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# Time series modeling in traffic safety research

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ABSTRACT

The use of statistical models for analyzing traffic safety (crash) data has been well-established. However, time series techniques have traditionally been underrepresented in the corresponding literature, due to challenges in data collection, along with a limited knowledge of proper methodology. In recent years, new types of high-resolution traffic safety data, especially in measuring driver behavior, have made time series modeling techniques an increasingly salient topic of study. Yet there remains a dearth of information to guide analysts in their use. This paper provides an overview of the state of the art in using time series models in traffic safety research, and discusses some of the fundamental techniques and considerations in classic time series modeling. It also presents ongoing and future opportunities for expanding the use of time series models, and explores newer modeling techniques, including computational intelligence models, which hold promise in effectively handling ever-larger data sets. The information contained herein is meant to guide safety researchers in understanding this broad area of transportation data analysis, and provide a framework for understanding safety trends that can influence policy-making.

## 1. Study objectives and methodology

Within transportation safety research (herein referred to as traffic safety research), data modeling has long been dominated by cross-sectional methods. These models consider the combined effects of various external factors on one or more safety measures within a single period. Despite their ubiquity, however, cross-sectional models can misinterpret the effects of a variable observed repeatedly over time – so-called "time series" data. Time series models, by contrast, facilitate the study of longitudinal changes in crash exposure, crash risk, and crash outcomes for a single subject (or group of subjects), to better establish estimates of their future values. For this reason, time series analysis is a powerful tool for analyzing transportation and traffic engineering datasets that may include an underlying temporal structure (Chatfield, 2010).

The use of time series models in traffic safety research is scarce, relative to the use of cross-sectional models. This may be attributed to numerous factors, including the lack of relevant data, as well as the complexity in the data structures of the safety issues in question. Nevertheless, in the current age where detailed real-time or near-real-time information may be acquired for individual vehicles or infrastructure elements at low cost, time-series modeling is well suited to lend a new perspective on classic safety issues.

Within the larger body of traffic safety research, there are several areas that have seen modest use of time series methodological techniques. These areas include, but are not necessarily limited to, driver behavior and education, pedestrian safety, alcohol use and driving, and roadway environmental factors. This paper critically reviews the current literature on time series analysis in these areas, details some of the common challenges in applying time series models, and explores future directions for data and methodological development.

The methodological strategy used for this publication was a non-exhaustive search of various peer-reviewed journals pertaining to traffic safety, economics, and human factors. From this review, publications which used time series analysis as their primary methodological component were catalogued, and the different elements of the research were identified. The following elements were used to categorize each reviewed publication:

- Research Topic
- Modeling Methodology
- Surrogate Measure of Safety (i.e., the response variable)
- Geographic Scope of Analysis
- Time Scale/Interval of Collected Data

The results of this identification process are a select number of publications, 53 in total, contained in Table 1. Note that not every

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**Table 1**
Overview of case studies in time series modeling in transportation safety research.

| Author Year | Study Period | Topic | | | | | | | | Method | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Alcohol Use | Photo Enforcem-ent | Safety Belt Use | Speed Limits | Weather Impacts | Pedestria-ns | Driver Behavior | Other | ARIMA | ARCH/ GARCH | GLM | SEM | VAR | Frequency Domain | Comp. Intelligen-ce | Markov |
| Abdel-Aty and Abdalla (2004) | 1999 | | | | X | | | | | | | | | | | | |
| Ahangari et al. (2016) | 1990–2010 | | | | | | | | X | | | X | | | | | |
| Ameen, et al. (2001) | 1978–1995 | | | | | | | | X | | | X | | | | | |
| Bergel-Hayat et al. (2013) | 1975–2005 | | | | | X | | | | | | | X | | | | |
| Blose and Holder (1987) | 1973–1982 | X | | | | | | | | X | | | | | | | |
| Boroujerdian et al. (2014) | 2004–2007 | | | | | | | | | | | | | | X | | |
| Brijs et al. (2008) | 2001 | | | | | X | | | | | | | | | | | |
| | 2004–2013 | | | | | | | | X | | | | | | | | |
| Campbell et al. (1991) | 1984–1988 | | | X | | | | | | X | | | X | | | | |
| Carnis and Blais (2013) | 1999–2010 | | X | | | | | | | X | | | | | | | |
| Chi et al. (2013) | 1998–2007 | | | | | | | | X | | | | | | | | |
| Commandeur et al. (2013) | 1969–1985 | | | | | | | | X | X | | | | | | | |
| Figlio (1995) | 1976–1993 | X | | | | | | | | X | | | | | | | |
| Foss et al. (2001) | 1991–1996 | X | | | | | | | | | | | X | | | | |
| García-Ferrer et al. (2006) | 1975–2003 | X | | | | | | | | X | | | | | | | |
| Giuffre (2014) | 2006–2012 | | | | | | | | X | | | | | | | | |
| Hadayeghi (2007) | 2000–2004 | | X | | | | | | | | | | | | | | |
| Holder and Blose (1987) | 1973–1982 | X | | | | | | | | X | | | | | | | |
| Holder and Wagenaar (1994) | 1976–1989 | X | | | | | | | | X | | | | | | | |
| Houston and Richardson (2002) | 1988–1997 | | | X | | | | | | X | | | | | | | |
| Huitema et al. (2014) | 2001–2010 | | | | | | | X | | | | | | | | | |
| Ko et al. (2004) | 2003 | | | | | | | X | | | X | | | | | | |
| Kopits et al. (2005) | 1963–1999 | | | | | | | | X | | | X | | | | | |
| Kweon et al. (2009) | 1980–2005 | | | | | | X | | | | | | | | | | |
| Lavoie (2017) | 2001–2013 | X | | | | | | | | | | | | | | | |
| Lord and Persaud (2000) | 1990–1995 | | | | | | | | X | | | | | | | | |
| Lu (1992) | *Not stated* | | | | | | | | X | | | | | | X | | |
| Ma (2010) | 2004–2007 | | | | X | | X | | X | | | | | | | | |
| Malyshkina et al. (2009) | 1995–1999 | | | | | X | | | | | | | | | | | X |
| Masten (2007) | 1994–2004 | | | X | | | | | | X | | | | | | | |

(*continued on next page*)