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1-24-2014

Modeling Injury Outcomes of Crashes involving Heavy Vehicles on Texas Highways

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Recommended Citation

Hernandez, Salvador, "Modeling Injury Outcomes of Crashes involving Heavy Vehicles on Texas Highways" (2014). *PSU Transportation Seminars*. 63.
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Background Intro

- As the national economy continues to recover , the volume of large-truck (GVWR>10,000 lbs.) will also experience a similar recovery
- The increase in truck traffic poses an increased hazard to passenger vehicle traffic
- Large trucks were responsible for more fatalities than passenger vehicles in the U.S. (FHWA, 2010; NHTSA, 2009)



Some Statistics

- Large trucks accounted for roughly
 - 4% of registered vehicles and
 - 8% of VMT in 2008,
 - 11% of motor vehicle involved crash deaths in 2008. (FHWA, 2010)
- Crash costs related to large truck collisions

Injury Categories	Cost (2005 USD)
Average cost per fatal crash	US\$3,604,518
Average cost per non-fatal crash	US\$195,258
Average cost per non-injury (PDO)	US\$15,114

Source: Zaloshnja and Miller, 2006

Societal Impacts

- Associated costs are remarkably high
 - expenses related to loss of lives,
 - medical attention, and insurance, and
 - short term and long term physical and emotional effects
- Economic impacts



Motivation

- State of Texas faced the greatest economic losses of any state at \$22.9 billion dollars in 2008
 - US from 2006 to 2010 → \$107.4 billion dollars
- Recent data indicated that in 2010 the State of Texas experienced:
 - 3,023 deaths
 - 59,660 serious injury crashes
 - 82,685 people sustaining serious injuries
- Very few studies have investigated injury severities associated with large truck involved crashes, especially utilizing state specific crash databases

Research Objectives – Purely Exploratory

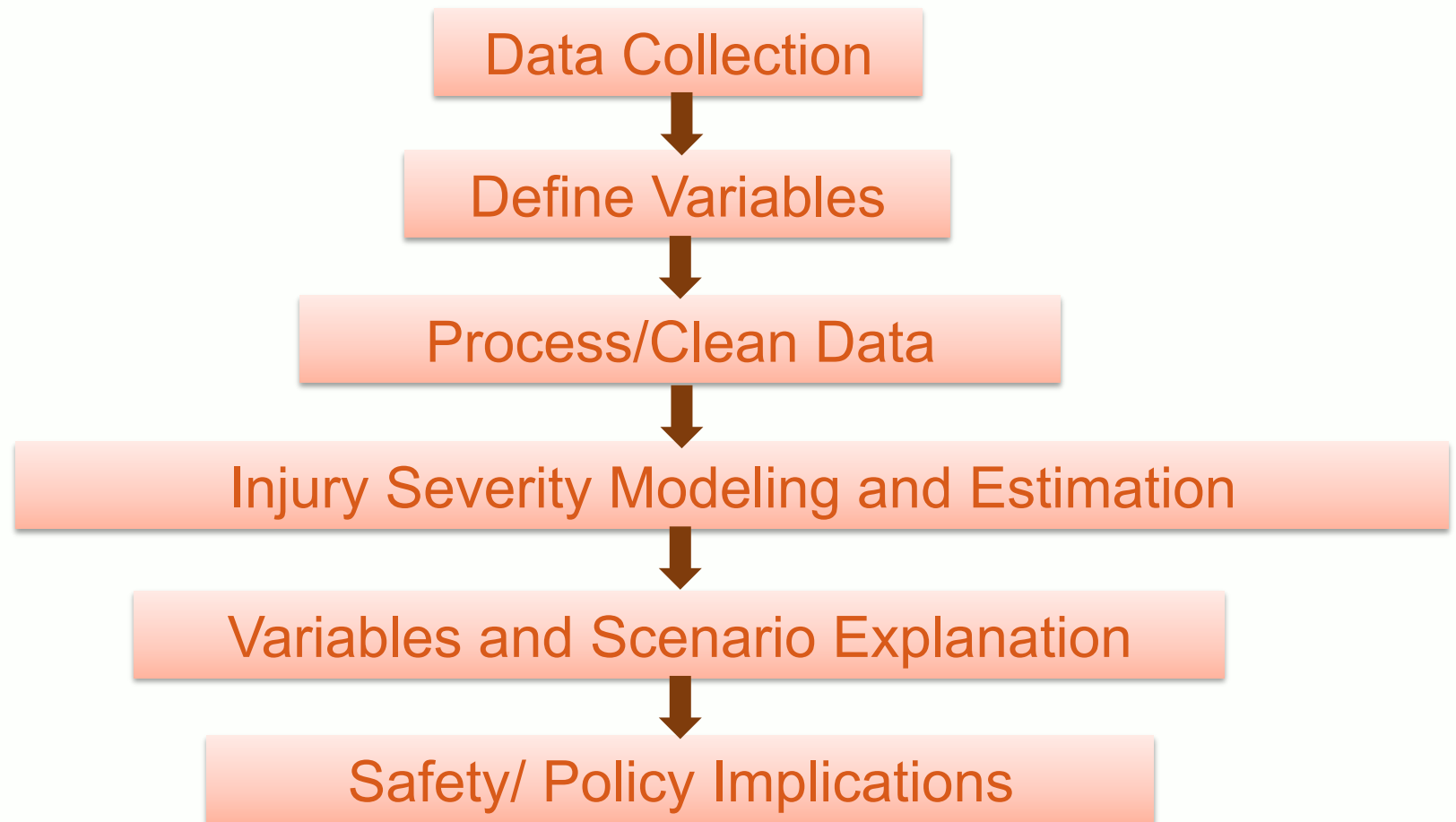
- The primary objective of this study is:
 - to analyze injury severity and understand and identify the factors of injury severity of large truck involved crashes
- A secondary objective is:
 - to account for any “unobserved heterogeneity” (i.e., unobserved factors that may influence an injury outcome) related to human, vehicle, and road-environment

WHY? Thorough understanding of the factors that affect the likelihood of a crash occurring or those which have occurred allows for effective countermeasure development

Research Area



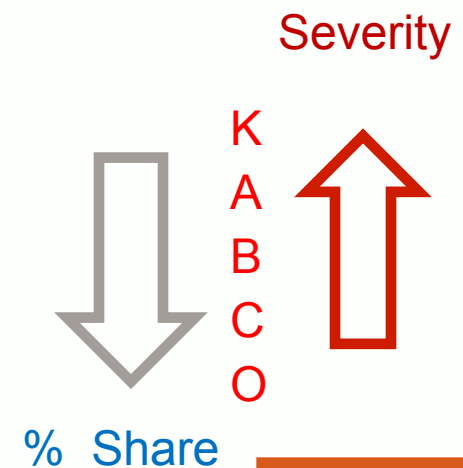
Research Steps



Data – Texas Crash Data

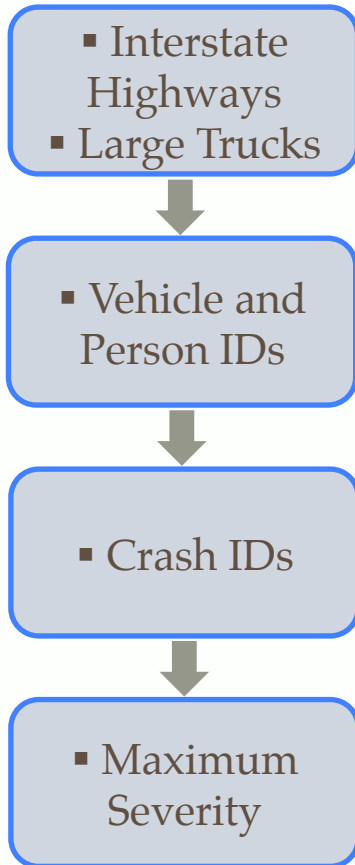
- The Crash Record Information System (CRIS) crash database of Texas was used to estimate injury severity models, where the KABCO severity scale was used to help define the injury outcomes as follows:
 - fatal, incapacitating, non-incapacitating, possible, and no injury (Property- Damage-Only),

Injury Levels	Police Reporting Scale
Fatal	K
Incapacitating	A
Non-incapacitating	B
Possible	C
No injury (PDO)	O

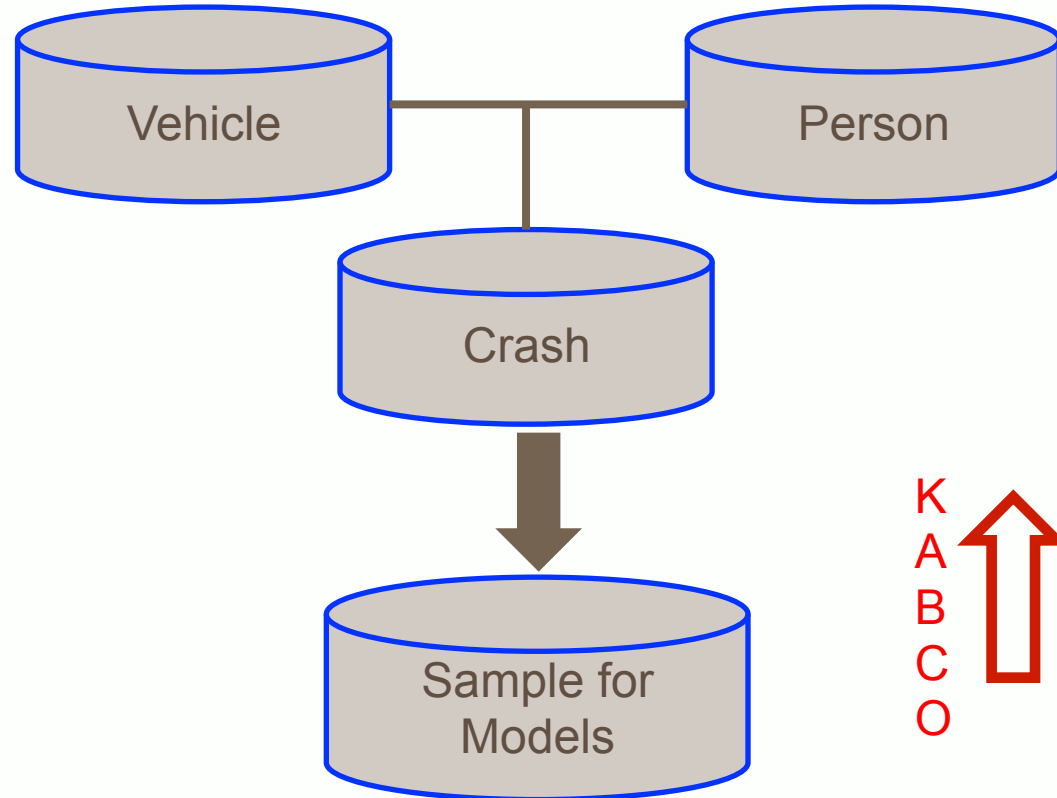


Data Processing - Data Fusion

2006 to 2010



SAS Data Processing/ Cleaning



K
A
B
C
O

Figure: Data Processing Steps in SAS

Methodological Approach

- Have detailed accident information, however the State of Texas is extremely large and diverse that:
 - **Unobserved heterogeneity is likely to exist among the population of large-truck crash-involved road users**
 - Due to differences in risk-taking behavior, physiological factors, driver training (especially for international drivers from neighboring Mexico), etc...
- Mixed logit (random parameters model) may be appropriate

Methodological Approach (Cont'd)

- Standard **Multinomial Logit (MNL)** estimation assumes that the estimated parameters are the same (fixed) for all observations.
- Violations of this assumption can occur if there is some compelling reason (to believe) that parameters vary across observations in a way that cannot be accounted for in the model
 - If not accounted for, may result in potential bias and erroneous statistical inferences

Methodological Approach (Cont'd)

Define:

$$S_{in} = \beta_i X_{in} + \varepsilon_{in}$$

Linear function

where

Variable	Description
S_{in}	is a severity function determining the injury-severity category i for large truck involved crashes n ;
X_{in}	is a vector of explanatory variables (e.g., driver, vehicle, road, and environment variables);
β_i	is a vector of estimable parameters; and
ε_{in}	is error term.

Methodological Approach (Cont'd)

If ε_{in} 's are assumed to be generalized extreme value distributed,

$$P_n(i) = \frac{\text{EXP}[\beta_i X_{in}]}{\sum_I \text{EXP}[\beta_i X_{In}]}$$

where

Variable	Description
$P_n(i)$	is probability of large truck involved incident n having severity outcome with I denoting all possible injury severity outcomes as hereunto presented

The Mixed Logit is:

$$P_{in} = \int \frac{\text{EXP}[\boldsymbol{\beta}_i X_{in}]}{\sum_I \text{EXP}[\boldsymbol{\beta}_i X_{In}]} f(\boldsymbol{\beta} | \boldsymbol{\varphi}) d\boldsymbol{\beta}$$

where

$f(\boldsymbol{\beta} | \boldsymbol{\varphi})$ is the density function of $\boldsymbol{\beta}$ with $\boldsymbol{\varphi}$ referring to a vector of parameters of the density function (mean and variance).

- With this, $\boldsymbol{\beta}$ can now account for segment-specific variations of the effect of X on large truck involved crash probabilities, with the density function $f(\boldsymbol{\beta} | \boldsymbol{\varphi})$ used to determine $\boldsymbol{\beta}$.

Mixed Logit

- Relaxes possible (independence of irrelevant alternatives) IIA problems with a more general error-term structure.
- Can test a variety of distribution options for β .
 - Normal, log-normal, triangular, etc...
- Estimated with simulation based maximum likelihood.
- For more on the Mixed logit I refer you to:

Washington, S., M. Karlaftis, and F.L. Mannering. *Statistical and econometric methods for transportation data analysis*. Chapman and Hall/CRC, Boca Raton, FL, Second edition. 2011

Empirical Setting

- Seek to model the maximum injury level sustained by the drivers involved in a crash
- Injury severities:

Injury Severity	Observations	Percent
Property damage only (PDO)	18,223	88.96%
Possible Injury (POSS)	1,120	5.46%
Non-incapacitating injury (Non- INCAP)	601	2.93%
Incapacitating injury (INCAP)	463	2.26%
Fatality (FATAL)	78	0.38%

- Total observations (N=20,495)

Selected Descriptive Statistics

Meaning of Variables in the Model	Mean	Std. Dev.	Severity outcome
Terrain of roadway (1 if level roadway surface, 0 otherwise)	0.764	0.425	Fatal
Time of day (1 if between 3 pm to 7 pm, 0 otherwise)	0.203	0.402	
Weather condition (1 if clear weather, 0 otherwise)	0.682	0.466	Incapacitating Injury
Land-use pattern at crash location (1 if rural area, 0 otherwise)	0.268	0.443	
Traffic flow at the time of crash (ADT per lane in each direction – veh/day/ln)	15397.3	8845.23	
Month of the year (1 if summer (June to August), 0 otherwise)	0.257	0.437	
Weather condition (1 if clear weather, 0 otherwise)	0.682	0.466	Non-Incapacitating Injury
Shoulder width (right shoulder width (feet))	19.727	3.555	
Time of the day (1 if between 3 pm to 7 pm, 0 otherwise)	0.203	0.402	
Land-use pattern at crash location (1 if urban area, 0 otherwise)	0.564	0.496	
Number of lanes on highways (1 if 4 lanes in one direction, otherwise)	0.428	0.495	Possible Injury
Time of the day (1 if between 12 am to 6 am, 0 otherwise)	0.159	0.366	
Months of year (1 if fall (September to December), 0 otherwise)	0.318	0.428	
Land-use pattern at crash location (1 if rural area, 0 otherwise)	0.268	0.443	
Gender of the occupants (1 if male, 0 otherwise)	0.944	0.229	No-injury (PDO)
Time of the day (1 if between 3 pm to 7 pm, 0 otherwise)	0.203	0.402	
Traffic flow at the time of crash (ADT per lane in each direction – veh/day/ln) (1 if veh/day/ln >2000, 0 otherwise)	0.985	0.122	
Surface condition at the time of crash (1 if dry surface, 0 otherwise)	0.810	0.392	
Age group (1 if age between 25 to 35, 0 otherwise)	0.178	0.382	No-injury (PDO)
Weather condition at the time of crash (1 if clear weather condition, 0 otherwise)	0.682	0.466	
Light condition of street (1 if the surrounding area is dark but outside is lighted, 0 otherwise)	0.119	0.324	
Land-use pattern at crash location (1 if urban area, 0 otherwise)	0.564	0.496	
Age group (1 if age between 45 to 55, 0 otherwise)	0.239	0.427	
Surface condition at the time of crash (1 if dry surface, 0 otherwise)	0.810	0.392	
Traffic flow at the time of crash (ADT per lane in each direction – veh/day/ln)	15397.3	8845.23	

Model Specification

Five Utility functions used in the Mixed Logit Approach

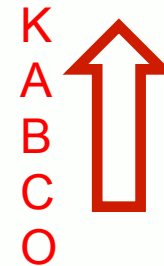
$$S_{FATAL} = \sum \beta_i X_{in} + \epsilon_{in}$$

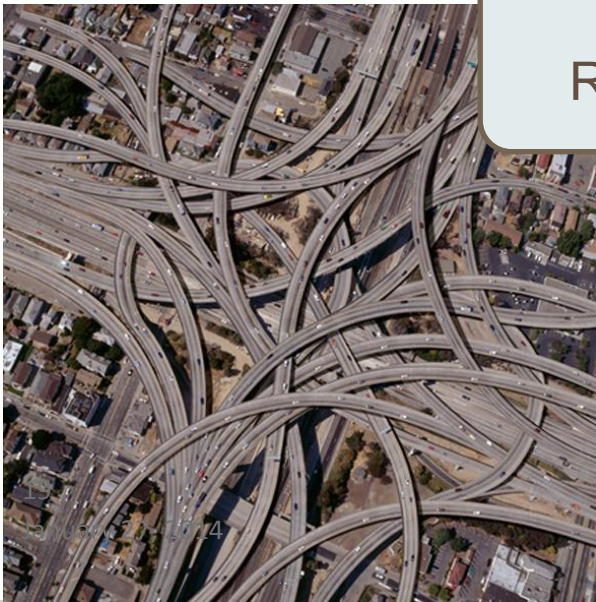
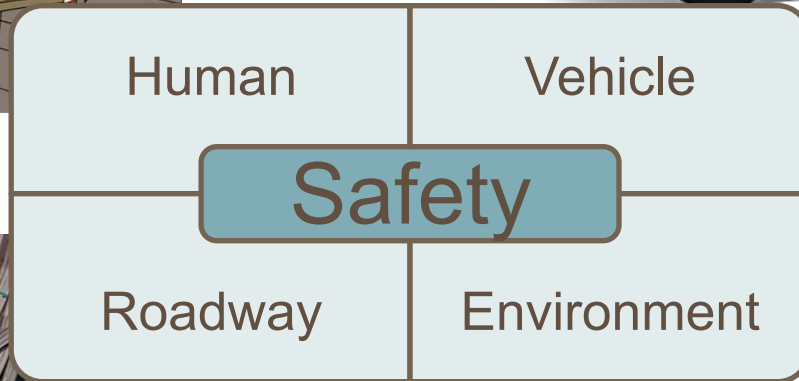
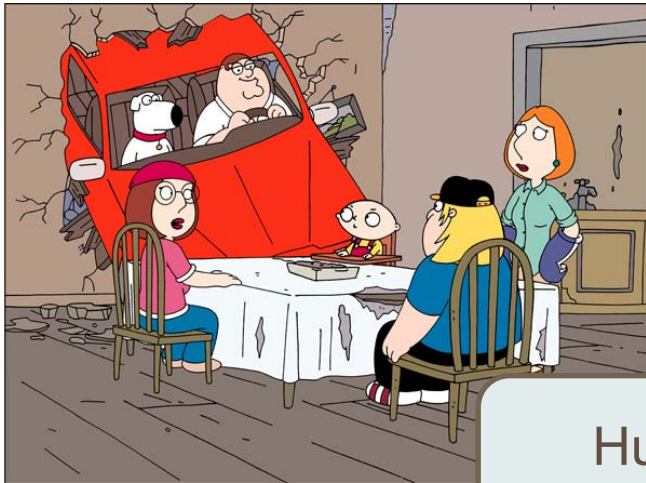
$$S_{INCAP} = \sum \beta_i X_{in} + \epsilon_{in}$$

$$S_{NON-INCAP} = \sum \beta_i X_{in} + \epsilon_{in}$$

$$S_{POSS} = \sum \beta_i X_{in} + \epsilon_{in}$$

$$S_{PDO} = \sum \beta_i X_{in} + \epsilon_{in}$$







Texas Case Study Findings

Drivers Characteristics	Temporal Characteristics	Lighting Characteristics
Male [POSS] ↓	3-7 PM [INCAP, POSS] ↓	Dark but lighted [PDO] ↓
25-35 yrs [POSS] ↓	12-6 AM [NON-INCAP] ↑	
45-55 yrs [PDO] ↑	Jun-Aug [INCAP] ↑	
	Sept-Dec [NON-INCAP] ↓	

Land use Characteristics	Traffic Characteristics	Weather Characteristics
Rural [F, NON-INCAP] ↑	ADT/LN/DAY >2K [POSS] ↓	Clear [F, PDO] ↑ [INCAP] ↓
Urban [INCAP, PDO] ↓	ADT/LN/DAY [F] ↓ [PDO] ↑	

 Increase likelihood
 Decrease likelihood

Road geometry Characteristics
4-lane [NON-INCAP] ↑
Right shoulder width [INCAP] ↑
Level surface [F] ↓
Dry surface [POSS, PDO] ↓

Random Parameter Findings

- **POSS:** The male indicator
 - Parameter normally distributed mean=-3.936 , S.D.=1.622
 - This suggests that about 0.7% of large truck involved crashes involving male drivers on average were more likely to result in possible injuries
- **PDO:** Age group indicator between 45 to 55 years of age
 - Parameter normally distributed mean=1.097, S.D.=1.866
 - This implies that about 72.2% of large truck involved crashes with this age group (45 to 55 years' old drivers) on average were less likely to result in non-injury crashes

Research Hypothesis Testing

Null hypothesis – H_0 : Statistically equivalent models FIX=RAN

Alternate hypothesis – H_A : RAN is superior

$$\chi^2 = -2 \left[LL_{FIX}(\beta^{FIX}) - LL_{RAN}(\beta^{RAN}) \right]$$

The χ^2 statistic for the likelihood ratio test with **six degrees** of freedom gave a value greater than the **99.99%** ($\chi^2 = 62.944$) confidence interval, indicating that the mixed logit model (i.e., **random parameter model**) is statistically superior to the corresponding multinomial model (i.e., **fixed parameter model**).

Summary (Key Findings)

- Higher traffic flow (i.e., vehicles per day per lane) reduces the likelihood of fatalities, but increases that of PDO crashes.
- Crashes occurring in rural settings result in a higher likelihood of fatalities and non-incapacitating injuries. In contrast, crashes occurring in urban settings result in a lower likelihood of incapacitating and PDO crashes.

Summary (Key Findings)

- Time of day such as 3 pm to 7 pm results in lower likelihood of fatalities, incapacitating and possible injuries. Additionally, time of day such as 12 am to 6 am results in higher likelihood of non-incapacitating injuries.
- Summer is likely to increase likelihood of incapacitating injuries, whereas fall is likely to decrease likelihood of non-incapacitating injuries.

Future Work

- Rural vs. Urban
- Time of Day
- Transferability of Models, e.g., Texas to Oregon etc...

Thank You!



Sources:

Islam, M.B., Hernandez, S., 2013. Modeling Injury Outcomes of Crashes involving Heavy Vehicles on Texas Highways. *Transportation Research Record: Journal of the Transportation Research Board*, (In Print).

Family Guy Image: <http://www.entertainmentearth.com/prodinfo.asp?number=AMFGG07#.UuIEomTTkTI>

Target Semi Truck Image: <http://www.dailymail.co.uk/news/article-2083323/Target-truck-driver-skids-icy-pond-8-feet-deep-water-Minnesota.html>

Spaghetti Bowl Interchange: <http://pastmycurfew.com/my-top-10-1-favorite-man-made-wonders/>