
Sources are vehicle inspection and interview.

Scope of CRSS

- Crash Report Sampling System (CRSS) – Replacing GES
 - CRSS scope is unchanged from GES
 - CRSS target population
 - All police reported motor vehicle crashes on traffic way
 - Larger (compared to CISS) sample size for better coverage of rare populations
 - Refined PAR strata to better cover more vehicle types

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The Crash Report Sampling System (CRSS) will replace GES as the record based survey.

CRSS scope is unchanged from GES.

CRSS target population:

All police reported motor vehicle crashes on a traffic way.

As GES, CRSS will have a large sample size when compared to CISS so it has better coverage of rare populations.

CRSS will have different PAR strata to cover more vehicle types in response to public data need.

CISS and CRSS - Relationship

- CDS sites are a sub-sample of GES sites
- CISS and CRSS are completely independent
 - Different PSU formation to cope with different operational constraints.
 - Different PSU sampling methods to produce efficient samples for both surveys

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The relationship between CISS and CRSS

In current NASS, CDS sites is a sub-sample of GES sites.

For CISS and CRSS, we noticed they have different target population (CISS focuses on more severe and more LMY crashes while CRSS collects data from all crashes) and they have different operation requirement (for example, CISS data collection requires travel and interview and possible on-scene investigation while CRSS only collect data from PARs). NHTSA decided to make CISS sites completely independent from CRSS sites so:

CISS and CRSS can have different PSU formation to cope with different operational constraints.

CISS and CRSS can have customized PSU sampling methods to produce efficient samples for both surveys

CISS Sample Design - Overview

- Three stage sample design
 - 1st stage – PSU
 - County or group of counties but reformed
 - 2nd stage – SSU
 - PJ or group of PJs
 - 3rd stage – TSU
 - PAR

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A quick overview of CISS sample design:

As CDS, CISS has a 3 stage sample design. Why do we chose multistage sample design? Single stage sample selection of crashes requires us to have the access to all the crashes in the nation and requires us to send technicians all over the country to collect the data. Obviously this is infeasible. So instead, we select the crashes in multi-stages.

Similar to CDS, CISS first stage sampling unit is a county or a group of adjacent counties, second stage sampling unit is police jurisdiction (PJ), and third stage sampling unit is police crash report (PAR).

Next, we talk about the three stages in more details.

CISS Sample Design – 1st Stage

- CISS PSUs
 - County or group of adjacent counties
 - At least 5 fatal crashes per year
 - Maximum end-to-end distance:
 - 65 miles for urban PSU
 - 130 miles for rural PSU
 - 1,784 PSUs formed from 3,117 counties
- CISS PSU Stratification
 - 8 primary strata (4 Census regions by 2 urbanicities)
 - ~3 secondary strata
 - Total 24 PSU strata
- CISS PSU Measure of Size (MOS)
 - Function of fatal, severe injury, LMY vehicle, MMY vehicle crash counts

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CISS PSU sample design

CISS PSUs are counties or groups of adjacent counties.

When we reform CISS PSUs, we tried to ensure PSUs are big enough to have at least 5 fatal crashes per year to be sampled from.

On the other hand, CISS is investigation based data collection so CISS PSUs cannot be too big, otherwise our technicians end up spending a lot of time driving around and no time to collect data. So for operational efficiency, we imposed a maximum end-to-end driving distance constraint to CISS PSU's geographic size: 65 miles for urban PSU and 130 miles for rural PSU. So CISS PSUs cannot be too small or too big.

As the result, total 1,784 PSUs were formed from 3,117 counties in the country. CDS has total 1,195 PSUs in the frame so average speaking, CISS PSUs are smaller than CDS PSUs. Later we will see from the optimum sample allocation results it is not necessary to make CISS PSU too big. The best way to improve the efficiency is to increase PSU sample size, not the PSU geographic size.

CISS PSUs were stratified into 8 primary strata formed by 4 Census regions and 2 urbanicity types (urban and rural) so that the PSU sample will be geographically and demographically balanced.

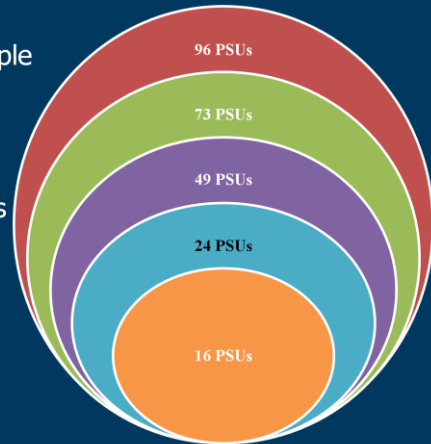
Each primary stratum was further stratified into about 3 secondary strata to further reduce the sampling error. As the result, total 24 PSU strata were formed.

PSU MOS is used to determine PSU selection probability.

CISS PSU MOS is a function of fatal, severe injury, LMY vehicle and MMY vehicle crashes. Therefore, the PSUs with more of these high interest crashes have better chance to be selected.

CISS Sample Design – 1st Stage

- Need for PSU Sample Size Scalability
 - Budget fluctuation
 - High cost of reselecting PSU sample
- Scalable PSU Sample
 - Start with a large PSU sample
 - Select a sequence of sub-samples
 - Keep deeply stratified
 - But collapse strata if necessary
 - Resulting selection probability is still proportional to size (PPS)



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CISS PSU sample selection

One challenge NHTSA faces is the budgetary fluctuation. When budget changes, the number of sites should also be changed. But the cost of reselecting complete new sites is high (because of the training of technician and obtaining the cooperation). Therefore, we need to select a scalable sample so that we can change the sample size with minimum change to the existing sample.

Our approach to a scalable PSU sample is:

- Start with a large PSU sample
- Select a sequence of sub-samples
- Keep deeply stratified
- But collapse strata if necessary
- Resulting selection probability is still PPS

As the result, we obtained a sequence of nested PSU samples. Any one of them can be used for data collection and the selection probabilities can be calculated.

CISS Sample Design – 2nd Stage

- SSU Frame
 - SSU: PJ or a group of PJs
 - MOS: function of 10 PAR domain counts
 - 3 strata by MOS size
- SSU Sample Selection
 - Sequential Poisson Sampling (SPS)
 - Scalability
 - non-cooperating PJs
 - PJ frame changes
 - Approximately PPS

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CISS SSU sample selection

Similar to CDS, CISS secondary sampling unit (SSU) is PJ or a group of PJs that handle the PARs of the selected PSU.

PJ MOS is a combination of 10 types of PAR counts of the PJ. We'll explain those 10 types of PARs later.

Within each PSU, PJs are stratified into 3 strata by their MOS (Certainty, Large, Small).

PJ sample is selected by sequential Poisson sampling. As the result of sequential Poisson sampling, the entire PJ frame can be used as a scalable PJ sample. This allows us to use replacement PJ for PJ refusals, or non-responding PJs. It also allows us to handle PJ frame changes such as: new PJs, closing PJs, PJ splitting, PJ merging, out-of-scope PJs, PJ MOS changes.

And the resulting selection probability is still approximately PPs.

CISS Sample Design – 3rd Stage

- TSU Frame
 - PARs in selected PJs
 - PARs classified into 10 domains by model year and injury
 - MOS: assigned to get desired # of cases for each domain
- TSU Sample selected using SPS to increase usable data

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CISS TSU sample selection

CISS third stage sampling unit is PAR.

Similar to CDS, in each selected PSU, technicians visit the selected PJs every week and list all the PARs accumulated since last visit. During the listing, PARs are classified into 10 analysis domains defined by model year and injury severity.

Different MOS is assigned to PARs in different domain to control the probabilities of PAR selection. High interest PARs have high chance to be selected. The expected number of cases to be selected from each domain is predetermined. We control how many cases we select from each domain in this way.

TSU sample is selected using sequential Poisson sample. This gives us PAR sample scalability so we can replace those cases with missing critical items such as vehicle internal information. In this way, we may be able to increase usable cases dramatically.

CISS Sample Design – 3rd Stage

CISS Analysis Domains	Description	Target Percent of Sample Allocation	Population Distribution
1	Fatal	5%	0.5%
2	LMY vehicle + passenger incapacitated	10%	0.9%
3	LMY vehicle + passenger injured	20%	8.7%
4	LMY vehicle + no injury	15%	17.5%
5	MMY vehicle + passenger incapacitated	6%	1.3%
6	MMY vehicle + passenger injured	12%	11.3%
7	MMY vehicle + no injury	10%	22.5%
8	OMY vehicle + passenger incapacitated	6%	1.5%
9	OMY vehicle + passenger injured	10%	11.9%
10	OMY vehicle + no injury	6%	23.8%
Total		100%	100%

LMY: ≤ 4 years old, 4 years old < MMY ≤ 9 years old, OMY: ≥ 10 years old

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CISS PAR domains are simplified to better address data needs. Only two variables are used to classify CISS PARs: injury severity and vehicle model year.

All fatal crashes are now in domain 1, followed by late model year vehicle crashes, medium model year vehicle crashes and old model year vehicle crashes. Among each type of model year, crashes are further classified by injury severity. Total 10 PAR domains were formed so that PAR MOS can be assigned to obtain the desirable sample allocation.

Associated with each PAR domain in the table are the target percent of sample allocation and estimated population distribution.

Domain 1, for example, although there are only about half percent fatal crashes in the crash population, but 5% of our sample comprises fatal crashes. Therefore, we heavily oversampled the fatal crashes.

On the other hand, almost 24% of crashes in the crash population are old model year vehicle crash without injury, compared to 6% of such crashes in our sample. So we under-sampled low interest crashes.

Therefore, the sample distribution is totally different from the population distribution by sample design. Unweighted estimates from the sample may be severely biased. Weights should be used to make design unbiased estimates.

CISS Sample Design – Sample Allocation

- Optimum Sample Allocation
 - The combination of PSU, PJ and PAR sample size that:
 - Minimize: standard errors
 - Subject to: total budget, current system precision, workload
- Minimize: $\sum_{g=1}^G V_{CISS}(\bar{y}_g) = \sum_{g=1}^G \left\{ \frac{S_{1,g}^2}{n} \left(1 - \frac{n}{N}\right) + \frac{S_{2,g}^2}{nm} \left(1 - \frac{m}{M}\right) + \frac{S_{3,g}^2}{nmk} \left(1 - \frac{k}{K}\right) \right\}$
- Subject to: $C = C_0 + nC_1 + nmC_2 + nmkC_3,$
- $V_{CISS}(\bar{y}_g) = \frac{S_{1,g}^2}{n} \left(1 - \frac{n}{N}\right) + \frac{S_{2,g}^2}{nm} \left(1 - \frac{m}{M}\right) + \frac{S_{3,g}^2}{nmk} \left(1 - \frac{k}{K}\right)$
- $\leq V_{CDS}(\bar{y}_g), \quad \text{for } g = 1, \dots, G.$
- $mk \geq l.$

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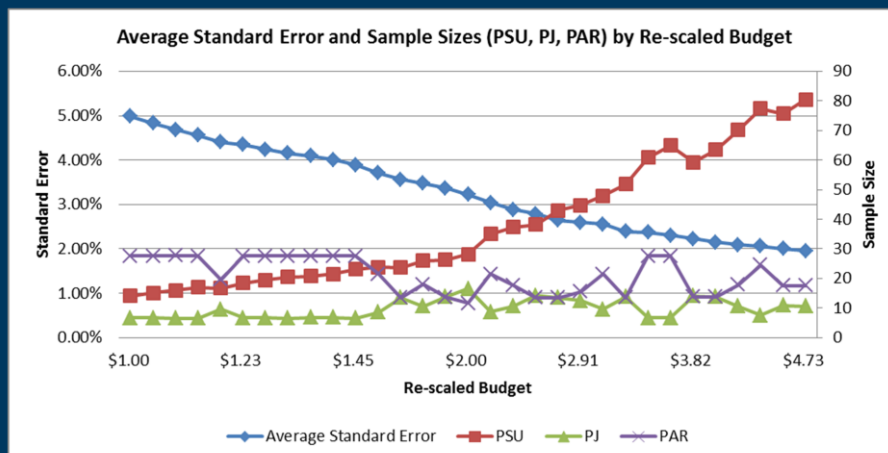
Since CISS has a three stage sample design, sample allocation means the combination of three sample sizes: PSU, PJ and PAR sample sizes.

An optimum sample allocation is the combination of PSU, PJ and PAR sample sizes that minimize the variance subject to the available budget. Adding the current system precision as constraints to ensure the new survey performs at least as good as the current survey.

NHTSA used mathematical optimization to find the approximately optimum sample allocation.

CISS Sample Design – Sample Allocation

Sample Allocation Result



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We ran the above optimization model under a range of budget levels under different caseload scenarios. This figure shows the results when 4 cases selected each week each PSU.

The horizontal axis is the rescaled budget levels. The vertical axis on the right is the sample size. The vertical axis on the left is the standard error for percentage estimates.

As budget increases, PJ sample size m and PAR sample size k tend to be stable, PSU sample size increases while the standard error decreases.

This indicates the most effective way of reducing the overall standard error is to increase PSU sample size, not PJ or PAR sample sizes. Selecting a lot of cases from a few PSUs is not an effective way to improve the precision of the estimates. It also indicates that it is unnecessary to form very large PSUs.

CRSS Sample Design - Scope

- Target Population
 - All police reported motor vehicle crashes on a traffic way
- Analytic Domains
 - Establish 9 PAR strata based on data needs
 - Target sample percentages for newly formed PAR strata

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Hi, This is Eun Young Noh, Mathematical statistician. I will go over the CRSS sample design.

CRSS sample design-Scope:

CRSS Target population is all police reported motor vehicle crashes on a traffic way.


Analytic domains were determined based on data needs. 9 analytic domains, which is called 9 PAR strata, were established with target sample percentages.

CRSS Sample Design – Scope (PAR strata)

Stratum	Description (Hierarchical Structure)	Target Percent of Sample	Percent of Population
1	Crashes with killed or injured pedestrian	9%	2.2%
2	Crashes with killed or injured motorcycle rider	6%	1.4%
3	LMY passenger vehicle crashes with killed or incapacitated occupant	4%	0.4%
4	OMY passenger vehicle crashes with killed or incapacitated occupant	7%	1.6%
5	LMY passenger vehicle crashes with injured occupant	14%	6.2%
6	Crashes involving medium or heavy truck or bus	6%	5.7%
7	OMY passenger vehicle crashes with injured occupant	12%	15.0%
8	LMY passenger vehicle crashes AND no one is killed or injured.	22%	28.4%
9	Crashes not in strata 2-9	20%	39.0%

LMY passenger vehicle: ≤ 4 years old, OMY passenger vehicle: ≥ 5 years old

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This table shows the 9 CRSS 9 PAR strata.

CRSS PAR strata have a hierarchical structure. It is constructed by combination of vehicle type, injury severity, and vehicle ages.

Compared to GES, CRSS has separate PAR strata for motorcycle and pedestrian crashes and passenger vehicles are divided by vehicle ages.

Similar to CISS, CRSS target sample percentage is different from the population percentage. Strata from 1 to 5 have higher target sample percentages than the population percentages, which include pedestrian or motorcycle crashes with fatality or injury, late model year passenger vehicle crashes with fatality or injury, and older passenger vehicle crashes with fatality or severe injury. This is because people are more interested in crashes of strata from 1 to 5, but those crashes are rare in the population. The target sample percentages can be reached by giving different sampling intervals by PAR strata as long as there are sufficient PARs.

CRSS Sample Design – 1st Stage

- PSU Formation
 - PSU: County or group of counties
 - PSU MOS is aligned with data needs
 - Linear Combination of crash estimates of 9 PAR strata
 - Minimum PSU Measure of Size
 - To ensure enough PARs in a PSU
 - 707 PSUs formed from 3,117 counties
- PSU Stratification
 - 8 primary strata (4 Census regions and 2 urbanities)
 - Further stratification to increase efficiency
 - 2-14 strata within each primary stratum
 - Total 50 strata

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CRSS Sample Design – First Stage:

CRSS has a three stage sample design, which is similar to the CISS sample design. The first stage sampling unit, which is called primary sampling units or PSU, is a county or group of adjacent counties.

PSU measure of size was defined by aligning with data needs. It is a linear combination of crash estimates of 9 PAR strata in a PSU. PSU measure of size was used in the PSU sample selection. If a PSU has big measure of size, that PSU has more chance to be selected.

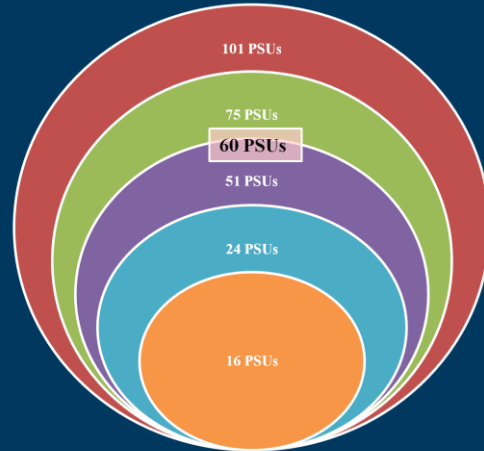
PSUs were formed to have larger PSU measure of size than the minimum PSU measure of size so that the selected PSUs have sufficient number of crashes in the different PAR strata. And therefore, the target sample percentages of 9 PAR strata can be reached and selected PARs have approximately equal selection probabilities within each PAR stratum.

In this way, a total of 707 PSUs were formed. Since CRSS is a record base survey, travel distance for crash investigation is not considered in the PSU formation, so CRSS PSU has much bigger geographic size compared to the CISS PSU.

After PSUs were formed, they were stratified. PSUs were stratified into 8 primary strata, first. Primary strata were formed by 4 Census regions and rural or urban areas. This primary stratification makes PSU sample geographically and demographically balanced. Then, PSUs were further stratified to increase efficiency. 2-14 strata were formed within each primary stratum. As a result, a total of 50 strata were formed.

CRSS Sample Design- 1st Stage

- Stratified PPS Sampling
- PSU Sample Scalability
 - To accommodate budgetary fluctuation
 - Start from a large PSU sample
 - Select a sequence of sub-samples from collapsed strata
 - PSU sample is possible with any sample size from 101 to 16



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After PSUs were formed and stratified, PSU sample was selected in each stratum by PPS sampling with PSU measure of size.

Like CISS PSU sample, CRSS PSU sample has scalability to accommodate budgetary fluctuation. Scalability has multi-phase structure, which starts from a large PSU sample to smaller PSU samples by selecting a sequence of sub-samples from the collapsed strata.

As shown in the picture, starting from a PSU sample with size 101, 5 scenarios of PSU sample were selected with sample size between 101 and 16. Also, PSU sample can be selected between scenarios. Therefore, PSU sample is possible with any sample size from 101 to 16.

For CRSS, we plan to implement data collection at 60 PSUs, which is between 75 PSU sample and 51 PSU sample.

CRSS Sample Design – 2nd Stage

- Second Stage Sampling Unit: PJ or Group of PJs
- PJ Frame
 - PJ or group of PJs in selected PSUs
 - MOS is aligned with data needs
 - Stratification
 - 3 strata based on PJ MOS
- PJ Sample Selection
 - Stratified Sequential Poisson Sampling
 - Approximately PPS
 - Sample Scalability
 - To handle PJ frame changes
 - To handle PJ non-cooperation

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CRSS Sample Design – Second Stage:

The second stage sampling unit is a police jurisdiction or group of police jurisdictions. PJ frame was constructed in the selected PSUs.

In the similar way to the PSU measure of size, PJ measure of size was defined as a linear combination of crash estimates of 9 PAR strata in a PJ to align with data needs. PJ measure of size was used in the PJ sample selection. If a PJ has big measure of size, that PJ has more chance to be selected.

PJs were stratified into 3 strata based on PJ measure of size. Very large PJs were stratified to a certainty stratum, and the remaining PJs were stratified to large or small PJ strata.

Then, PJ sample was selected by sequential Poisson sampling in each stratum, which is approximately PPS. Sequential Poisson sampling allows scalable or flexible PJ sample. PJ frame changes often because new PJs open and some PJs close, merge, or split. When this happens, sequential Poisson sample can select PJ sample from the revised PJ frame with minimal changes in the original PJ sample. This is important because PJ cooperation is hard and expensive. PJ sample scalability also handles PJ non-cooperation.

CRSS Sample Design – 3rd Stage

- Third Stage Sampling Unit: Police Crash Report
- PAR Frame
 - PARs in selected PJs
 - 9 PAR strata determined as analytic domains
- PAR Sample Selection
 - Systematic sampling
 - Sample is selected by PSU, PJ, and PAR Stratum
 - Sampling interval is determined
 - To reach the target sample allocation by PAR strata
 - To have approximately equal weight by PAR strata

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CRSS Sample Design – Third Stage:

The third stage sampling unit is a police crash report, PAR.

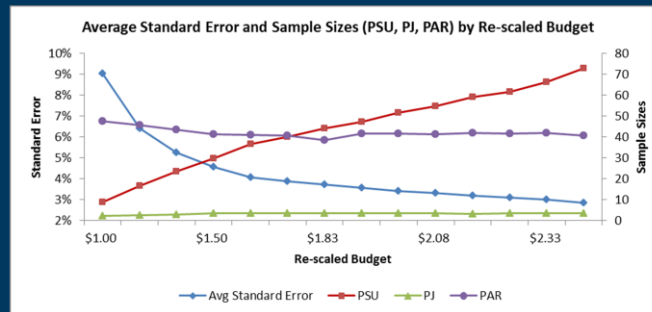
PAR frame is all police crash reports in the CRSS scope. PARs are listed in the selected PJs and stratified into 9 PAR strata which were determined as analytic domains.

Then, PAR sample is selected by systematic sampling in each PSU, PJ, and PAR stratum. PAR sampling interval is determined by PSU, PJ, and PAR stratum so that the target sample percentages of 9 PAR strata can be reached and all PARs in a PAR stratum have approximately equal weights.

In general, PAR sampling interval is shorter for the PAR stratum where the target sample percentage is larger than population percentage. On the other hand, for the PAR stratum where the target sample percentage is smaller than population percentage, PAR sampling interval is longer.

CRSS Sample Design – Optimal Sample Allocation

- PSU, PJ, and PAR sample sizes that
 - Minimize variance subject to a spectrum of budget scenarios
 - At least as good as GES in precision
- As budget increases, PSU sample size increases and variance decreases.



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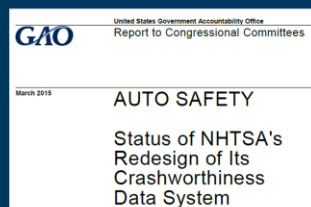
CRSS Sample Design – Optimal sample allocation:

In CRSS, optimum sample allocation was used to find the combination of PSU, PJ, and PAR sample sizes that minimize variance subject to a spectrum of budget scenarios. The optimization also considers CRSS should be at least as good as the current system, GES, in precision.

This picture shows the optimization result which is similar to the CISS optimization result. Re-scaled budget is on the horizontal line. PSU sample size is red, PJ sample size per PSU is green, PAR sample size per PJ is purple, and the standard error is blue. We can see that when budget increases, PSU sample size increases and the standard error decreases. But the PJ or PAR sample sizes are stable. This means that when budget increases, PSU sample size should be increased to get better precision instead of increasing PJ or PAR sample sizes.

Improvements in Re-design

- Independent sample design
- Scalable samples through Sequential Poisson Sampling
- Measure of size is aligned with data needs
- PSUs were formed to have enough crashes
 - CISS: At least 5 fatal crashes
 - CRSS: Minimum MOS
- Deep PSU stratification
- Optimal sample allocation
- GAO Study on NHTSA NASS Re-design



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You have heard the significant efforts underway to align the new CRSS and CISS with the evolving data needs and to provide more efficient and robust estimates. While we are retaining the investigative and records-based approach of NASS/CDS and NASS/GES in CISS and CRSS, respectively, we are designing them as independent systems as they serve different needs and answer different questions.

We have taken advantage of advances in survey methodology to incorporate scalability at most stages of these complicated data systems. These scalabilities have been designed based on what we have learned from the current systems in terms of addressing changing budgetary scenarios, non-cooperation of police jurisdictions, changes in the frame as well as providing replacement cases when vehicles cannot be investigated.

The measure of size (MoS) have been aligned with the data needs to not just maximize the chances of getting crashes of interest but also make the resulting estimates more efficient.

For CISS, the PSUs were formed to have at least 5 fatal crashes annually to ensure that the severe crashes get investigated. They were also formed with operational considerations in mind. The CRSS PSUs were formed with a Minimum Measure of Size (Min MoS) so we can generate and track estimates across all strata.

We have employed deep stratification at the first stage to get full representation across all geographic regions, urbanicity and crash populations.

We developed a robust mathematical optimization model to determine what the optimal sample allocation was across all three stages of the sample for a given budget to minimize variance.

Additional Design Activities

- Design weight calculation
- Weight calibration - use auxiliary information for
 - Non-response adjustment
 - Coverage error correction
 - Consolidate estimates of different surveys
 - Reduce standard errors
- Develop and publish analytic guidelines on combining data
 - CISS + CDS
 - CRSS + GES
 - CRSS + CISS (PAR only)

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A lot of work remains to be done. In addition to implementing the CISS and CRSS designs, protocols for estimation have to be established.

A major area of focus is on weight calibration. Studies are underway to perform a series of adjustments using auxiliary information that will be collected by NHTSA. For example, estimates of fatal crashes from CRSS will have to be consistent with those reported from FARS (a census of all fatal crashes).

Another major area of work will involve providing analytic guidelines to users and analysts of CISS and CRSS data. We understand that there will be a lot of questions from analysts on how to combine data from the new and old systems for their analysis so they have enough sample size. We do not have any guidance at this point, but we are actively pursuing these areas and will issue guidance on proper usage.

Sample Design – Implementation Plan

- CISS
 - 5-site Pilot in 2015
 - 24 sites up and running for Phase 1 by end of 2016
 - ~4,000 cases from 24 sites
- CRSS
 - Full implementation in 2016
 - 60 sites
 - ~50,000 cases

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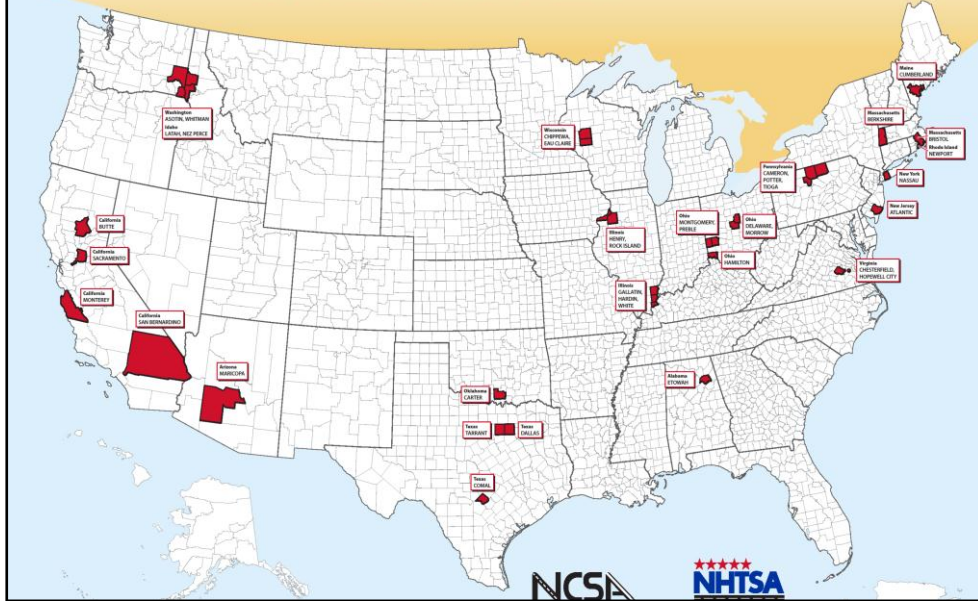
CRSS Implementation Plan:

NHTSA plans to implement the CRSS with 60 PSUs, 6 to 9 PJs per PSU, and around 50,000 PARs in 2016.

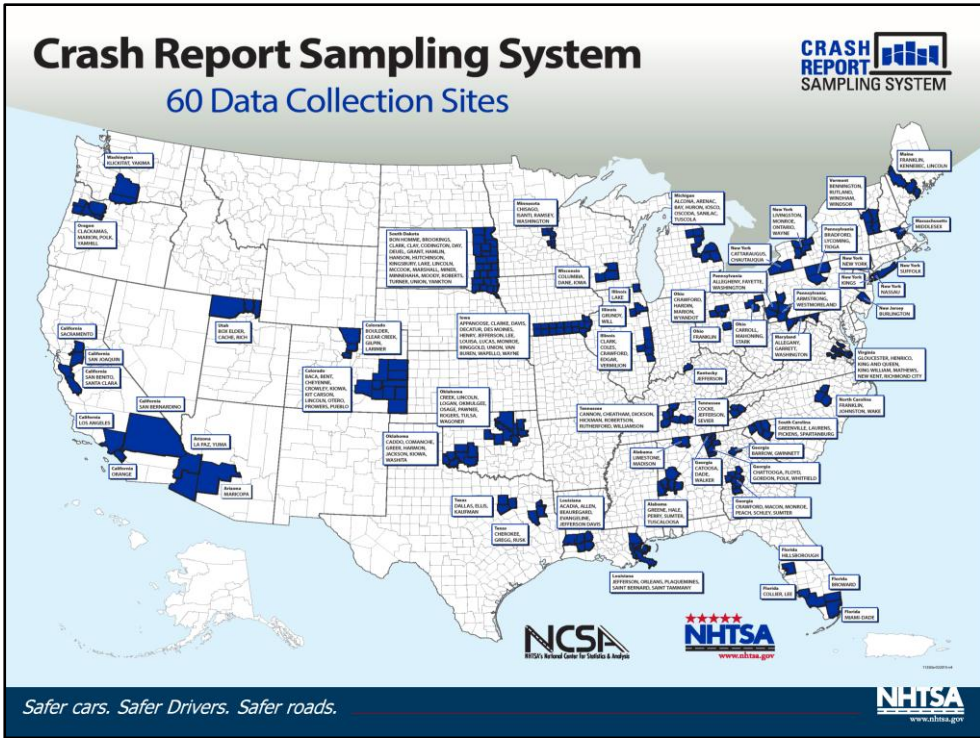
USDOT7

Crash Investigation Sampling System

24 Phase I Data Collection Sites



This map shows the geographic distribution of the first 24 CISS PSUs.



This map shows 60 sampled PSUs in the nation.

Questions

Also send questions/comments to
datamod@dot.gov

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