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A REVIEW OF STATISTICAL METHODS USED FOR INTERVENTION EVALUATION

(*Pendekatan Kaedah Berstatistik dalam Penilaian Intervensi – Satu Sorotan*)

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ABSTRACT

The adopted United Nations General Assembly through Resolution A/RES/74/299 "Improving global road safety" with the Decade of Action for Road Safety 2021-2030 targets to prevent at least 50% of road deaths and injuries by 2030. The global plan called for a holistic approach to road safety and continued improvements in the vehicles and road, enhancement of laws and law enforcement; and provision of timely, life-saving emergency care for the injured. Various road safety interventions and programs have been implemented worldwide with the aim to reduce fatalities and injuries. The importance of evaluating the impact of intervention through sound statistical approaches is definite. As intervention could be conducted in many ways, so can the methods. By design, randomized control trials hold the gold standard in intervention evaluation. However, there are many circumstances where it is not feasible, and researchers opted for a quasi-experimental approach especially when it involves ethical or financial constraints. This paper reviews three approaches used for intervention evaluation: the difference-in-differences method, segmented regression of interrupted time series, and interventional autoregressive integrated moving average, in the field of road safety. The aim is to review the methods used for intervention evaluation or program effectiveness. The Scopus database and available research reports from World Health Organization and related agencies were used to search for available pieces of literature for the year 2013 onwards.

Keywords: intervention evaluation; statistics; methodology

ABSTRAK

Resolusi A/RES/74/299 "Menambahbaik keselamatan jalan raya global" Perhimpunan Agung Bangsa-bangsa Bersatu menyatakan komitmen global dalam mengurangkan sekurang-kurangnya 50% kematian dan kecederaan menjelang tahun 2030, melalui Dekad Tindakan Keselamatan Jalan Raya 2021-2030. Pelan global ini menyeru kepada satu pendekatan menyeluruh dan penambahbaikan berterusan dalam aspek penambahbaikan keselamatan kenderaan dan jalan raya, undang-undang dan penguatkuasaan, dan rawatan kecemasan dalam tempoh masa yang bersesuaian dan pantas. Pelbagai intervensi dan program keselamatan jalan raya dilaksanakan diseluruh dunia bagi mengurangkan kematian dan kecederaan. Kepentingan penilaian impak intervensi melalui kaedah berstatisik tidak dinafikan lagi. Kepelbagaian intervensi yang dijalankan menuntut kepelbagaian, dan rekabentuk ujian kawalan rawak adalah rekabentuk yang terbaik. Namun begitu, rekabentuk ini tidak dapat dijalankan, terutamanya jika melibatkan etika kajian dan juga kekangan kewangan sehingga penyelidik terpaksa memilih untuk menggunakan pendekatan eksperimen-kuasi. Kertas kerja ini menyoroti tiga kaedah yang digunakan dalam penilaian keberkesanan intervensi iaitu beza dalam beza, bagi siri masa terganggu dan autoregresif integrasi purata bergerak bergangguan, dalam bidang keselamatan jalan raya. Tujuan kertas kerja ini adalah untuk mengulas kaedah-kaedah yang digunakan dalam penilaian keberkesanan intervensi keselamatan jalan raya. Sorotan ini menggunakan kaedah bibliometrik dengan mengambilkira kertas kerja yang diterbitkan dalam pangkalan data Scopus, laporan-laporan daripada Badan Kesihatan Dunia

dan juga laporan dari agensi berkaitan keselamatan jalan raya, dari tahun 2013 sehingga yang terkini.

Kata kunci: penilaian intervensi; statistik; metodologi

1. Introduction

Road deaths are a global pandemic that kills about 1.35 million lives annually (World Health Organization 2018). The first Decade of Action 2011-2020, was launched in the year 2011 with the tagline, "Together we can save millions of lives" with its Global Plan and best practices in road safety from around the world. The effort in reducing fatalities and injuries was then continued with the second Decade of Action 2021-2030 under the Sustainable Development Goals (SDG). The United Nations General Assembly through Resolution A/RES/74/299 "Improving global road safety" with the Decade of Action for Road Safety 2021-2030 targets to prevent at least 50% of road deaths and injuries by 2030 was adopted. The global plan called for a holistic approach to road safety and continued improvements in the vehicles and road, enhancement of laws and law enforcement; and provision of timely, life-saving emergency care for the injured. The resolution is also documented in the Sustainable Development Goals (SDG) 3.6.1.

In the last three decades, the number of road fatalities per 100,000 population in Malaysia is shown a decline from an index of 29.77 in the year 1996, to an index of 19.40 in the year 2018 (Sarani *et al.* 2020) despite the growth in the motorization rate, refer to Figure 1. The establishment of the Road Safety Research Center (RSRC) in the '90s, spearheaded many road safety research, especially within the 3E's elements, engineering, education and enforcement. The first national road death target aimed to alert the government to acknowledge road safety problems in the country. Through the Road Safety Council, the Road Safety Department was established to strengthen road safety efforts with the Malaysia Road Safety Plan 2006-2010. The positive achievement could mainly be driven by road safety programs outlined both in the first and the second road safety plan spanning from the year 2006-2020, including improvement in road engineering through an automated enforcement system, changes in the driving curriculum, the introduction of road safety education, new car assessment program and others as summarized in (Ishak & Syed Md Rahim 2020; Sarani *et.al* 2009; Ismail *et al*. 2019; Jamil *et.al* 2014; Kassim *et al.* 2018).

Locally, through the second Malaysia Road Safety Plan 2014-2020, Malaysia has established a national target of road death reduction by half (5,358) from the forecasted figure of 10,716 deaths in the year 2020 (Syed Md Rahim *et al.* 2018). In 2017-2019, the number of road fatalities showed a positive reduction from 7,152 in the year 2016 to 6,167 in the year 2019, and a further decrease to 4,634 in the year 2020 (Royal Malaysian Police 2021), less than the target set. Though the global effect of the pandemic COVID-19 is quite significant, especially in restricting mobility and hence reducing exposure on the road (Sarani *et al.* 2009; Ismail *et al.* 2019; Katrakazas *et al.* 2020), the continuous effort in reducing road fatalities and injuries through various programs and interventions conducted should not be overlooked.

Intervention refers to an effort to intervene something, or to make things better. A road safety intervention refers to a concentrated effort consistently conducted to reach a designated outcome, either to reduce injuries and fatalities or to avoid road crashes, for better health outcomes. However, in road safety intervention, it is more important to know which intervention does not work or could bring more harm (Turner *et al.* 2021). As road accident is a multi-factor event, the multidisciplinary approach in designing road safety intervention is a norm, hence the criteria in intervention evaluation vary.

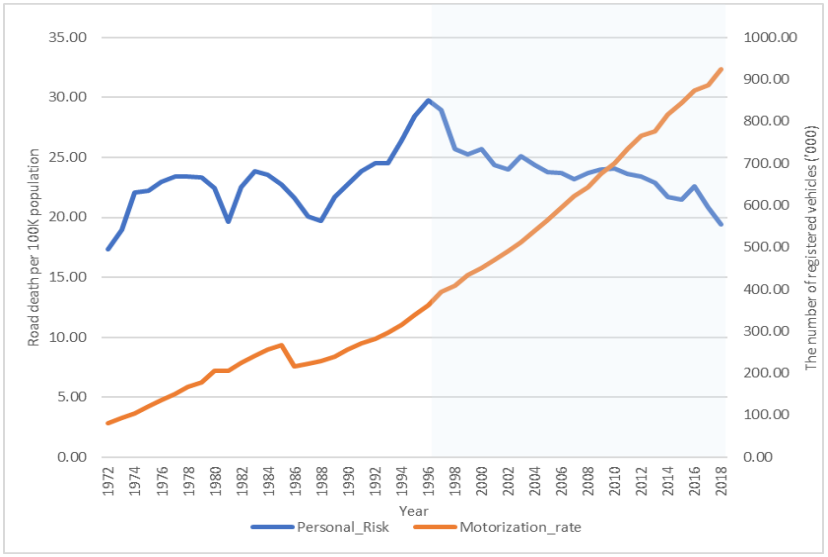

Figure 1: Road fatalities per 100,000 population and motorization rate (Sarani *et al.* 2020)

This paper aims to summarize the statistical approaches used for intervention evaluation, focusing on the interrupted time series, regression analysis and interventional autoregressive integrated moving average, in the field of road safety. The aim is to review the methods used for intervention evaluation or program effectiveness, based on published papers in the Scopus database. A bibliometric analysis is conducted to search for patterns and trend focusing on intervention evaluation in the field of road safety.

2. Data and Methods

Based on the Scopus database, a list of publications from the year 2013 onwards were extracted, to include the recent ten years of development and progress of the statistical approaches in intervention evaluation. A scoping review on interrupted time series data by Ewusie *et al.* (2020), utilizing 1,389 articles found 98.27% of the articles on interrupted time series (ITS) were application papers where 45% were used in the clinical field, 32% were used in public health or policy, pharmaceutical 17.4% and 5.1% in guideline implementation. A small portion of papers, 1.73% out of 1,389 papers, discussed on the development or the improvement of the existing methods and comparative analysis of ITS with other methods.

Keywords used are first restricted to any documents containing “road safety intervention” in any parts of the title, abstract or body of the text. The second tier of search contains the word effect* OR evaluate*. Another set of searches on the methods used in intervention evaluation was conducted using the keyword of “interrupted time series” AND “road safety”. All documents that matched the search criteria were then extracted and analyzed using descriptive analysis. A bibliometric analysis was conducted to see trends in the methods used in intervention evaluations. A few systematic review documents were referred to to gain better understanding of statistical methods used in evaluating road safety intervention.

3. Results

A search on “road safety intervention” in Scopus revealed 148 documents for the year 2013 to date, with an average of 14 publications per year, mostly published by Western countries. The United Kingdom has the highest of 31 publications, followed by Australia at 22 and the

United States, at 20. Malaysia had three publications under the topics. The top five journals on the subject are Accident Analysis and Prevention, Transport Research Part F Traffic Psychology and Behaviour, Injury, Journal of Safety Research and Safety Science. The most cited paper is on crash risk and aberrant driving behaviours among bus drivers: the role of personality and attitudes towards traffic safety by Mallia *et al*. (2015) published in AAP, cited by 132 authors. For recently published documents, the number of papers cited is quite low, but it does not mean the paper is less important than the most cited papers. In line with the industrial revolution and technological advancement, recent papers on road safety intervention use virtual technology in assessing road users' behavior, risk assessment and the global estimates of road safety risk.

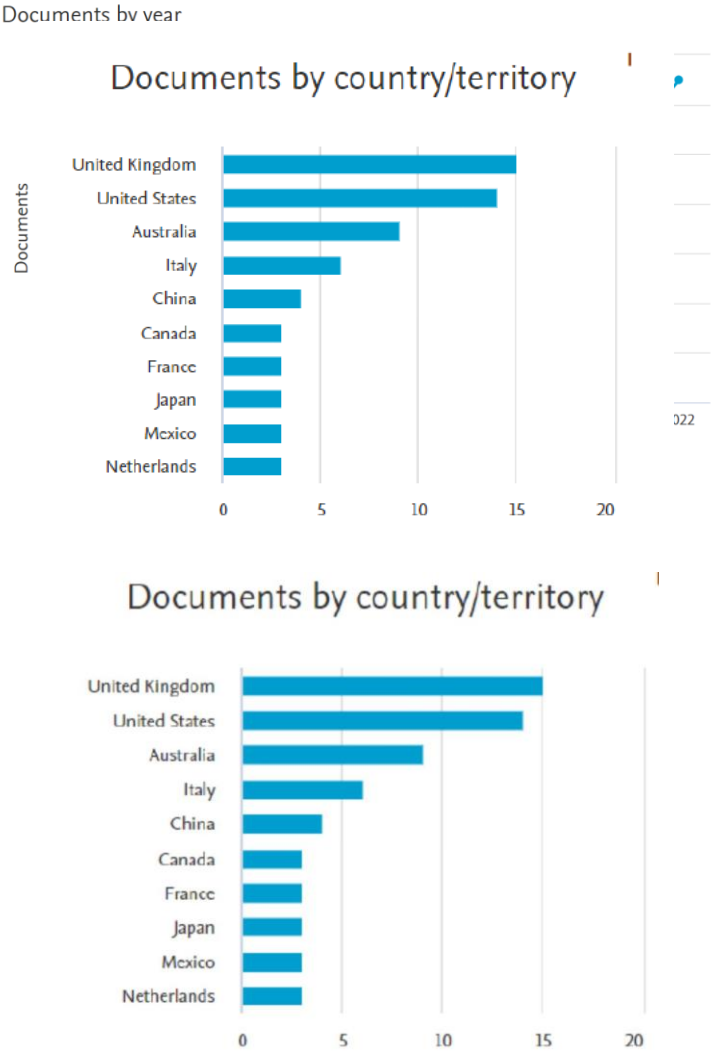

Figure 3: Top-10 countries published documents relating to road safety intervention

Dwelling into methods additional keywords added "road safety intervention" AND evaluate* OR effect* to the search, which reduce the search results to 78 documents. A further summary of the methods used to evaluate road safety intervention effectiveness is summarized below, based on the 78 documents. The increasing trends are obvious for the

topics, with an average of 7 articles per year, dominated by the Westeren countries (United Kingdom, United States, Australia, Italy, France and the Netherlands). China and Japan are the two Asia countries in the league. It is important to see the number of publications by country, as each region suffers from different road safety problems. For example, the issue with a motorcyclist is more prominent in Asia as compared to European countries. Similarly, the risk on the road varies across the region, where Africa has the highest rate of 26.6 per 100,000 populations, while South-East Asia comes second with 20.7 deaths per 100,000 population (World Health Organization 2018). The difference in risk seems to be reflected in the number of publication relating to road safety intervention.

3.1. *Methods used in intervention evaluation*

Generally, there are several statistical methods used in intervention evaluation (Li *et al.* 2021; Turner *et al.* 2019; Fredriksson & de Oliveira 2019). However, the focus of this paper is to look into the three most mentioned in the recent papers, namely difference-in-difference, segmented regression of interrupted time series (ITS), and interventional autoregressive integrated moving average (ARIMA). A systematic review that harvest almost 200 papers on interrupted time series highlighted most common statistical approach used is a regression (31%), 19% used Auto-Regressive Integrated Moving Average (ARIMA), while another 17% were undetermined. Autocorrelation was mentioned to be present by 63% of the papers reviewed, however, only 1% give an estimate for autocorrelation coefficients (Turner *et al.* 2019). In the area of road safety, the use of ARIMA and Intervention Time Series Analysis (ITSA) models to evaluate the effectiveness of road safety intervention is not new (Haque & Haque 2018; Quintero Valverde *et al.* 2023; Carnis & Blais 2013; Huitema *et al.* 2014; López-Ruiz *et al.* 2014; Martínez *et al.* 2020; Sebego *et al.* 2014). A literature search in Scopus showed there are 26 recent papers hit using the keywords of "Interrupted Time Series" AND "Road Safety", for publications published between 2013 and 2022. On average, there are about six papers published on the topic per year, and a growing interest, as 61.5% are produced in the year 2018 onwards. The search on segmented regression using the keywords of TITLE-ABS-KEY ("segmented regression" AND "road safety") returned one document written by Shanthosh *et al.* (2020) which is published in Accident Analysis and Prevention with title of "Effectiveness of child restraint legislation to reduce motor vehicle related serious injuries and fatalities: A national interrupted time series analysis".

On the other hand, a Scopus search on "Difference-in-difference" methods and "road safety" revealed 19 documents from the year 2013 onwards, with an average of two papers per year. However, there is a tendency of an increase in the number of document produced, as 15 out of 19 (78.9%) documents was from the year 2018 to 2022. Most cited article was written by Martínez-Ruíz *et al.* (2019), with 19 citations, on impact of having camera enforcement for traffic violations in Columbia. Another prominent paper is authored by Aney and Ho (2019) on traffic safety regulation and motorists' behaviour, were cited 11 times. The recent years publications, authors and the number of citations per paper are as follows:

For the third approach, the search using TITLE-ABS-KEY (intervention* AND arima AND "road safety") returned only eight documents, with an average of one publication per year per author. The low number of documents could be due to the fact that ARIMA itself is a specific detailed methods under the time series umbrella, hence there is a probability that those documents that use the methods are also fall in the interrupted time series (ITS) topic search.

Table 1: Papers utilizing Difference-in-difference approach in road safety

Authors	Title	Year	Cited by
Brands D., Klingen J., Ostermeijer F.	Hands on the wheel, eyes on the phone: The effect of smartphone usage fees on road safety	2022	
Bauernschuster S., Rekers R.	Speed limit enforcement and road safety	2022	
Alves P.J., Emanuel L., Pereira R.H.M.	highway concessions and road safety: Evidence from Brazil	2021	1
Rebollo-Sanz Y., Rodríguez-López J., Rodríguez-Planas N.	Penalty-point system, deterrence and road safety: A quasi-experimental analysis	2021	1
Dionne G., Liu Y.	Effects of Insurance Incentives on Road Safety: Evidence from a Natural Experiment in China*	2021	1
Burtch G., Greenwood B.N., McCullough J.S.	Ride-hailing services and alcohol consumption: Longitudinal analysis	2021	1
Li H., Zhang Y., Ren G.	A causal analysis of time-varying speed camera safety effects based on the propensity score method	2020	5
Nazif-Munoz J.I., Puello A., Williams A., Nandi A.	Can a new emergency response system reduce traffic fatalities? The case of the 911-emergency response system in the Dominican Republic	2020	6
Cooper B., Gehrsitz M., McIntyre S.G.	Drink, death, and driving: Do blood alcohol content limit reductions improve road safety?	2020	3
Pereira A.M., Pereira R.M., Dos Santos J.P.	For whom the bell tolls: Road safety effects of tolls ouncongested SCUT highways in Portugal	2020	1
Bonander C., Holmberg R.	Estimating the effects of a studded footwear subsidy program on pedestrian falls among older adults in Gothenburg, Sweden	2019	8
Aney M.S., Ho C.	Deadlier road accidents? Traffic safety regulations and heterogeneous motorists' behavior	2019	11
Martínez-Ruíz D.M., Fandiño-Losada A., Ponce de Leon A., Arango-Londoño D., Mateus J.C., Jaramillo-Molina C., Bonilla-Escobar F.J., Vivas H., Vanlaar W., Gutiérrez-Martínez M.I.	Impact evaluation of camera enforcement for traffic violations in Cali, Colombia, 2008–2014	2019	19
Nehiba C.	Give me 3': Do minimum distance passing laws reduce bicyclist fatalities?	2018	3
Xu Y., Sun C., Ye Z., Zhao Q.	The influence of road lighting on safety at crossings	2018	1
Bertoli P., Grembi V.	The life-saving effect of hospital proximity	2017	10
Harper S., Strumpf E.C.	Primary Enforcement of Mandatory Seat Belt Laws and Motor Vehicle Crash Deaths	2017	8
Bélanger-Gravel A., Gauvin L., Fuller D., Drouin L.	Implementing a public bicycle share program: Impact on perceptions and support for public policies for active transportation	2015	7
Bhalla K., Paichadze N., Gupta S., Kliavin V., Gritsenko E., Bishai D., Hyder A.A.	Rapid assessment of road safety policy change: Relaxation of the national speed enforcement law in Russia leads to large increases in the prevalence of speeding	2015	9

4. Discussion

Most of the papers appeared in the Scopus search on road safety intervention topics illustrates the importance of the topics, with 148 hits and the trend is increasing yearly. Most of the road safety intervention documents either summarizing a specific road safety intervention, applied to vehicles, road users, or improvement on the roads itself. These papers usually describe how intervention is planned, conducted and whether the final outcome of the intervention is met. However, not all describe the statistical analysis of intervention, on how the intervention is being evaluated.

Then, another search detailing on the intervention evaluation were conducted. Out of 78 documents found on road safety intervention evaluation, 45 documents highlight the intervention conducted with the methods. The rest of the documents were selected because the phrase "road safety intervention" is present in the abstract section. The 45 documents containing various road safety intervention were then categorized based on the methods used in evaluating the intervention. Before-after study and case control analysis is likely to be used in human behaviour related intervention, such as peer influence, road safety education, family roles in changing attitudes and speeding and drunk driving. On the other hand, time series analysis and regression is used to evaluate multi facetted national road safety intervention, or long term impact of a particular intervention or trend analysis over time.

Intervention is evaluated by the design of how it is conducted. The best approach is by using experimental design where all possible influencing factors could be counted for. However, in dealing with road safety intervention, the use of quasi-experimental is quite normal, especially when the intervention is implemented nationwide. Each of the approach has its own data requirements, assumptions, advantage and disadvantages, and should be used depending on the data collected. For example, difference-in-difference approach usually involved two groups, with two period of comparison that can be use for panel data or cross sectional data. The analysis assumes there is a parallel trend for both groups, in the absence of intervention, and no spillover effects. On the other hand, the segmented regression of the interrupted time series usually applied to one group with two periods, before intervention is implemented and after. It assumes no systematic change in the characteristics of the cohort over time, and requires the stationarity assumption. These small pros and cons of each approach makes every approach is unique and good understanding is needed before one is able to use them properly, Hence, it is highly recommended that this study is extended to provide an in-depth analysis of each statistical approach used in intervention evaluation, especially in road safety, where intervention varies.

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