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A Systematic Literature Review of Motorist-Pedestrian-City Planner Interactions: Towards the Creation of a Framework for Future Research

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A Systematic Literature Review of Motorist-Pedestrian-City Planner Interactions: Towards the Creation of a Framework for Future Research

by

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Abstract

Motorist-pedestrian accidents are the product of human behavioural interactions. These behavioural interactions are studied by many different fields to intervene to prevent such an accident. A systematic literature review was conducted to retain articles that targeted motorist-pedestrian-city planner interactions at crosswalks. A Google Scholar search with keywords yielded 973 articles related to pedestrians, motorists, and crosswalks. Following a rigorous search criteria, 60 articles were retained. Those 60 articles were then codified using a classification system. Articles were classified based on their: a) year of publication, b) intervention components, c) crosswalk type, d) location of the observation sites, and e) journal type. The classification system resulted in the creation of a framework that can be used by future researchers to analyze trends across a given period. Results of the study found that of the 60 articles retained from 1977-2020, 43 were from civil engineering journals (71.67%), 11 were from safety journals (18.33%), and 6 were from applied behaviour analysis journals (10.00%). The most common intervention components were the use of antecedent interventions (e.g., adding environmental stimuli to the crosswalk to prompt behaviour) and cross-contextual factors (i.e., the authors evaluated pedestrian and motorist behaviours under more than one treatment, condition, or time of day). Discussion points are generated for the possibilities of this framework based on the present study's results and shortcomings.

Keywords: Systematic literature review, framework, behavioural interactions, motorist, pedestrian, city planner

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To my wife, Emma. I could not have completed this degree without your unwavering love and encouragement. I will spend a lifetime attempting to parallel that same devotion.

"As our circle of knowledge expands, so does the circumference of darkness surrounding it."
— Albert Einstein

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Chapter 1: Behavioural Interactions, the Five-Term Contingency, and Interventions

Pedestrian-motorist accidents are the product of human behaviour. There is a strong positive correlation between motorist density, pedestrian density, city planning efforts (e.g., intersection complexity, lanes in the road [see Zhang et al., 2019], and injury and fatalities (Dai et al., 2010; Dumbaugh et al., 2011; Dumbaugh et al., 2009; Quistberg et al., 2015; Yu, 2015). The World Health Organization estimates that pedestrians and cyclists might be involved in 26% of all the 1.35 million traffic fatalities in 2018, and Transport Canada's National Collision Database (NCDB, 2017) suggests pedestrians account for 16.3% of all traffic related deaths in 2017.

Because accidents are in some way the result of human behaviour, studying and intervening on accident-related behaviours are prime territory for behaviour analysts, in which a focus on antecedents, consequences, motivating operations (MOs), and contextual factors is key. For example, in studying pedestrian injury and fatalities at roundabouts, one must consider the motorist's behaviour when entering the roundabout, pedestrian's behavior before and while in the roundabout, city planner behaviour in the design of the roundabout, and how each of these interact with each one another and also with contextual factors like time of day (e.g., lunch hour when foot traffic is high versus early morning hours when foot traffic might be lighter) to create a pedestrian-motorist conflict.

However, behaviour analysts are not the only profession who can make meaningful contributions to the study and treatment of pedestrian safety. Other fields, such as transportation safety or civil engineering have undertaken efforts to keep pedestrians safe, such as with the introduction of speed humps in reducing pedestrian injuries (Tester et al., 2011), having law

enforcement provide motorists citations for crosswalk violations (Britt et al., 1995), and introducing in-pavement flashing lights to alert both pedestrians and motorists of possible conflicts (Karkee et al., 2010).

Given that there are multiple fields interested in pedestrian safety, it might be good for behaviour analysts to first consider a framework. Through creating a framework, one will be able to depict what research has been completed, the components of those articles, the trends across those articles, and what areas of study still need to be addressed. A proposed framework is the focus of this investigation, but before we can consider how to use it, we must first create it. Basing the framework on the five-term contingency will give us a place from which we can begin to translate these other works.

Sources of Influence

Antecedent Interventions. An antecedent intervention is one in which the environment is altered to prompt particular behaviour. For example, signage as an intervention has been shown to be effective in prompting pedestrians to look both ways before crossing the road, which replaces unsafe behaviour such as walking through the road without first assessing it for danger (Van Houten et al., 1999). Choice-making opportunities also serve as an antecedent strategy. For example, the city of Winnipeg, Canada introduced skywalks and underground walkways so that pedestrians have the option to avoid using road-level crosswalks.

Consequence Interventions. Consequence-based interventions consist of reinforcement and punishment procedures[1] being implemented after behaviour has occurred. Van Houten et al., (1985) demonstrated that providing motorists with a reward package for successfully yielding to pedestrians led to increases in motorists yielding at intervention spots. Over time, the results generalized to crosswalks where no intervention occurred.

Punishment procedures include law enforcement pulling over motorists for failing to yield, going through stop signs, or speeding, for example. Skinner (1953) noted that by punishing a behaviour, that behaviour is less likely to be produced on a future similar occasion. However, Skinner further explained that punished behaviour can lead to negatively reinforced behaviour by teaching people to learn how to avoid contacting punishers; for example, by purchasing a device that detects when law enforcement is near so they can discriminate when to speed while driving. Furthermore, the overall punishing effect depends on how aversive the reprimand, fine, and social exclusion is for being labelled as a "speeder". Finland has attempted to standardize the fines across individuals; for example, McKenna (2018) noted that an income-based fine of $103,660 was distributed to a Nokia director for driving 25km/h over the speed limit. Based on this intervention, an individual living paycheck-to-paycheck would receive a lesser fine for the same crime, but the overall punishing factor would be relatively standard.

Motivating Operations. Motivating operations alter the value of some consequence, making reinforcers more or less reinforcing and punishers more or less punishing (Michael,

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[1] Here I distinguish between procedures and processes; as a procedure, the "reinforcement" or "punishment" might not change behaviour in the anticipated manner. The idea, however, is that generally the procedure should match the processes at least some of the time.

1982). Consider, for example, a pedestrian who needs to cross a busy intersection and is running late for work. The value of crossing the street increases under this condition, and they might then cross despite a “Don’t Walk” sign present. Interventions aimed at motivating operations might take the form of advertising campaigns, such as with campaigns that highlight the last text sent from a distracted driver before they died in an accident in an effort to devalue texting while driving (i.e., unimportant texts were written and were involved in the motorist accident).

Context. Behaviour analysts analyze behaviour under the influence of certain contextual factors. Cinnamon et al., (2011) noted that high-incident intersections were likely to vary with respect to their etiology or cause. Articles may evaluate behaviour under the influence of factors such as time of day, temperature, or the presence of stimuli. Time of day can influence pedestrian and motorist behaviour because of the contextual factors that are present. During morning rush hour on a weekday, there are more cars on the road so a pedestrian may be observing more stimuli which can contribute to their safety. On the other hand, during the night, there are typically fewer cars on the road, but visibility is worse. The context is important because it is the environment that plays an important role in how a person behaves.

Article Characteristics

Additional article characteristics were tracked with the aim of assisting practitioners and researchers navigate this literature. These characteristics included the year of publication, the type of intervention used, the location(s) the study took place, the types of crosswalks (i.e., marked or unmarked) at the intervention site, and the journal type. The year of publication is important for future researchers to consider because traffic laws are constantly changing. This does not mean that an article becomes more irrelevant the older it becomes; it just means that

future researchers should be mindful of the culture and laws of those times. For example, combined, smartphones and other mobile cellular devices are owned by 96% of people in advanced economies and 78% in emerging economies (Global Attitudes Survey, 2018). Due to a recent increase in accessible technology in the 21st century, more interventions are conducted targeting distracted motorists (e.g., motor insurance campaigns, signage prompting motorists to refrain from using their mobile device while driving) and targeting distracted pedestrians (e.g., markings on the ground reading "LOOK UP").

Location is an important article characteristic as different cities will have different cultures, laws, populations, and budgets for infrastructure. Even an article with the most detailed methods section would likely differ in results when conducted on the busiest crosswalk in downtown Tokyo, Japan versus when conducted in on a quiet neighbourhood crosswalk in Winnipeg, Canada. Citizens of a city have their own previous history of pedestrian and motorist interactions—which will vary across cities and countries. The laws might vary across cities as each city will have its own history of pedestrian or motorist injury. Each city will have their own infrastructure budget which fluctuates based on necessity for change to influence citizens to engage in safe behaviour.

The type of crosswalk that the article uses as an intervention site plays an important role not only in the article but for future researchers as well. Looking back at contextual factors, we know that the context—the environment and antecedent conditions under which behaviour occurs—plays an important role in inducing, altering, or preventing behaviour from occurring. The two types of crosswalks that are used by city planners are marked and unmarked. According to Manitoba Public Insurance (Manitoba Driver's Handbook - Sharing the Road, 2019),

unmarked crosswalks are extensions of sidewalks across a road at an intersection—no markings or signs are required. Marked crosswalks include crosswalks at intersection controlled by traffic lights, school crosswalks and pedestrian crosswalks.

Crosswalk types are contextual factors that could play an important role in observing differential levels of behaviour under the influence of the same intervention. For example, motorists may be more likely to engage in observing behaviour (e.g., looking, searching) for pedestrians while approaching marked crosswalks as opposed to unmarked crosswalks. Environmental stimuli arranged by the city planner creates a specific context that is designed to prompt this observing behaviour in motorists.

Classifying the journal in which the article was published serves to quantify each field's yearly articles about motorist-pedestrian-city planner interactions. Since individual journals publish articles within a particular field of study, the content of each article is then viewed under that field's "lens". Furthermore, classifying articles by their journal is valuable as general trends can be analyzed across decades of research. Future researchers can then observe the number of studies in a given year. If a specific culture shift begins (e.g., the mass usage of cellphones by drivers), researchers can then observe if more studies were conducted during this time.

Types of Behavioural Interactions

As pedestrian-motorist conflicts are a product of behavioural interactions within the context of the roadway, we must understand the behaviour of the motorist, the pedestrian, the city planner, and the interactions between them all (see Figure C1 for a representation of the overlap between these three factors). Four interactions emerge between 1) the motorist and the pedestrian, 2) the motorist and the city planner, 3) the pedestrian and the city planner, and 4) the

motorist, pedestrian, and the city planners. While individual behaviour can be of interest, this investigation is concerned only with the motorist-pedestrian-city planner interactions as these are the most complex level of interconnected behavioural interactions between the three parties.

However, as has been stated previously, the behaviour-analytic literature is not the only literature that has addressed issues of pedestrian safety. Thus, the purpose of this paper is to create a framework by which behaviour analysts and professionals from other fields can read and integrate literature into their understanding of motorist-pedestrian-city planner behavioural interactions. Secondly, this paper is focused on addressing the trends over time across different types of fields (i.e., civil engineering, safety, and applied behaviour analysis).

Chapter 2: Method

Phase 1: Literature Review

Google Scholar was used to find sources related to pedestrian safety by using the Boolean operator AND with the following search criteria: “pedestrian” AND “crosswalk” AND “motorist” experimental. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, all research articles were evaluated for participants, intervention, comparisons, outcomes, and experimental design. If the reviewer was unsure if the source is relevant, the source was retained for later review. Experimental articles written in English that targeted both pedestrian and motorist behaviour (separately or a direct conflict) at a crosswalk or intersection were retained. Articles must have included at least one baseline and treatment. In lieu of a baseline phase, articles that compared dependent measure(s) across treatment conditions were retained. Research articles needed to be conducted in-vivo—simulation articles were not retained. If inclusion criteria were met, abstracts were reviewed. If conditions were still met following an abstract review, the research article was retained. If at least 50 articles were not retained after all exclusion criteria had been applied, forward citations of previously retained sources would be conducted until 50 articles had been retained. Following the use of the search terms, Google Scholar produced approximately 970 results. Following the first round of the literature review, 167 articles were retained. Articles were then downloaded directly from Google Scholar, interlibrary loan, or from contact with the article’s authors. Methods, measures, and general procedures of all 167 articles were then read to determine if the article met the inclusion criteria. Following an in-depth review, 57 articles were retained. Article titles were not retained if they could not be located by the first author through Google Scholar,

interlibrary loan, or through contact of the article's authors. Sixty articles met the inclusion criteria.

Phase 2: Classification System

Once a list of relevant sources was obtained, articles were codified based on year, intervention components, crosswalk type, location, and journal type. Following codifications, articles were then placed into the table "*Article Characteristics"* (see Table B1).

Intervention Components. An article's procedure was classified as an antecedent intervention and codified as "*A"* if the procedure introduced environmental alterations to prompt a target behaviour (e.g., introducing signage, pavement markings). An article's procedure was classified as a consequence intervention and codified as "*C"* if the article introduced a consequence for observed behaviour (i.e., reinforces procedure or punishment procedure). An article's procedure was codified as "*MO"* if the procedures introduced an environmental change which establishes a motivation to access a reinforcer or makes an aversive consequence more aversive. An article was codified as "*CO"* if the procedures evaluated behaviour across contexts (e.g., if behaviour was measured at 4:00pm versus 4:00am), across stimuli (e.g., behaviour was measured under the conditions of two different types of traffic signs), or environment (e.g., area of a city, state/province).

Publication Year. Articles were classified based on the year they were published. Non-examples of a publication year were: the years the article was submitted for publication, the year the article was received, accepted, or finally accepted by a journal.

Crosswalk Type. Articles were classified based on the type of crosswalk that was used in the article. The crosswalk's state prior to the intervention is what the classification was based

on. An article was classified as taking place at an *unmarked crosswalk* if an intervention site took place at an extension of a sidewalk across a road at an intersection without markings or signage. An article was classified as taking place at a *marked crosswalk* if an intervention site took place at a crosswalk controlled by traffic lights, school crosswalk, or pedestrian crosswalk.

Location. Articles were classified based on the site(s) that the intervention took place. The amount of sites per city were written in parentheses, followed by the name of the city, and finally the province or state abbreviation. Articles retained outside of North America used the country's name instead of a province or state.

Journal Type. Articles were classified based on the type of journal in which they were published. The first author located a journal's website, online copy, or physical copy of a journal so that a mission statement could be read. If a journal indicated that it published articles with a main emphasis on an application of the experimental analysis of behaviour, it was classified as an "*Applied Behaviour Analysis"* journal. If a journal indicated that it published articles with a main emphasis on urban planning, urban development, or transportation engineering, it was classified as a "*Civil Engineering"* journal. If a journal indicated that it published articles with a main emphasis on accidents, injuries, or health, it was classified as a "*Safety*" journal.

Inter-rater reliability (IRR) procedure

A second rater was trained to codify articles for the purposes of evaluating IRR. To participate as a second rater, the person needed to either be a graduate student in an applied behavior analysis program or hold a BCBA or BCBA-D certification.

Appendix E contained the materials used to train the second rater. These materials included written instructions on how to correctly codify articles based on year, intervention components, crosswalk type, the observation sites used in the intervention, and the journal type.

Training the second rater. Training of the second rater was done by using behavioral skills training (similar to Lang, 2016). First, the second rater was given the written instructions for codifying articles and table placement for interaction type. Each component of the instructions was reviewed vocally with the second rater. Articles used for training were not eligible for later IRR sessions as the second rater would have prior practice with them. The last phase of training consisted of testing and feedback.

During training, the second rater was presented with two randomly selected articles on pedestrian safety that met the inclusion criteria and was allowed time to codify the article in terms of intervention and place the article's various codifications into a practice table named, "*Article Characteristics: Training*". Feedback followed each written response. Correct responses were defined as producing a correct year of publication, the correct intervention component(s), the correct crosswalk type(s), the correct number of observation sites and the city/area in which those observations took place, and the correct journal type. Incorrect responses were defined as producing an incorrect year of publication, an incorrect intervention component(s), an incorrect crosswalk type(s), an incorrect number of observation sites and/or the city/area in which those observations took place, and/or an incorrect journal type. Vocal praise followed correct responses, and corrective feedback followed incorrect responses. Corrective feedback consisted of (i) brief explanations with reference to the written instructions and (ii) the second rater erasing and rewriting their codification and placement. If the second rater produced an incorrect response

following corrective feedback, the corrective feedback procedure was represented until the second rater produced a correct response.

If both raters did not agree on both articles, the mastery criterion for testing was defined as 100% correct responses across three consecutively presented articles.

IRR procedure. Following the mastery of the training component, the second rater was presented with a random sample of articles that represented 15% of all articles retained for codification. If the first author and the second rater agreed on all the first five articles, then the IRR portion was complete. If the first author and the second rater did not agree on all the first five articles, retraining occurred containing the same training procedures above. Immediately following retraining, the second rater was presented with five new articles retained for codification. After retraining, if the first author and the second rater did not agree on all five articles, the second rater was dismissed from the study and a new second rater was recruited for training.

IRR was calculated using the Cohen's Kappa calculation. An IRR score of less than 0.40 is poor reliability, 0.40-0.59 is fair reliability, 0.60-0.74 is good reliability, and above 0.75 is excellent reliability (Watkins & Pacheco, 2000). IRR was conducted with 15% of all retained studies. The reliability between the first author and the second rater was 100% for the two training articles and 100% for the first five articles, demonstrating excellent reliability.

Chapter 3: Pilot Investigation

A pilot investigation was conducted ensure the method section produced meaningful classifications of the retained articles. In an article from Boyce et al. (2000), the researchers evaluated a commitment and incentive program for an entire community. Members of a college community signed promise cards to use a crosswalk when they were pedestrians and to yield to pedestrians when they were motorists. Participants were given a prize coupon for promoting pedestrian safety. Overall, the article's intervention used a combination of antecedent, consequence, and a manipulation of motivating operations. The article also evaluated the changes in behaviour at different crosswalks. Therefore, the article's intervention components were classified as "*A, C, MO, CO".* Since the article observed behaviour changes at sites that included some sort of marking, signage, or signaling, the article's crosswalk type was classified as "*Marked".* Boyce et al. (2000) was published in *Environment and Behavior (EAB),* a journal that "examines relationships between human behavior and the natural and built environment" (SAGE Journals, 2020). Since the journal's main emphasis on an experimental analysis of behaviour, the article was classified as "*Applied Behaviour Analysis*".

Chapter 4: Results and Discussion

Over the course of 1977 to 2020, three main fields published articles in which different interventions, observations sites, and characteristics of observations sites were used to measure motorist and pedestrian behaviour. The results of the classification system are presented in Table B1. Of the 60 articles, 59 evaluated behaviour across contexts (98.33%), 56 included antecedent interventions (96.67%), 5 included consequence interventions (8.33%), and 2 included the manipulation of motivating operations (3.33%). A comparison of intervention components used in the articles are depicted in Figure D5.

Most commonly, antecedent and/or cross-context components were used in the article. As an example, Van Houten, Malenfant, & McCusker (2001) introduced advanced yield markings at three separate locations. Using a multiple baseline design, the authors evaluated behaviour across three different contexts using the same intervention. Additionally, Pulugurtha et al. (2015) introduced pedestrian hybrid beacons (PHBs) at three different locations. To supplement the analysis, the authors evaluated motorist and pedestrian behaviour at morning and evening peak hours.

Consequence interventions were the second-to-least represented in the literature review. Studies that included motivating operation manipulations were the least represented in the literature review. Boyce et al. (2000) used a reward system for pedestrians and motorists who engaged in safe behaviour. Participants observed to engage in this safe behaviour were provided with ballots that could be exchanged for possible larger rewards. The reason that this increased motivation to engage in behaviour was because of the promise of a reward. Oppositely, Van Houten et al., (2013) promised impending enforcement for motorists who failed to yield in the

approaching crosswalks. Both studies achieved significant results in prompting pedestrians or motorists to engage in safe behaviour, but the question remains why these interventions are not more widely conducted. Van Houten et al., (1985) offer a possible explanation as to why a reward condition may fail to increase safe behaviour. They note that the reward condition may not have been effective because "the drivers who were stopped for yielding may have usually engaged in this behavior anyway. In other studies, successful applications of incentives to increase seat belt use involved advertising the intervention in advance" (p. 109).

Civil engineering articles observed behaviour at 4,853 sites (95.29%) (see Figure D1); safety articles observed behaviour at 216 sites (4.24%) (see Figure D2); and applied behaviour analysis articles observed behaviour at 24 sites (0.47%) (see Figure D3).

The comparison of journal publications for motorist-pedestrian-city planner interaction articles are depicted in Figure D4. Of the 60 articles retained, 44 were from civil engineering journals (71.67%), 10 were from safety journals (18.33%), and 6 were from applied behaviour analysis journals (10.00%). The comparison of crosswalk types used in the articles are depicted in Figure D6. Of the 60 articles, 58 evaluated interventions at marked crosswalks (96.67%), 11 evaluated interventions at unmarked crosswalks (18.33%), and 9 evaluated interventions at both marked and unmarked crosswalks (15.00%).

The purpose of this paper was to create a framework by which behaviour analysts and professionals from other fields could read and integrate literature into their understanding of motorist-pedestrian-city planner behavioural interactions. The point of this framework was to view non-ABA work in the lens of the five-term contingency. Each major field of study has much to offer in analyzing and treating solvable problems of everyday life. This framework

becomes an optional, potential benefit for future research for any field studying motorist, pedestrian, and city planner behaviour.

With 44 of articles, the civil engineering field represented the majority of the retained articles in this study. Antecedent interventions within these articles included: pedestrian hybrid beacons, rectangular rapid flashing beacons, countdown signals, advanced yield markings on the pavement, and others to prompt a specific behaviour to occur. Civil engineering articles also conducted observations at the most crosswalks when compared to safety and applied behaviour analysis articles. Even without the study by Chen et al. (2012), which included an outlier of 4,462 observation sites, civil engineering articles would still make up a large majority of crosswalk used to observe motorist and pedestrian behaviour.

There is no major discernable difference between the codifications of articles from the three journal types. All three types of journals used antecedent and consequence interventions. All three journal types evaluated behaviour across various contexts. The most common pairing in an article's procedure was that of an antecedent intervention and the use of cross-contextual factors to observe a change in behaviour. Regardless of field, articles consistently used this pairing from 1977-2020. Basic experimental research designs implore that all researchers conduct some sort of baseline, introduce an independent variable, and measure that independent variable's effect(s) on a given dependent variable.

Only two articles included the manipulation of motivating operations to observe a change in behaviour. An explanation for a lack of research in this area could be that having a person at a crosswalk to reward behaviour or having police officers at a crosswalk to punish illegal behaviour is time-consuming and costly in real-world setting. Whereas antecedent interventions

are implemented and do not require any sort of plan to have pedestrians or motorists contact contingencies.

Articles codified in the table *"Article Characteristics"* were listed in descending order based on the year they were published. With a major technology change over the last few decades, future researchers can used this framework to see if there has been increase in articles published to address distracted driving or distracted walking. Technological advances may have contributed to an increase in distractions for motorists as well as pedestrians. With these distractions, pedestrian and motorist interactions have had a variable change and this framework could identify if published literature has adapted to ever-changing environmental conditions.

Some limitations were present in this study. First, to keep focused on a singular topic, classifying combinative interventions was not addressed. Combinative interventions are interventions that intentionally use multiple components to observe a larger effect on behaviour. For example, motivating operations can be combined with punishment procedures to make that punishment even more severe. A single component intervention may just use antecedent manipulations (*"A"),* whereas a combinative interventions that use antecedent and consequence interventions would then be classified as "*A+C".* The present study only classified intervention components separately to let future researchers know that those components existed within that study. Future research could investigate the trends of combinative interventions as well as compare combinative interventions (e.g., "*A+C+MO*) to single component interventions (e.g., "*C"*).

Second, as the scope of the study focuses on motorist-pedestrian-city planner interactions, a limitation is that it is not clear whether the results represent the actual trends of the

civil engineering, safety, or applied behaviour analysis fields. From the original 167 articles, many articles were not retained as they primarily focused on motorist-city planner interactions. With the remaining retained articles from the literature review that focused on motorist-pedestrian-city planner interactions, (N = 60), it is possible that a small population of articles contributed to a lack of representation.

Third, further analyses of the other possible behavioural interactions were not conducted. The individual components of motorist-pedestrian conflicts (see Figure C1) may need further investigation. Future research could analyze the trends of motorist-pedestrian interactions (e.g., gestures or visibility), motorist-city planner interactions (e.g., signage, advance yield markings, or traffic infrastructure), and pedestrian-city planner interactions (e.g., pedestrian pavement markings, activating push-buttons, jaywalking).

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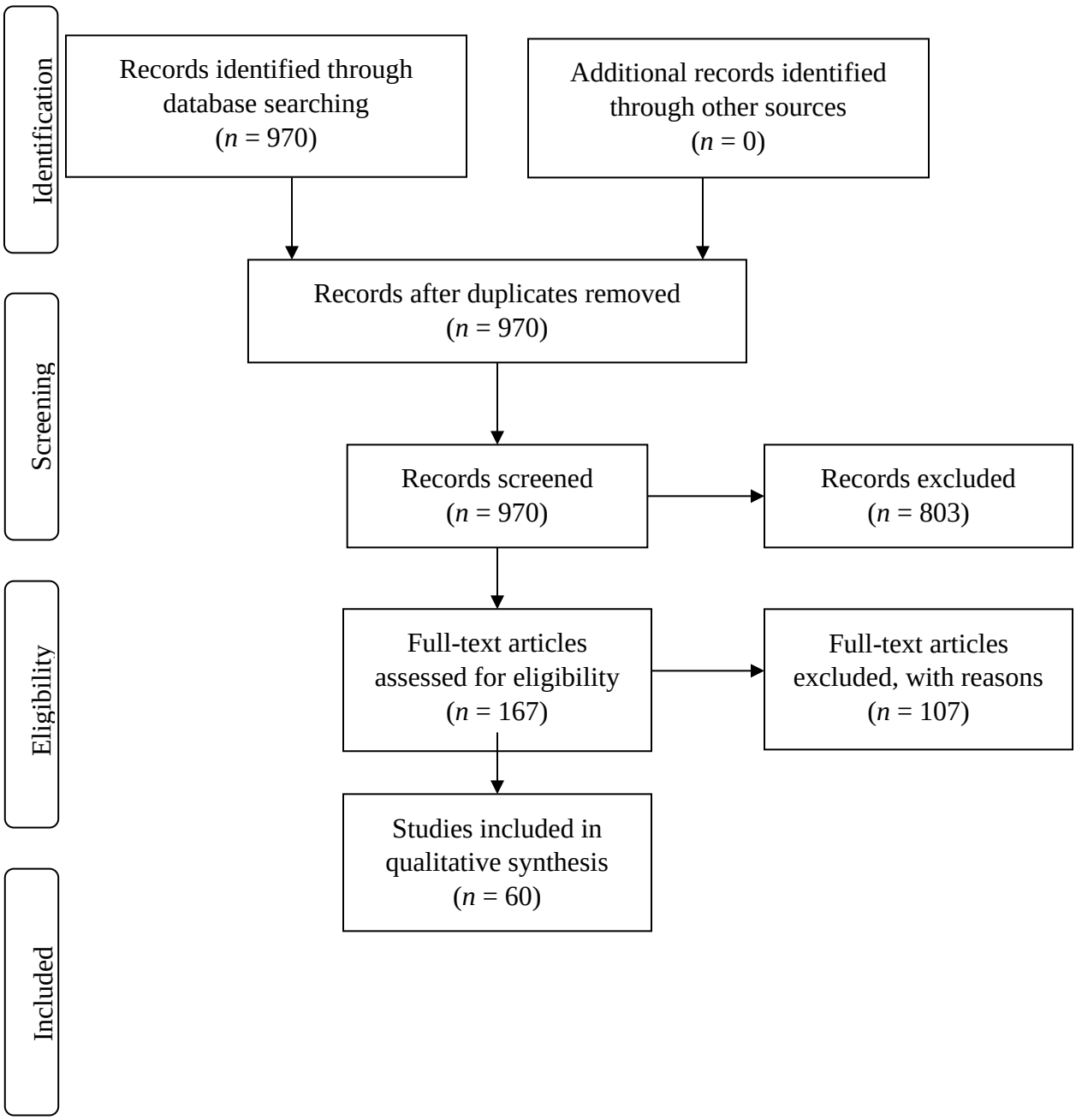
Appendix A

Table A1

PRISMA Flow Diagram



Appendix B

Table B1

Article Characteristics

Author(s)	Year of Publication	Article Type	Crosswalk Type	Location	Journal Type
Jalayer, Patel, Szary, & Hamas	2020	A, CO	Marked	(1) Teaneck, NJ (1) Asbury Park, NJ (1) Garfield, NJ (1) Morris Plains, NJ (1) Newark, NJ (1) Princeton, NJ (1) Rutherford, NJ (1) Woodbridge, NJ	Civil Engineering
Zhang, Qiao, & Fricker	2020	CO	Marked	(2) Lawrence, KS	Civil Engineering
Høye & Laureshyn	2019	A, CO	Marked	(4) Trondheim, Norway	Civil Engineering
Hamood & Gupta	2018	A, CO	Marked	(6) Delta, BC (3) Surrey, BC	Civil Engineering
Dougald	2016	A, CO	Marked	(1) Ashburn, VA	Civil Engineering
Iasmin, Kojima, & Kubota	2016	CO	Marked	(3) Kawaguchi, Japan	Civil Engineering
Iasmin, Kojima, & Kubota	2016	CO	Marked	(3) Kawaguchi, Japan	Civil Engineering

Table B1 Continued

Author(s)	Year of Publication	Article Type	Crosswalk Type	Location	Journal Type
Porter, Neto, Balk, & Jenkins	2016	A, CO	Marked	(5) University Campus in Virginia, USA	Civil Engineering
Godavarthy & Russell	2016	A, CO	Marked	(2) Lawrence, KS	Civil Engineering
Gitelman, Carmel, Pesahov, & Chen	2016	A, CO	Marked	(4) Netanya, Israel (4) Hod Hasharon, Israel (4) Herzlia, Israel (4) Karmiel, Israel	Civil Engineering
Pulugurtha & Self	2015	A, CO	Marked	(3) Charlotte, NC	Safety
Dougald	2015	A, CO	Marked	(1) Loudoun County, VA	Civil Engineering
Foster, Monsere, & Carlos	2014	A	Marked	(2) Portland, OR	Civil Engineering
Gedafa et al.	2014	A, CO	Marked	(5) University of North Dakota Campus, Grand Forks, ND (3) Grand Forks, ND	Civil Engineering
Eapen	2014	A, CO	Marked	(1) Las Vegas, NV	Civil Engineering

Table B1 Continued

Author(s)	Year of Publication	Article Type	Crosswalk Type	Location	Journal Type
Van Houten, Malenfant, Blomberg, Huitema, & Casella	2013	A, C, MO, CO	Marked	(12) Gainsville, FL	Civil Engineering
Pulugurtha, Vasudevan, Nambisan, & Dangeti	2012	A, CO	Marked	(8) Las Vegas, NV	Civil Engineering
Chen, Chen, & Ewing	2012	A, CO	Marked & Unmarked	(4,462) New York City, NY	Civil Engineering
Vasudevan, Pulugurtha, Nambisan, & Dangeti	2011	A, CO	Marked	(3) Las Vegas, NV	Civil Engineering
Strong & Ye	2010	A, CO	Marked & Unmarked	(21) Pennsylvania, USA	Safety
Pulugurtha, Nambisan, Dangeti, & Vasudevan	2010	A, CO	Marked	(6) Las Vegas, NV	Civil Engineering
Branyan	2010	A, CO	Marked	(2) Washington, DC	Civil Engineering
Godavarthy	2010	A, CO	Marked	(4) Manhattan, KS (3) Lawrence, KS	Civil Engineering

Table B1 Continued

Author(s)	Year of Publication	Article Type	Crosswalk Type	Location	Journal Type
Pulugurtha, Desai, & Pulugurtha	2010	A, CO	Marked	(106) Charlotte, NC	Safety
Dangeti, Pulugurtha, Vasudevan, Nambisan, & White	2010	A, CO	Marked	(4) Las Vegas, NV	Civil Engineering
Hunter, Srinivasan, & Martell	2009	A, CO	Marked	(1) St. Petersburg, FL	Safety
Ellis & Van Houten	2009	A, CO	Marked & Unmarked	(8) Miami-Dade County, FL	Civil Engineering
Nambisan, Pulugurtha, Vasudevan, Dangeti, & Virupaksha	2009	A, CO	Marked	(1) Las Vegas, NV	Civil Engineering
Davis & Hallenbeck	2008	A, CO	Marked & Unmarked	(1) Spanaway, WA (1) Shoreline, WA (1) Kent, WA (1) Airway Heights, WA (3) Spokane, WA	Civil Engineering

Table B1 Continued

Author(s)	Year of Publication	Article Type	Crosswalk Type	Location	Journal Type
Van Houten, Ellis, & Marmolejo	2008	A, CO	Marked	(1) Miami Lakes, FL (2) Coconut Grove, FL	Civil Engineering
Benekohal, Medina, & Wang	2007	A, CO	Marked & Unmarked	(24) Champaign, IL	Civil Engineering
Schattler, Wakim, Datta, & McAvoy	2007	A, CO	Marked	(13) Peoria, IL	Civil Engineering
Markowitz, Sciortino, Fleck, & Yee	2006	A, CO	Marked	(9) San Francisco, CA	Civil Engineering
Eccles, Tao, & Mangum	2004	A, CO	Marked	(5) Montgomery County, MD	Civil Engineering
Huybers, Van Houten, & Malenfant	2004	A, CO	Marked	(6) Halifax, NS	Applied Behaviour Analysis
Van Houten & Malenfant	2004	C, CO	Marked & Unmarked	(4) Miami Beach, FL	Applied Behaviour Analysis
Harrell, David-Evans, & Gartrell	2004	A, CO	Marked	(2) Edmonton, AB	Applied Behaviour Analysis
Nee & Hallenbeck	2003	A, C, CO	Unmarked	(2) Shoreline, WA	Civil Engineering

Table B1 Continued

Author(s)	Year of Publication	Article Type	Crosswalk Type	Location	Journal Type
Bechtel, MacLeod, & Ragland	2003	A, CO	Marked	(1) Oakland, CA	Safety
Van Houten, McCusker, Huybers, Malenfant, & Rice-Smith	2002	A, CO	Unmarked	(12) Halifax Regional Municipality, NS (2) Truro, NS (4) Wolfville, NS (6) Kentville, NS	Civil Engineering
Van Houten, Malenfant, & McCusker	2001	A, CO	Marked	(3) Halifax Regional Municipality, NS	Civil Engineering
Huang & Cynecki	2001	A, CO	Marked	(3) Cambridge, MA (1) Corvallis, OR (2) Seattle, WA (2) Durham, NC (2) Greensboro, NC (1) Montgomery County, MD (2) Richmond, VA (4) Sacramento, CA	Safety
Van Houten & Malenfant	2001	A, CO	Marked & Unmarked	(2) St. Petersburg, FL	Civil Engineering

Table B1 Continued

Author(s)	Year of Publication	Article Type	Crosswalk Type	Location	Journal Type
Van Houten& Malenfant	2001	A, CO	Marked	(8) St. Petersburg, FL (2) Clearwater, FL (1) Halifax, NS	Safety
Prevedouros	2001	A, CO	Marked	(1) Honolulu, HI	Civil Engineering
Van Houten, Malenfant, & Steiner	2001	A, CO	Marked	(8) St. Petersburg, FL (2) Clearwater, FL (1) Halifax, NS	Civil Engineering
Huang, Zegeer, Nassi, & Fairfax	2000	A, CO	Marked	(1) Seattle, WA (7) New York State (2) Tuscon, AZ (1) Portland, OR	Civil Engineering
Huang, & Cynecki	2000	A, CO	Marked	(3) Cambridge, MA (1) Corvallis, OR (2) Seattle, WA (2) Durham, NC (2) Greensboro, NC (1) Montgomery County, MD (2) Richmond, VA (4) Sacramento, CA	Safety

Table B1 Continued

Author(s)	Year of Publication	Article Type	Crosswalk Type	Location	Journal Type
Jones & Tomcheck	2000	A, CO	Marked & Unmarked	(104) Los Angeles, CA	Civil Engineering
Boyce & Geller	2000	A, C, MO, CO	Marked	(5) Blacksburg, VA	Applied Behaviour Analysis
Huang	2000	A, CO	Marked	(1) Gainsville, FL (1) Lakeland, FL	Civil Engineering
Hughes, Huang, Zegeer, & Cynecki	2000	A, CO	Marked	(1) Los Angeles, CA (2) Rochester, NY (1) Phoenix, AZ	Civil Engineering
Van Houten, Healey, Malenfant, & Retting	1998	A, CO	Marked	(2) Dartmouth, NS	Civil Engineering
Van Houten & Malenfant	1992	A, CO	Marked	(2) Dartmouth, NS	Safety
Malenfant & Van Houten	1990	A, C, CO	Marked	(13) St. John's, NL (14) Moncton-Dieppe, NB (7) Fredericton, NB	Safety
Van Houten	1988	A, CO	Marked	(2) Dartmouth, NS	Applied Behaviour Analysis

Table B1 Continued

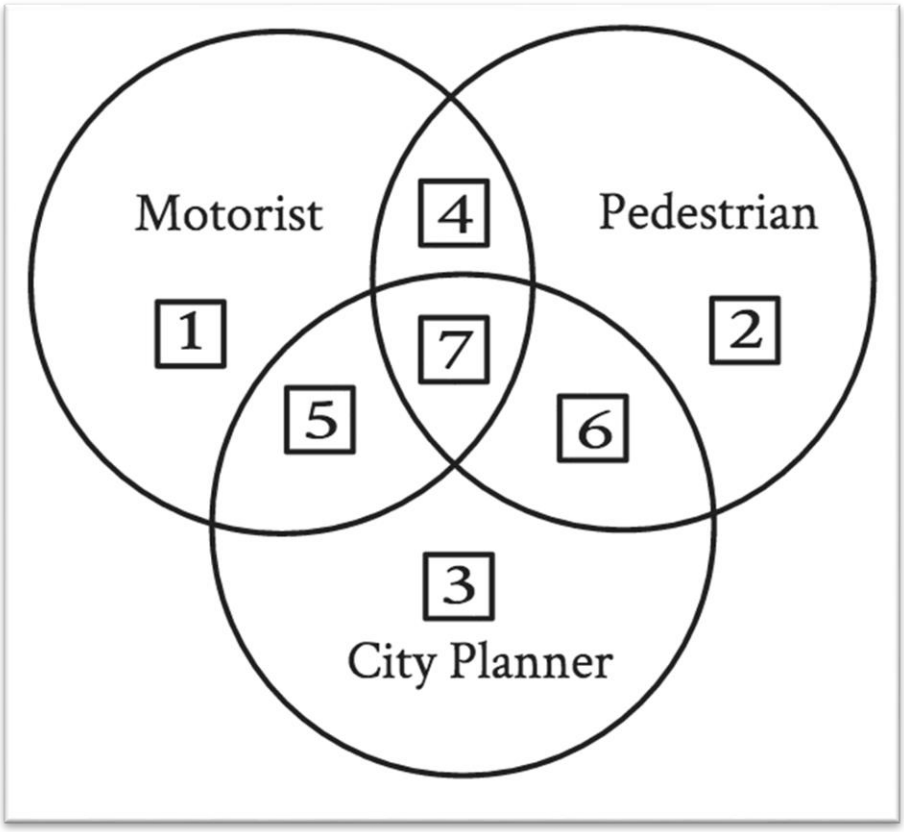
Author(s)	Year of Publication	Article Type	Crosswalk Type	Location	Journal Type
Van Houten, Malenfant, & Rolider	1985	A, C, CO	Marked	(5) Dartmouth, NS	Applied Behaviour Analysis
Zegeer, Cynecki, & Opiela	1984	A, CO	Marked	(4) Detroit, MI (2) Ann Arbor, MI (4) Saginaw, MI, (9) Washington, DC (8) Milwaukee, WI	Civil Engineering
Hauck	1979	A, CO	Marked & Unmarked	(17) Peoria, IL	Civil Engineering
Janoff, Freedman, & Koth	1977	A, CO	Marked	(7) Philadelphia, PA	Civil Engineering

Note. Characteristics of articles used in the systematic literature review including year of publication, intervention components, type of crosswalks used in the observation sites, locations of the crosswalks within the article, and the journal type. Articles are listed beginning with the most recently published article to the earliest.

Appendix C

Figure C1

Motorist-Pedestrian-City Planner Behavioural Interactions

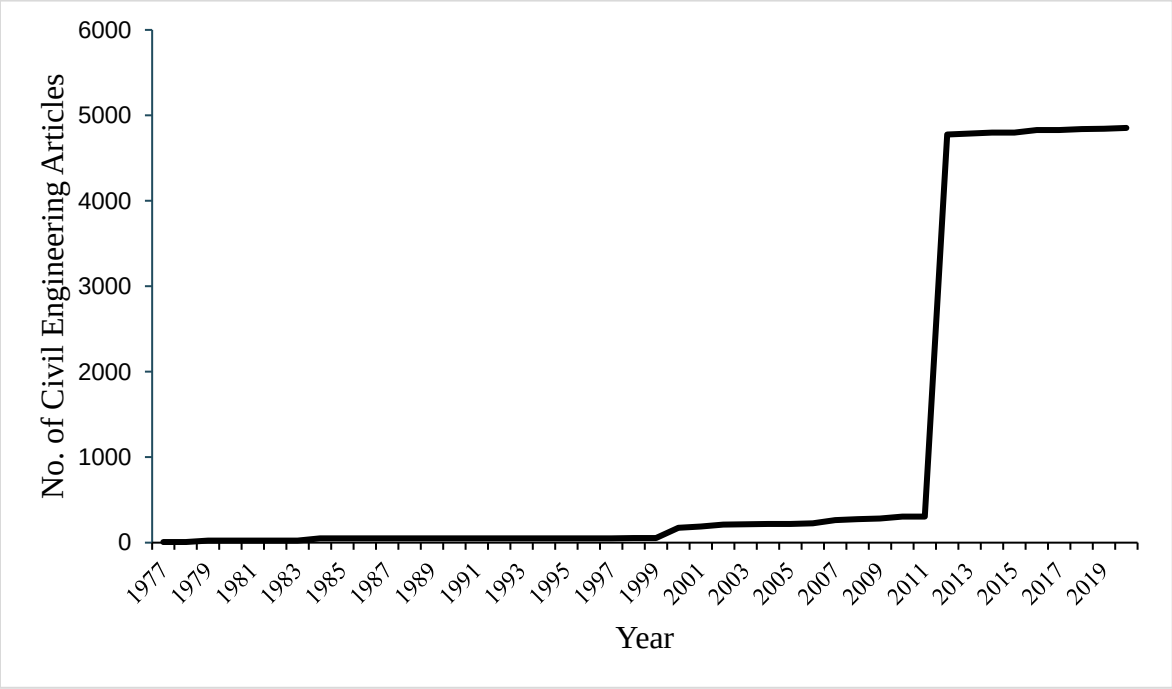


Note. Diagram depicting the people involved in pedestrian-motorist conflicts and how each of their behaviour interacts with the behaviour of the other two groups. The large circles represent behaviour of 1) the motorist, 2) the pedestrian, 3) the city planner. The overlaps are behavioural interactions between 4) the motorist and pedestrian, 5) the motorist and city planner, 6) the pedestrian and city planner, and 7) the motorist, pedestrian, and city planner.

Appendix D

Figure D1

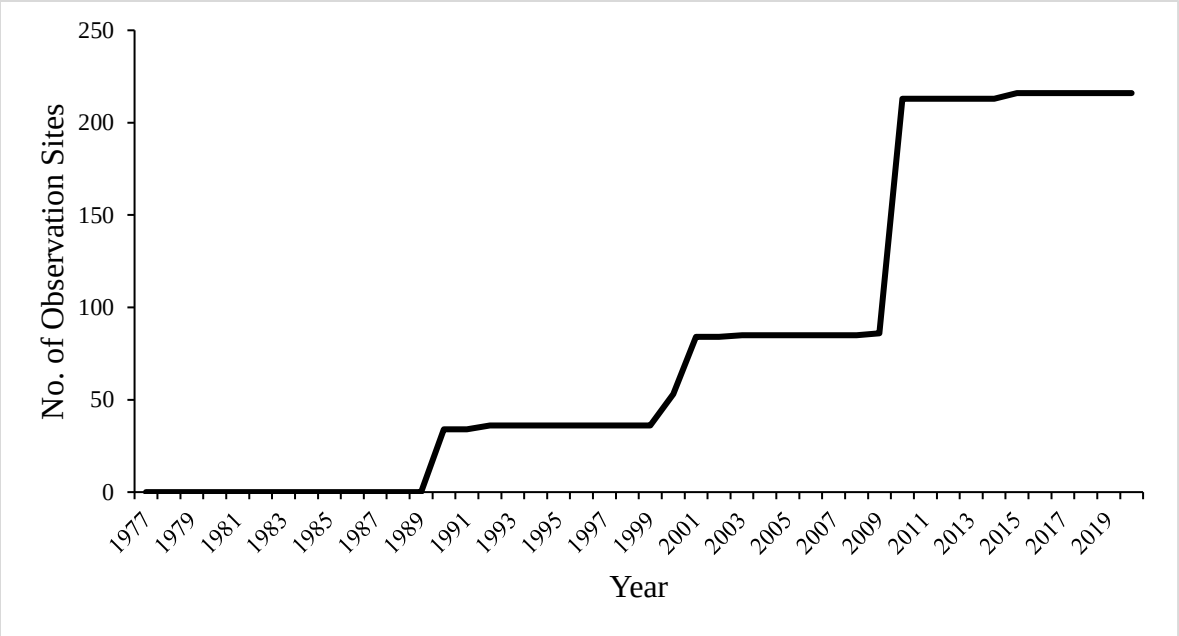
Cumulative Observation Sites in Civil Engineering Articles



Note. Cumulative number of contexts used in articles in the fields of Civil Engineering across 1977-2020. Chen et al., (2012) account for a large spike in the data with 4,462 observation sites in the article. Note the vertical axis' maximum value of 6000.

Figure D2

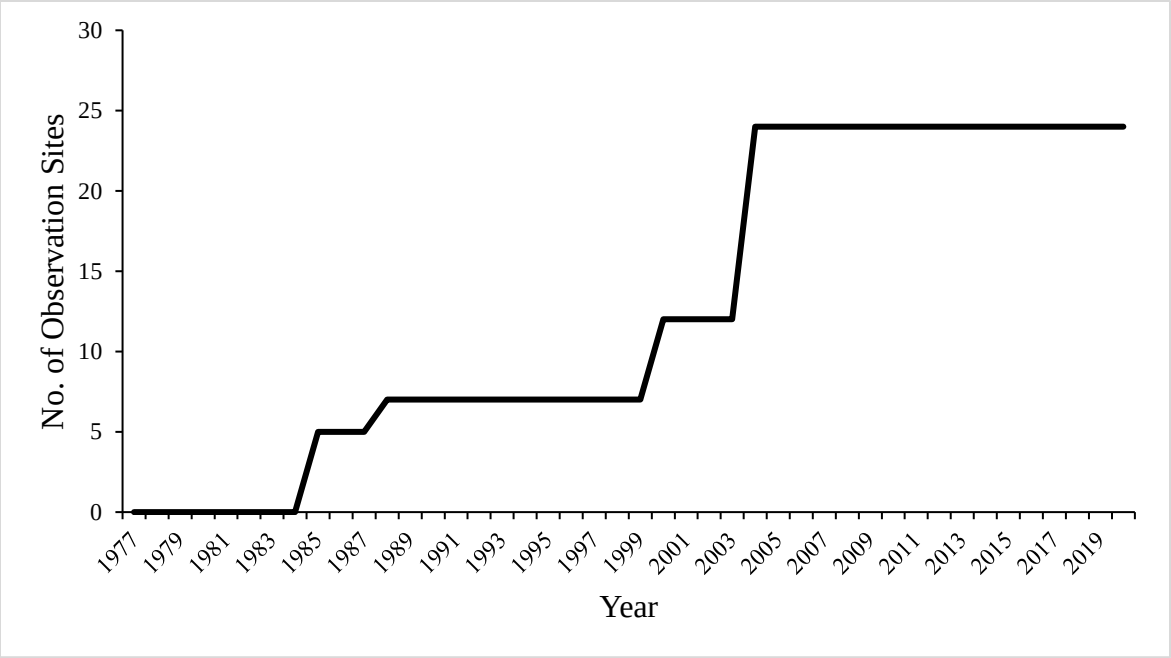
Cumulative Observation Sites in Safety Articles



Note. Cumulative number of contexts used in articles in the field of Safety across 1977-2020. Note the vertical axis' maximum value of 250.

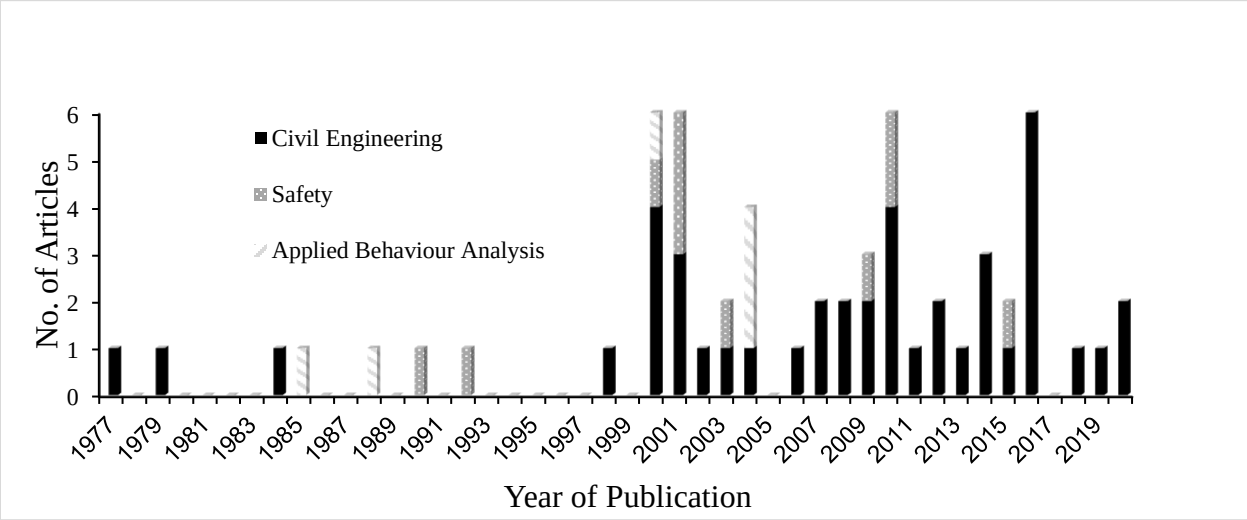
Figure D3

Cumulative Observation Sites in Applied Behaviour Analysis Articles



Note. Cumulative number of contexts used in articles in the field of Applied Behaviour Analysis across 1977-2020. Note the vertical axis' maximum value of 30.

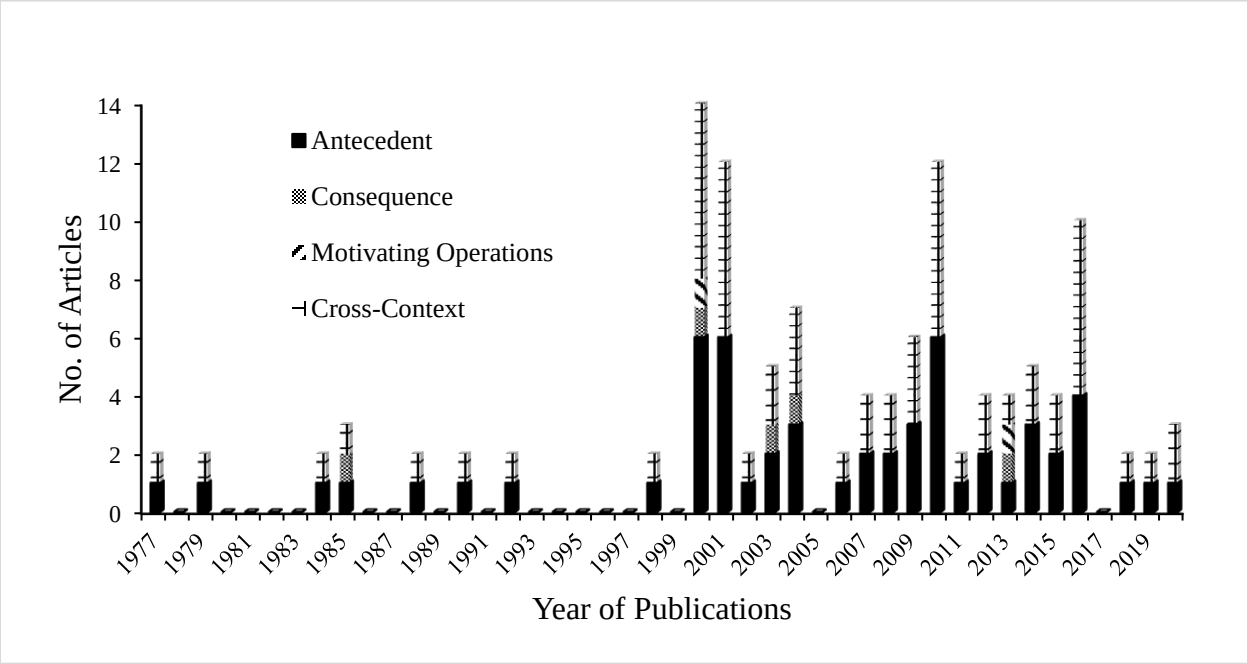
Figure D4
Number of Articles per Field per Year



Note. Differences in the number of publications in the fields of Civil Engineering, Safety, and Applied Behaviour Analysis across 1977-2020.

Figure D5

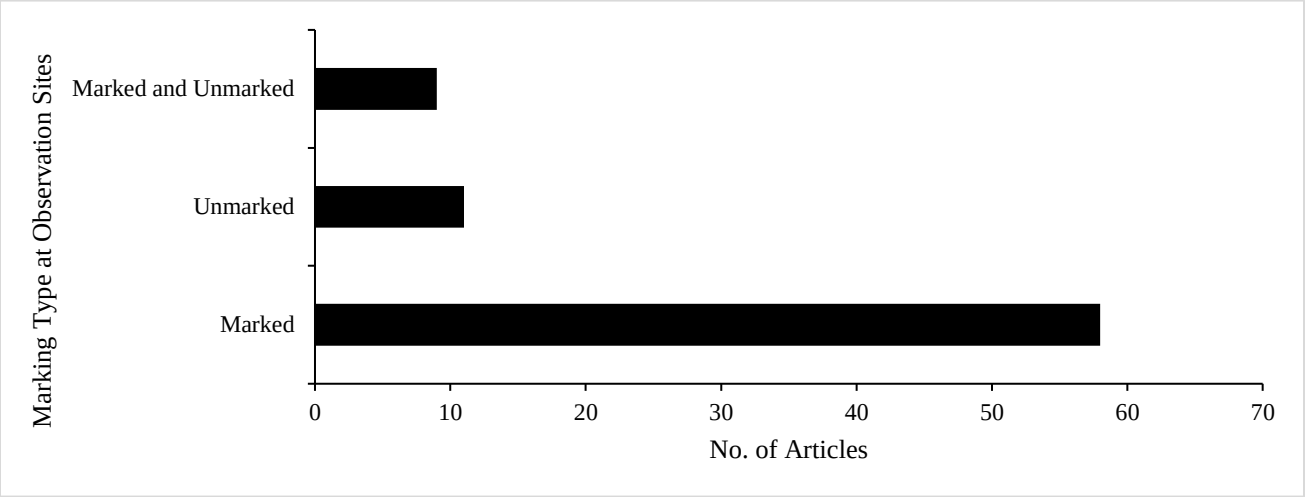
Intervention Components per Article per Year



Note. Differences in the number of intervention components used in Civil Engineering, Safety, and Applied Behaviour Analysis articles across 1977-2020.

Figure D6

Number of Articles by Crosswalk Type at Observation Sites



Note. Number of articles across 1977-2020 that used marked, unmarked, or marked & unmarked observation sites.

Appendix E

Codification Instructions for IRR

Intervention Components. Classify an article's procedure as an antecedent intervention and codify it as "*A"* if the procedure introduced environmental alterations to prompt a target behaviour (e.g., introducing signage, pavement markings). Classify an article's procedure as a consequence intervention and codify it as "*C"* if the article introduced a consequence for observed behaviour (i.e., reinforces procedure or punishment procedure). Classify an article's procedure as including a manipulation of motivating operations and codify it as "*MO"* if the procedures introduced an environmental change which establishes a motivation to access a reinforcer or makes an aversive consequence more aversive. Classify an article's procedure as a including cross-contextual factors and codify it as "*CO"* if the procedures evaluated behaviour across contexts (e.g., if behaviour was measured at 4:00pm versus 4:00am), across stimuli (e.g., behaviour was measured under the conditions of two different types of traffic signs), or environment (e.g., area of a city, state/province). Place the article's intervention components into the table "*Article Characteristics"*.

Publication Year.

Classify articles based on the year they were published. Non-examples of a publication year were: the years the article was submitted for publication, the year the article was received, accepted, or finally accepted by a journal. Place the year the article was published into the table named "*Article Characteristics".*

Crosswalk Type.

Classify articles based on the type of crosswalk that was used in the article. The crosswalk's state prior to the intervention is what the classification is based on. Classify the article's procedure as having used an *unmarked crosswalk* if an intervention or observation site took place at an extension of a sidewalk across a road at an intersection without markings or signage. Classify the article's procedure as having used a *marked crosswalk* if an intervention site took place at a crosswalk controlled by traffic lights, school crosswalk, or pedestrian crosswalk. If the article's procedures used both marked and unmarked crosswalks, the classification becomes "*marked & unmarked"*. Place the type of crosswalk (*Marked, Unmarked, or Marked & Unmarked)* used in the article into the table named "*Article Characteristics*".

Location. Classify articles based on the site(s) that the intervention took place. Write the number of sites in parentheses, followed by the name of the city, and finally the province or state abbreviation. Articles retained outside of North America used the country's name instead of a province or state.

Journal Type.

Classify an article based on the type of journal in which they were published. Locate the journal's website, online copy, or physical copy of the journal so that a mission statement can be read. If a journal indicates that it publishes articles with a main emphasis on an experimental analysis of behaviour, classify it as an "*Applied Behaviour Analysis"* journal. If a journal indicates that it publishes articles with a main emphasis on urban planning, urban development, or transportation engineering, classify it as a "*Civil Engineering"* journal. If a journal indicates that it publishes articles with a main emphasis on accidents, injuries, or health, classify it as a "*Safety*" journal. Place the article's journal type into the table named "*Article Characteristics*".

If the journal name cannot be found within the article document, locate the article on Google Scholar. Access the page in which the article is found to find the journal. Proceed to locate the journal's website and read the mission statement for codification purposes.