

# Data foundations for relationships between economic and transport factors with road safety outcomes

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## Abstract

Economic conditions and policies affect transport, resulting in road safety consequences. This paper describes the selection, acquisition, description and assessment of available, appropriate and suitable data for research of this topic.

Data on economic, transport, and road safety were collected and subjected to exploratory analysis and basic diagnostic tests, finding it to be generally suitable to support further analysis, with qualifications and limitations. Appropriate, and suitable data were found to support analysis of the relationships between economic and transport factors and road safety outcomes.

Simple regression models identified initial, basic relationships between four road safety outcomes and nine economic activity factors reinforcing the importance of these factors as determinants of road safety outcomes. Characteristics of the data dictated more sophisticated analysis is required to produce more reliable results. The data and initial information provides a solid foundation to base further investigations of relationships between economic and transport factors with road safety.

## Keywords

Estimate, Fatality factor, Macroeconomics, Model, Road safety

## Introduction

The need for people to travel and goods to be transported is described as a 'derived demand' meaning it is not an end in itself, but serves a more fundamental purpose. Transport is a necessary facilitating activity for industrial, community, commercial or other 'economic activity'. Travel generally results in crashes, with human, financial and other intangible consequences. Relationships between economic factors, transport factors and road safety outcomes have been investigated previously, but employing different methods and with varying results.

Many subsequent analyses can occur if economic factors can be related to road safety outcomes, so this work provides a foundation for further research, including:

- forecasting future safety outcomes;
- estimating the effect of changing economic conditions;
- estimating the effect of strategies and policy or program countermeasures; and
- assessing the effect of economic, transport, land use or social policies (such as taxation, or road pricing).

Before embarking on investigation of relationships, it is essential to understand the purposes of identifying relationships and the suitability of the data for the analysis. Both the analysis and the data must be 'fit for purpose'. This paper describes the selection, acquisition, description and assessment of available, appropriate and suitable data for further research of the economic influences on road safety, and some initial results.

The objectives of the early stages of this study include:

- identifying key findings relating from previous work regarding the association between changes in the economy and road crashes;
- describing the association between economic variables of the Western Australian economy and serious casualty crash outcomes; and
- preparing data and estimates suitable for further policy and forecasting analysis.

The following data were collected and used as the parameters in this study:

- economic factors (production, consumption, employment, fuel, etc.);
- transport system variables (vehicle kilometres travelled, speed camera use, etc.); and

- road safety outcomes (crashes, crash severity, crashes by road user).

This paper reports the following first stages of a larger, more comprehensive research project and includes:

- the description and review of data;
- diagnostic testing to ensure suitability of data;
- investigation of interrelationships within economic, transport and road safety data groups;
- initial investigation of relationships between and within economic and transport factors and road safety outcomes; and
- discussion and description of results.

This work is consistent with robust analysis producing sound conclusions, by recognising and dealing with three essential, distinct and complementary elements:

- a rationally based conceptual and analytical framework;
- the appropriateness and validity of data; and
- a valid statistical analytical method.

The first of these requires description and explanation beyond what is possible here, in order to provide a justifiable logical basis. Therefore this description based on theory and practice is to be described in further papers which are in preparation, although the concepts are based on previous literature.

## Background

There are a great many measures representing economic factors which can be considered as explanatory variables in analyses. A review of aggregate models for road safety accidents (1) identified 14 studies which had considered various macro-economic and other factors in explaining road accidents. Additional transport, and road safety policy or other factors are also included in some studies. The most common factors found to be relevant were the amount of vehicle travel, vehicle population, income in its various forms and the percentage of young drivers. These studies were not entirely consistent in either the factors considered or the analytical methods used, with some studies reporting contradictory results with respect to certain parameters, such as fuel price.

Road safety measures which have been investigated more commonly include fatalities per vehicle or per vehicle mile travelled (VMT) and injury crashes per vehicle or per VMT (1). Economic factors have not so consistently been related to road safety outcomes but economic activity has been represented by disposable income, Gross National Product

(GNP), industrial manufacturing, income and consumption with additional factors including unemployment size or rate and fuel costs (1).

The number of road fatalities has been positively correlated with per capita disposable income (2), as has fatal injury rates with gross domestic product (GDP) per capita (3), and GDP (4) (5). Unemployment rate has been correlated with reduced road fatality rates (5) (6) (7) (8) (9). An inverted U-shape relationship between national economic growth and road fatalities has been observed, with low income countries exhibiting high fatality rates compared with high income countries (11) (12) (13).

Analytical methodology has evolved from earlier simple methods to more sophisticated techniques and frameworks in more recent years. Initial research often uses ordinary least squares (OLS) linear regression (2) (3) (4) (5) with few variables, including time. Auto-Regressive Integrated Moving Average (ARIMA) (6) (7) and the more general Structural Time Series Modelling (STSM) (8) has been used to effectively account for autocorrelation between observations in a time series. Poisson and Negative Binomial forms of regression analysis have been used in a range of studies (9) (10) (11) (12) (13).

Sequential modelling frameworks have been developed based on motor vehicle travel as the major factor representing exposure to road crashes, to which the various analytical techniques could be applied, such as the 'DRAG' framework, from the French words for travel demand, accident frequency and severity. The DRAG concept combines separate functions of vehicle travel, crashes per unit vehicle travel and crash severity per crash (14). However, to describe the effect of economic factors, the framework is expanded to include the relationship with economic factors which affect the amount of vehicle travel. A revised DRAG model indicated that employment and real retail sales increase personal injury road accidents (15).

Results of all these studies support the hypothesis that economic factors can affect road safety outcomes, although intermediate stages are recognised which may be investigated independently, such as suggested by the DRAG concept. These previous studies suggest a wide variety of road safety outcomes may be related to economic factors and that various methodologies may be applied to analyse their relationships. There are inconsistencies between the analyses where different forms of relationships and different relevant factors were found. The most common economic factors which relate to road safety are reported to be economic activity (real GDP), population, disposable income, unemployment and transport (travel and vehicles). Some factors including industrial production, fuel consumption and fuel prices have been less commonly found to be related. Other factors have been postulated but not yet found to be related. The most common analytical

techniques reported include single and multi-variable OLS linear regression, structural time series modelling (STSM), auto-regressive integrated moving average (ARIMA) and Poisson and Negative Binomial models.

It is also evident throughout the literature that the elements of data suitability and modelling which ensure valid results are, at best, not clearly described. In most cases, consistency with these requirements is not described at all, questioning the validity of the results (1). One of the most important unresolved issues is the choice of explanatory variable, for which no rational basis is often described, raising the question of whether spurious relationships have been developed and reported in the literature (16).

## Data and methods

The initial data analysis is based on the proposition that economic activity is a driver of travel, which results in exposure to crashes. This essentially adds a travel generation element to a consolidated DRAG framework. The important distinctions within the DRAG framework are intended to be separated in later developments of the project. The overall relationships between economic factors and road safety outcomes reported here implicitly combine the individual DRAG elements.

### Data selection

The research objectives defined the desirable range and preference for type of data. Data were collected from public and restricted sources for 16 economic factors, 12 transport system variables, and 15 road safety outcome measures, either quarterly or annually for the period from 1985 to 2009, shown in Table 1, some of which have been combined. Other scaled measures often used in road safety, such as fatalities per capita could be derived for further investigation or comparison. Commonly used measures of economic activity are real gross domestic product (GDP) or real gross national product (GNP). GNP however, is only estimated at the national level whereas we wish to use data for the State of Western Australia.

Thus, real gross state product (GSP) is the relevant similar measure. Various other factors, such as alcohol sales, could potentially be relevant to road safety, but were not available. Relevant transport variables were also collected, but are beyond reporting here. The categorisation of some factors, such as fuel sales and price is uncertain since they could be considered as economic or transport system factors.

Many measures have been used to describe road safety outcomes, each with advantages and weaknesses. Fatalities are probably the most common and reliable measure, but suffer from low frequencies which challenges the validity of statistical analysis. All suffer from definitional issues

and data inaccuracies. While data are available for various crash outcomes, road safety effects and policy has more recently focussed on the number of people killed and seriously injured (KSI). KSIs is a preferred, but emerging metric, which is intended to reflect the major human cost of road safety as opposed to measurable or direct costs (17). The definition of KSIs alone is an important issue and the subject of considerable discussion regarding definitions and data collection and is therefore too complex to be discussed further here. KSIs are represented by the number of people reported to have been killed or hospitalised, based on Department of Health records. The validity of the hospitalisation statistic is fraught with many measurement issues, particularly regarding thresholds of severity of injury and definitional changes although the data series will be accepted as presented for analysis without further dwelling on these issues. Other measures are available but are generally not preferred by users. KSI crashes represent the number of crashes where people are killed or seriously injured, based on reports to Police.

The number of crashes is available for particular road user groups (passenger vehicles, trucks, motor cyclists, cyclists and pedestrians). Various other outcome measures are also available, including fatalities, and intermediate measures, such as vehicle kilometres travelled, and could be used for analysis if appropriate.

Initially, the data were summarised according to common introductory exploratory analysis describing the number of observations, mean, variation, and bounds, for both annual and quarterly data. The data were reviewed visually to identify the form of relationships, possible outliers, or other abnormalities. No major issues were identified. Seven of the annual parameters are available for less than the 25 year annual observations and one of the quarterly parameters is not available for the whole period. These limitations need to be taken into account during sophisticated analysis, but do not affect the introductory analysis.

### Data assessment

In order to avoid model misspecification and misleading results several diagnostic tests are performed on the data to ensure that they are valid for analytical purposes. Tests for correlation, multicollinearity, normality and stationarity were conducted.

Within one of the groups (economic, transport and road safety) data may be subject to correlations which may affect the relationships with factors in other groups which needs to be taken into account. The correlations between economic factors show that most macro-economic factors are very closely related with correlation coefficients often nearing or exceeding 0.9. The correlations with petrol sales and unemployment are slightly less strong and negative for the latter, indicating that unemployment falls as other

Table 1. Summary of annual economic factors and road safety outcome measures

Parameter (1985-2009)	Mean	Standard Deviation	Lowest Observation	Highest Observation	Observations (annual/ quarter)	Metric (units)
<b>Economic Factor</b>						
Gross State Product	123448	30820	81442	180008	20/100	\$ Million
Gross State Product /capita	65529	10147	50861	81317	20/100	\$ Million
Gross State Income	20139	3368	15202	25748	18/100	\$ Million
Gross State Income /capita	53902	13147	38300	81317	18/100	\$ Million
Gross Disposable Income	45359	18474	24375	91729	20/100	\$ Million
Industrial Value Added	115732	31333	73459	172437	20/100	\$ Million
State Final Demand	21915	7783	12813	38775	25/100	\$ Million
Net International Exports	4837	3213	1187	12646	22/88	\$ Million
Retail Turnover	3873	1428	2030	6394	25/100	\$ Million
Employment	878.2	160.6	642.6	1179	25/100	No. of people
Unemployment	59.35	13.20	34.45	87.51	25/100	No. of people
Unemployment Rate	6.632	1.940	3.048	10.69	25/100	Percent
Population	1815775	229958	1436900	2269655	25/100	No. of people
Fuel Consumption	2594	521.7	1737.4	3506	25/100	Gigalitres
Petrol Sales	1805308	142359	1521956	1995565	25/100	Litres
Petrol Price	82.52	24.80	52.4	141.4	25/100	Cent/litre
<b>Road Safety Outcome Measure</b>						
Fatalities	207.3	23.24	163	247	25/100	} Number
Crash - Total number	37439	2156	31914	41636	25/100	
KSIs	3752	570.8	2916	5016	25/100	
Crash - Passenger vehicle	35994	2096	30514	39794	25/100	
Crash - Heavy vehicle	2633	347.2	1949	3408	25/100	
Crash - Motorcycle	1222	221.0	929	1788	25/100	
Crash - Bicycle	701.8	138.6	544	1058	25/100	
Crash - Pedestrian	671.4	112.3	511	849	25/100	
Crash - Fatal	186.6	20.27	151	220	25/100	
Crash - KSI	2300	216.1	1678	2650	25/100	
Crash - Major property damage only	21090	3229	15702	27147	25/100	
Crash - Minor property damage only	7901	2163	3623	13437	25/100	
Road Injury - Motor vehicle	2598	531.6	1794	3713	25/100	
Road Injury - Bicyclist	569.6	156.1	265	841	25/100	
Road Injury - Pedestrian	376.3	48.78	292	449	25/100	

economic factors increase. The strong cross correlations suggest caution when developing multivariate relationships or mathematical models.

Assessment of correlations between transport factors indicate many correlations with coefficients exceeding 0.8, although travel for different types of vehicle is less strongly correlated and motorcycle travel least strongly correlated. While there is a correlation between general transport factors with the policy factors of speed cameras and random breath tests, it is likely to be spurious since such measures are discretionary (subject to control by government and potentially subject to change at any time), so are unlikely to be structurally linked to other economic or transport factors.

Most road safety outcomes measures are not highly correlated. The numbers of passenger vehicle crashes

are correlated with the total number of crashes since the majority of crashes involve cars. The numbers of property damage only crashes are correlated with both these factors for the same reason that the majority of crashes are minor. The number of KSIs is highly correlated with the number of people hospitalised since the number of fatalities is very small. The number of fatalities is correlated with the number of fatal crashes and other correlations also exist.

As groups, general economic factors are strongly correlated with transport factors. Road safety outcome measures as a group are not highly correlated with economic factors. Multicollinearity occurs when two or more predictors in a model are correlated and provide redundant information about the response which was tested by calculating variance inflation factors (VIF) for each predictor. The results indicate considerable multicollinearity between factors,

so related factors should be used together cautiously in multivariable estimation. At the same time, there are sufficient differences between factors (such as the employment and fuel factors) to suggest valid multivariable models could be developed. Based on these results it is at least reasonable to include one economic activity factor, one fuel use factor, fuel price, and two employment factors in such estimations.

Normality (normal distribution of data) is a required attribute of data for many common statistical techniques, but not all. For the analysis of sensitivity and robustness, the Skewness and Kurtosis test, is employed to test normality. Almost all annual data, including the key road safety outcome measures reported below, and the majority of the quarterly data, were found to be normally distributed.

An important assumption often made when analysing time series data is that it is stationary, meaning the means and variances of the random error component of the data are constant over the period. Variables whose random error mean and variance changes over time are known as non-stationary or unit root variables. If the assumption is not true a resulting model may be misspecified and the results may be inappropriate. Time-series data can be conveniently described by the number of times it must be differenced to make it stationary. Stationarity of the selected main parameters was tested with the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. Optimum lag length is determined by Akaike Information Criterion (AIC), Schwarz Bayesian Information Criterion (SBIC), and Hannan and Quinn Information Criterion (HQIC). The results indicate that most of the variables are non-stationary in their levels. However, the stationarity property was found in the first difference of the variables. Therefore the time series nature of the variables needs to be respected during analysis.

## Results of alternative analysis model forms

The availability and suitability of data and whether it is relevant to meet the research objective should be understood in the light of the issues described in the introduction and previous studies. Both the alternatives for the outcome measures and explanatory factors (or independent and dependent variables) need to be carefully considered, in conjunction with the data characteristics and quality. Subsequently the modelling commences with the simplest forms following the principle of Ockham's Razor, but with the potential to move towards more sophisticated techniques to take account of additional factors which may be relevant. In this case the investigation covered the most fundamental economic factor; economic activity, although even this is described in nine available forms which were considered against four alternative measures of road safety

outcomes. While the available data extends to many more factors, it is beyond the scope of this paper to do more than describe the basic characteristics of relevant available data and explore the first of a potentially large number of alternative models.

In the first instance, relationships between economic activity and road safety factors were estimated using OLS regression. Alternative forms of model were initially investigated for key relationships followed by all economic activity parameters. These or similar model forms have been used in previous analyses, generally without justifying applicability. The forms reflect non-linearities in the data although many other forms may be valid and could be further investigated. Some forms suit further analysis such as multiplicative or additive effects of additional factors which could possibly be included in multivariable analysis. These assessments identify any preference of model form or economic activity for modelling.

Statistically valid models and closer fit to observations were preferred. Only models with statistically valid coefficients ( $P > 0.95$ ) were considered valid. Adjusted  $R^2$  and root mean squared error (RMS Error) were used as the primary measures to compare the quality of fit between the observations and the estimation. These measures are not perfect however, particularly since transformations change the  $R^2$  value numerically, so direct comparison between models is not always possible. In general terms, simpler models are preferred over more sophisticated estimations unless an overriding rationale exists.

## Alternative forms of model for estimation

Seven different forms of model were compared for the estimation of four key road safety outcome measures based on Gross State Product as the measure of economic activity:

Linear model	$y = b_0 + b_1 \cdot x$	[1]
Log - linear model	$y = b_0 + b_1 \cdot \ln(x)$	[2]
Linear - log model	$\ln(y) = b_0 + b_1 \cdot x$	[3]
Log - log model	$\ln(y) = b_0 + b_1 \cdot \ln(x)$	[4]
Exponent model 1	$y = b_1 \cdot b_2^x$	[5]
Exponent model 2	$y = b_0 + x^{b_1}$	[6]
Log exponent model	$\ln(y) = b_0 + b_1 \cdot x$	[7]

The results of the alternative model forms are summarised in Table 2, which indicates that more complex models are often not statistically valid ( $P > 0.95$ ) and do not consistently produce better explanations of the

observations. Only the exponent model 1 [5] and the log exponent model [7] consistently produce valid models and the quality of the estimations from these models is consistently high. The normality of the data means transformations are not necessary to ensure validity of the estimations.

These models are illustrated together in Figure 1 which visually confirms the statistical measures and the high similarity between different model estimates, despite the non-zero axes overemphasising the degree of variation in the observations and hence the differences from the estimation. Similar graphs for other factors confirm little differences between the forms of models for estimations of other road safety outcomes based on economic activity.

### Alternative explanatory economic activity factors

Estimates of road safety outcomes (KSIs) based on nine different measures of economic activity were compared and are summarised in Table 3. These results indicate that any of measures of economic activity produce valid models and the quality of the estimations from these models is consistently high. The similarity between the economic measures as explanatory variables is likely to be due to

the high correlation between the factors. Many of these factors (e.g. retail turnover, industrial value added) are subcomponents of other factors (e.g. gross state product).

The results of these models are combined with the observed value of economic activity for each year to produce estimates of KSIs yearly as illustrated in Figure 2. This visually confirms the statistical measures and the high similarity between different explanatory variables, again despite the overemphasis resulting from the non-zero axes. In this figure, the number of KSIs annually are calculated based on the estimated relationship between the economic factor and KSIs then using the observed level of economic activity for each year.

Some particular issues need to be understood in the comparison of the alternative models shown in Table 2 and Figures 1 and 2. The best measure and model may be determined in the case when only a single explanatory variable is used, but this does not imply that the same variables, analytical techniques or models remain the most appropriate when multiple variables or transformations are applied.

All except the linear model involve transformations of at least one of the variables. However, results of statistical analyses are only directly comparable in terms of fit via the R-squared value if they involve the same transformation, or none. The lower statistical values of some models do not imply they are necessarily poorer representations of the data. As noted above, with models which use transformed data, the statistical measures are representative of the transformed data rather than the original data. The axes in Figures 1 and 2 are drawn with axes which are not at zero, in order to highlight the differences between the models, which are clearly very minor. If axes were extended to zero, the differences in the lines of each model would be indistinguishable. At the same time, if the axes were extended to zero it would also be clearer than the models closely represent the data, with small differences between the observations and any of the models, as indicated by the high R<sup>2</sup> values. The differences between the alternative models is best understood from the graphical representation rather than the statistical values.

Road safety outcomes are often reported against time, particularly annually. Trends over time may be reported based on OLS which will not necessarily adequately accommodate autocorrelation. Doing so also hides the nature of underlying factors which may be also be changing. One benefit of the assessment described here is to ‘decouple’ the estimate from time as a dependent variable, while still allowing estimations to be displayed against time.

**Table 2. Statistical comparison of alternative models forms**

Relationship and Model	Valid Coefficients (P>0.95)	RMS Error	Adjusted R <sup>2</sup>
<b>Fatalities v GSP</b>			
Linear model	-		
Log-linear model	-		
Linear-log model	-		
Log-log model	-		
Exponent model 1	b <sub>1</sub> , b <sub>2</sub>	21.65	.9886
Exponent model 2	-		
Log exponent model	b <sub>0</sub> , b <sub>1</sub>	.1082	.9996
<b>KSIs v GSP</b>			
Linear model	b <sub>0</sub> , b <sub>1</sub>	459.7	.4403
Log-linear model	b <sub>0</sub> , b <sub>1</sub>	.1211	.4240
Linear-log model	b <sub>0</sub> , b <sub>1</sub>	471.3	.4118
Log-log model	b <sub>0</sub> , b <sub>1</sub>	.1231	.4045
Exponent model 1	b <sub>1</sub> , b <sub>2</sub>	453.7	.9862
Exponent model 2	b <sub>1</sub>	466.2	.9854
Log exponent model	b <sub>0</sub> , b <sub>1</sub>	.1209	.9998
<b>Crashes v GSP</b>			
Linear model	b <sub>0</sub> , b <sub>1</sub>	1763	.4002
Log-linear model	b <sub>0</sub> , b <sub>1</sub>	.0484	.3969
Linear-log model	b <sub>1</sub>	1686	.4514
Log-log model	b <sub>0</sub> , b <sub>1</sub>	.0462	.4503
Exponent model 1	b <sub>1</sub> , b <sub>2</sub>	1776	.9977
Exponent model 2	b <sub>1</sub>	1699	.9979
Log exponent model	b <sub>0</sub> , b <sub>1</sub>	.0484	1.000
<b>KSI crashes v GSP</b>			
Linear model	-		
Log-linear model	-		
Linear-log model	-		
Log-log model	-		
Exponent model 1	b <sub>1</sub> , b <sub>2</sub>	228.3	.9900
Exponent model 2	-		
Log exponent model	b <sub>0</sub> , b <sub>1</sub>	.1072	.9998

Note: Errors and R<sup>2</sup> are not comparable between models with different transformations

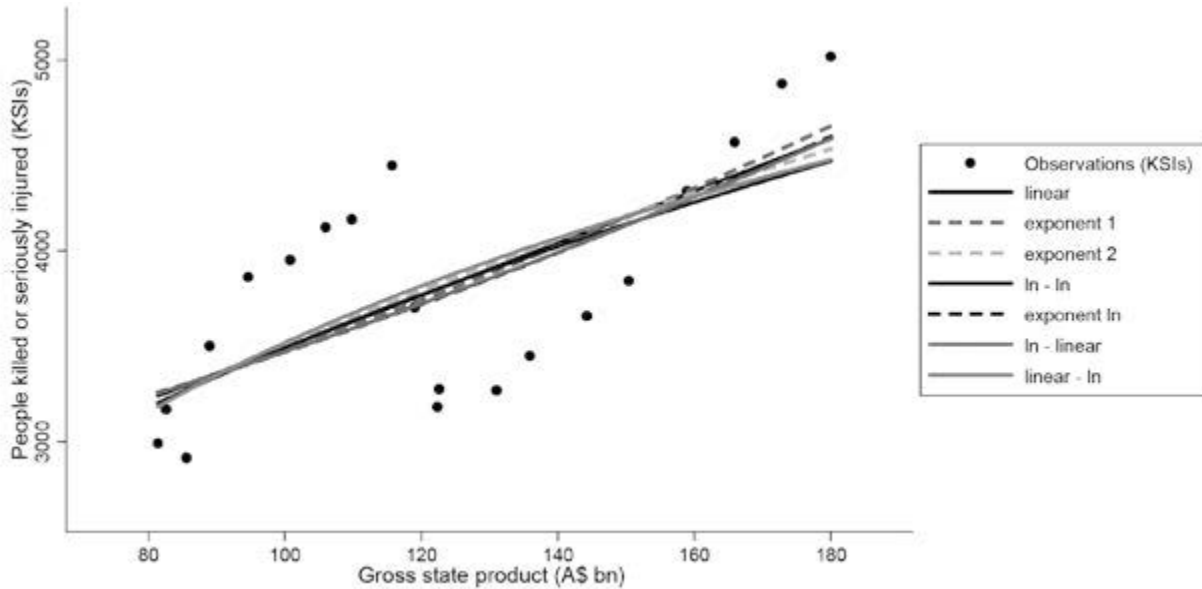


Figure 1. Graphed comparison of alternative forms of model

Table 3. Comparison of alternative economic activity as explanatory factors

Economic Activity Measure with model parameter	Coef.	Std. Err.	P>t (t test)	95% Conf. Interval		RMS Error	Adjusted R-squared	
				low	high			
Gross State Product (GSP)	$b_1$	2420	272.6	0.000	1848	2993	453.7	.9862
	$b_2$	1.000004	8.18e-7	0.000	1.000002	1.000005		
GSP per capita	$b_1$	1848.9	340.1	0.000	1134	2563	460.4	.9858
	$b_2$	1.000011	2.65e-6	0.000	1.000005	1.000017		
Gross State Income (GSI)	$b_1$	2311	446.2	0.000	1365	3257	506.3	.9835
	$b_2$	1.000026	9.17e-6	0.000	1.000006	1.00004		
GSI per capita	$b_1$	2540	284.7	0.000	1936	3143	441.4	.9874
	$b_2$	1.000008	1.90e-6	0.000	1.000004	1.000012		
Gross Domestic Income (GDI)	$b_1$	2896	200.8	0.000	2474	3317	444.3	.9868
	$b_2$	1.000006	1.28e-6	0.000	1.000003	1.000009		
Industrial Value Added (IVA)	$b_1$	2525	269.9	0.000	1958	3092	461.9	.9857
	$b_2$	1.000004	8.23e-7	0.000	1.000002	1.000005		
State Final Demand (SFD)	$b_1$	2750	174.4	0.000	2389	3111	396.3	.9900
	$b_2$	1.000014	2.51e-6	0.000	1.000009	1.000019		
Retail Turnover (RT)	$b_1$	2845	202.1	0.000	2427	3263	438.6	.9866
	$b_2$	1.000007	1.61e-5	0.000	1.000037	1.0001		
Net International Exports (NE)	$b_1$	3178	142.2	0.000	2881	3474	423.5	.9877
	$b_2$	1.000003	6.76e-6	0.000	1.00002	1.00005		

## Discussion and conclusions

This introduction to a larger project which will involve further analysis followed a robust and thorough process to prepare and understand the suitability of data for the purposes of relating economic effects to road safety outcomes. Considerable amounts of relevant, appropriate and suitable data were found to be available to support the intended future analysis.

The assembled data was found to be suitable for the purpose based on visual assessments, descriptive statistics and statistical tests. Apart from minor issues, two important

characteristics need to be taken into account when using the data. Collinearity between variables and groups of variables exist, so caution should be exercised when developing multivariate models. Much of the data is autocorrelated, (i.e. related over time) so attention should be given to respecting the time series nature of the data during further analysis.

Seven alternative forms of model for estimating relationships were investigated and found to produce similar results, but only an exponent model and a log transformed model were statistically valid in all four cases tested. Based on the similarity of the results of different

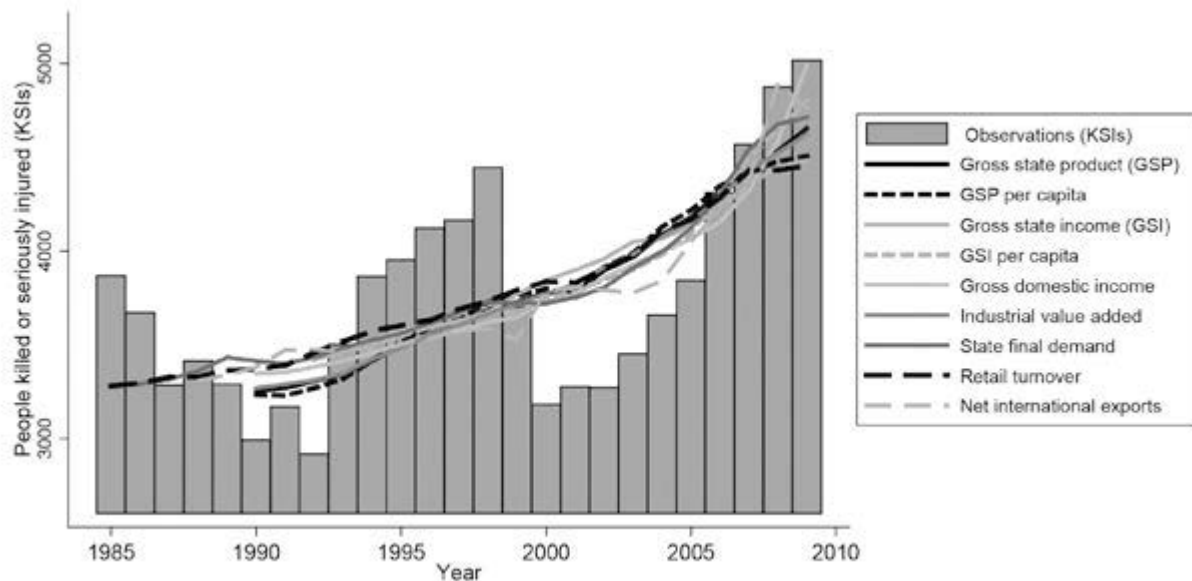


Figure 2: Estimate of people killed or seriously injured each year based on different measures of economic activity

forms of model, the exponent model 1 (equation [5]) is preferred due to statistical validity and consistency across estimates of all measures. Also, previous literature and the expectation that linearity has not been evident in many road safety outcomes over a longer period suggest linear models may not be appropriate. Compared to a linear model, the exponent model diverges at the extremities and the centre of the range which better matches the characteristics of the outcome variables being examined.

Nine alternative measures of economic activity were investigated and all found to be valid as explanatory variables, with each explaining a significant amount to the variation in the road safety outcome measures. Gross state product (GSP) is preferred as an explanatory variable due to it being a broad measure, frequently used, commonly understood and widely available. Consistent with previous studies economic activity has previously been positively correlated with increasing road safety measures (1) (2) (3) (4), however other studies have not directly compared different measures of economic activity.

Relationships were found between road safety outcomes and economic factors supporting the importance of considering these factors as relevant for understanding road safety outcomes and during investigation. While good levels of explanatory power have been found, other factors could be important in estimating road safety outcomes. Multivariate and other non-linear estimates may produce more informative results.

The data and initial information investigated in this study provides a solid foundation on which to base further investigations of relationships between economic and transport factors with road safety and subsequent investigations.

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## References

1. Hakim S, Shefer D, Hakkert AS, Hocherman I. A critical review of macro models for road accidents. *Accident Analysis & Prevention*. 1991;23(5):379-400.
2. Zlatoper TJ. Determinants of motor vehicle deaths in the United States: A cross-sectional analysis. *Accident Analysis & Prevention*. 1991;23(5):431-6.
3. Van Beeck EF, Borsboom GJ, Mackenbach JP. Economic development and traffic accident mortality in the industrialized world, 1962-1990. *International Journal of Epidemiology*. 2000;29(3):503-9.
4. Granados JAT. Increasing mortality during the expansions of the US economy, 1900-1996. *International Journal of Epidemiology*. 2005;34:1194-202.
5. Gerdtham U-G, Ruhm CJ. Deaths rise in good economic times: Evidence from the OECD. *Economics & Human Biology*. 2006;4(3):298-316.
6. Wagenaar AC. Effects of macroeconomic conditions on the incidence of motor vehicle accidents. *Accident Analysis & Prevention*. 1984;16(3):191-205.
7. Reinfurt DW, Stewart JR, Weaver NL. The economy as a factor in motor vehicle fatalities, suicides, and homicides. *Accident Analysis & Prevention*. 1991;23(5):453-62.
8. Scuffham PA, Langley JD. A model of traffic crashes in New Zealand. *Accident Analysis & Prevention*. 2002;34(5):673-87.
9. Thoresen T, Fry T, Helman L, Cameron M. Linking economic activity, road safety countermeasures and other factors with the Victorian Road Toll. Monash University Accident Research Centre, 1992 Report 29.



10. Noland RB. Traffic fatalities and injuries: the effect of changes in infrastructure and other trends. *Accident Analysis & Prevention*. 2003;35(4):599-611.
11. Anbarci N, Escaleras M, Register C. Traffic fatalities and public sector corruption. *KYKLOS*. 2006;59(3):327-44.
12. Law TH, Noland RB, Evans AW. Factors associated with the relationship between motorcycle deaths and economic growth. *Accident Analysis & Prevention*. 2009;41(2):234-40.
13. Law TH, Noland RB, Evans AW. The sources of the Kuznets relationship between road fatalities and economic growth. *Journal of Transport Geography*. 2010.
14. Gaudry M. Un Abrege de DRAG, un Model de la Demande Routiere, des Accidents et de Leur Gravite, Applique au Quebec de 1956 a 1982. Montreal: Universite de Montreal, Centre de recherche sur le transports Ddse; 1986 November 1986. Report No.: Publication #698.
15. Tegnér GB, Lucassi VML. Time-series models for urban road traffic and accidents in Stockholm. TRANSEK Consultants; undated.
16. Oppe S. The development of traffic and traffic safety in six developed countries. *Accident Analysis & Prevention*. 1991;23(5):401-12.
17. Hughes BP, Newstead S, D'Elia A. Outcomes-Based National Road Safety Performance Measures. Australasian College of Road Safety National Conference; Melbourne, Australia 2011.

# Contributed articles

## United Nations Road Safety Collaboration (UNRSC)

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### Establishing the UNRSC

Following the release of the World Report on Road Traffic Injuries in April 2004, the General Assembly passed a resolution, put forward by the Omani Ambassador to the United Nations, establishing the UN Road Safety Collaboration. The World Health Organisation was the UN agency assigned to chair the Collaboration. The objectives of this group are:

- To strengthen global and regional coordination on road safety through information exchange and multi-sectoral cooperation.
- To advocate and encourage demand and additional resources for road safety, including through major advocacy events.
- To support assessments of the magnitude of the road safety problem, harmonised data collection and research on risk factors implemented by its members along their own work programs and mandates, in a coordinated manner.
- To coordinate and support dissemination of documentation of good practices in prevention and road traffic injury reduction efforts in regions and countries developed by its members.
- To coordinate and support further development of guidelines for effective road safety interventions in the areas of prevention; risk management; limitation of consequences of crashes; sustainable management of road infrastructure and safety equipment; and appropriate legislative models; elaborated by its members.
- To coordinate and support further development of guidelines for appropriate legal and medical response to crashes.
- To coordinate promotion of individual and institutional capacity development on road safety implemented by its members.
- To coordinate efforts within the UN system and to encourage a culture of road safety within these organisations.