Traffic rule violations - Red Light Running

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Please note: The studies included in this synopsis were selected from those identified by a systematic literature search of specific databases (see supporting document). The main criterion for inclusion of studies in this synopsis and the DSS was that each study provides *a quantitative effect estimate*, preferably on the number or severity of crashes or otherwise on road user behaviour that is known to be related to the occurrence or severity of a crash. Therefore, key studies providing qualitative information might not be included in this synopsis.

1 Summary

Goldenbeld, C., van Schagen, I. , August 2017

1.1 COLOUR CODE: RED

Road safety experts agree that red light running is a risk factor since it is a demonstrable causal factor in part of the crashes and since it demonstrably leads to two basic types of traffic conflicts at intersections: right-angle and left turn-opposed conflicts. Red light running is associated with very severe crash outcomes (fatality or serious injury).

1.2 KEYWORDS

traffic rule violations, red light running, crash risk, car drivers, cyclists, pedestrians

1.3 ABSTRACT

Red light running is a risky traffic violation leading to traffic conflicts at intersections that may result very serious injury. Crashes related to red light running compose a substantial part of urban road safety. It has been estimated that pedestrians' relative crash risk is eight times higher when they cross an intersection at red light instead of green (or yellow) light. Another study estimated a 10 to 15 times increase in fatal crash risk for all transport modes due to red light running. Red light running is fairly scarce amongst drivers (a few drivers per 1,000 vehicles), but fairly frequent among cyclists and pedestrians (percentages may run up to over 50% at specific days, times and locations). Red light running is influenced by several factors, including age and gender, static and dynamic characteristics of the intersection, day and time, and weather. Most research has been done in busy, large metropolitan city areas in China, Europe and the USA.

1.4 BACKGROUND

What is red light running?

Red light running is entering an intersection any time after the signal light has turned red. A vehicle (or cyclist) is said to "enter" the intersection when it crosses the stop line or an equivalent location on the intersection approach (Bonneson & Zimmerman, 2004). Similarly, red light running of pedestrians can be defined as entering the road, either at an intersection or midblock, any time after the pedestrian signal has turned red. There are some qualifications to this simple definition. Road users who are inadvertently in an intersection when the signal changes, (waiting to turn left, for example), cannot be considered as red light runners. At locations where a right turn on red is permitted, drivers who fail to come to a complete stop before turning may be considered red light runners.

How does red light running affect road safety?

Road safety experts worldwide agree that red light running is a risk factor based on evidence that red light running is an apparent causal factor in part of the crashes, and further analytical and empirical evidence that red light running increases risk of traffic conflicts. There are two common types of road safety conflict due to a red light violation: right-angle and left turn-opposed conflicts (Bonneson & Zimmerman, 2004). These two conflicts tend to occur at different times during the red indication. A right-angle conflict occurs after the driver/cyclist in a conflicting traffic stream reacts to the signal's change to green and travels into the intersection. Thus, the right-angle conflict is likely to occur after the first few seconds of red have lapsed. A left-turn-opposed conflict occurs when: (1) a left-turn movement is permitted to turn through gaps in the opposing through traffic stream, and (2) the left-turn completes the permitted turn just after the light changes to red. Drivers of left-turning vehicles waiting in the intersection at the end of the phase may unintentionally turn in front of an opposing through vehicle, believing that its driver will stop for the red indication. Thus, left-turn conflicts are likely to occur soon after the start of red (possibly prior to the end of the all-red interval) (Bonneson & Zimmerman, 2004).

Although the evidence points towards red light running as a risk factor, very few studies have actually quantified the risk increase as a function of red light running. For pedestrians, it has been estimated in one study that the relative crash risk of red light violation is eight times higher than for legal crossing at signalised intersections (King et al., 2009). Using a case-control design, Aarts et al. (2016) estimated that - all modes of transport included - red light running increased fatal crash risk 10 to 15 times.

How many road users engage in red light running?

- For car drivers, studies show that the rate of red light violation per 1000 vehicles varies between 1.3 and 5.3 in the USA and Australia (Australia: 3.9; Oxnard, California: 1.3; Arlington, Virginia: 3; Fairfax, Virginia: 3.7 ; Texas:4.1; Tuscaloosa, Alabama: 5.3; as reported in Attawi, 2014). European figures are not available.
- Cyclists frequently engage in red light running in large city areas. Richardson (2015) lists results for several studies: Beijing, China (two studies: 50%, 64%), London, UK (two studies: 16%, 17%), Melbourne, Australia (three studies: 7%, 9%, 37%), Michigan, USA (one study: 23%), Oregon, USA (one study: 10%).
- Pedestrians also frequently engage in red light running, with red light running violations reported for about one third of pedestrians in Lille (Dommes et al., 2015), for 20% of pedestrian crossings in Brisbane Queensland (King et al., 2009), and 13.5% of pedestrians in Tel Aviv, Israel (Rosenbloom, 2009).

Which factors influence the frequency of red light running?

The frequency of red light running is influenced by many personal as well as road and traffic related factors, for example:

- For car drivers the frequency has been found to depend on the following (intersection) factors: traffic volume, cycle length, advance detection for green extension, speed, signal coordination, approach grade, yellow interval duration, proximity of other vehicles, presence of heavy vehicles, delay, intersection width, and signal visibility (Bonneson & Zimmerman, 2004).
- For cyclists, Meel (2013) identified the following characteristics that were associated with increased red light running rates: male cyclists, young adults, experienced cyclists, bad weather, long waiting times, reduced credibility/low conflicting traffic flow, short crossing distance, herding (when there are other people violating the red light they are more likely to also violate the red light) and a low percentage of trucks and buses.

1.5 OVERVIEW OF CODED RESULTS

- It has been estimated that the relative crash risk of red light violation for pedestrians is eight times higher than for legal crossing at signalised intersections. Relative risk estimates for red light running by drivers and cyclists have not yet been made.

- Whereas red light running by drivers is infrequent – a few drivers per 1000 vehicles – cyclists and pedestrians have been shown to be frequent red light violators – with percentages running over 50% at specific days, times and locations.
- Red light running is associated with various static and dynamic characteristics of intersections, traffic composition, personal characteristics, day, time and weather, and with social-cultural factors.
- A strong predictor for red light running by drivers is loss of attentional visual field (AVF) (especially in the vertical meridian).
- The red light running of cyclists can be distinguished into risk taking red light running where the cyclist does not stop at all when the light is red, and opportunistic red light running where the violation occurs after the cyclist has stopped.

1.6 NOTES ON STUDY METHOD AND TRANSFERABILITY

It should be noted that studies on red light running are generally limited in scope (observations on a few intersections in one city area) and that the studied intersections are not randomly selected, i.e. studies tend to focus on the busier and more complex intersections in urban environments. Furthermore, most studies look at the prevalence of red light running; there are hardly any studies that assessed the effect on the accident risk of red light running. Given the fact that results differ to a large extent between cities, and within cities between different locations (i.e. intersections), it is clear that the results are very much linked to local intersection conditions and that transferability is restricted.

2 Scientific Details

2.1 DESCRIPTION OF CODED STUDIES

Table 1 presents information on the main characteristics of the 14 coded studies. 3 studies concerned drivers (D), 5 cyclists (C), 4 pedestrians (P), 1 all road users (A), and 1 bus drivers (B).

Table 1: Overview of characteristics of 14 coded studies

Study	Mode	Main study method and road user	Measurement
Porter & England, 2000, USA,Virginia	D	The study focused on RLR of *drivers* on 6 intersections in 3 Southeast Virginia cities. Appr. 44,000–115,000 vehicles enter each of these intersections daily. 2 four-way intersections for each city were chosen.	Observations were carried out between February and April, 1997. Weekday observations were scheduled so that of 6 intersections, one from each city, were observed daily during a continuous 2-hour period between 3 p.m. and 6 p.m. (the hours within which most weekday crashes occurred in Virginia).
Rosenbloom et al., 2004, Israel	P	This observational study investigated *pedestrian behaviour*, including red light running, as a function of gender, age, and type of cultural environment (secular city vs religious orthodox city).	The sample consisted of 1047 *pedestrians* who were observed at 2 busy urban intersections. The observations were conducted in 3 separate intervals at 2 busy intersections in Ramat-Gan (secular area) and Bnei-Brak (ultra-orthodox area) during the afternoon hours.
King et al., 2009, Australia, Brisbane	P	Observation survey of *pedestrian behaviour* at 6 signalised intersections in the Brisbane Central Business District, having high volumes of pedestrians and vehicles.	Each intersection was observed for one half-hour period during 5 different time periods over the day; early morning (8 a.m.–10 a.m.), mid-morning (10 a.m.–12 p.m.), midday (12 p.m.–2 p.m.), mid-afternoon (2 p.m.–4 p.m.), and late afternoon (4 p.m.–6 p.m.), on Thursdays and Fridays in 2 successive weeks in November.
Rosenbloom, 2009, Israel, Tel Aviv	P	An observational study that compared the road behaviour of individual *pedestrians* at an intersection with a traffic signal to that of groups of pedestrians (at the same intersection).	1392 *pedestrians* were unobtrusively observed in an urban setting at a pedestrian street crossing of undivided streets; 842 were female (60.5%) and 550 were male (39.5%). the observations took place between 7:30 and 8:30 in the morning.
West et al., 2010, USA, Maryland	D	Multiple measures of vision and cognition were collected at the baseline examination of a population of 1,425 *drivers* aged 67-87 years in greater Salisbury, Maryland.	Each *driver* had real-time data collected on 5 days of driving performance at baseline and again at 1 year. Failure to stop at a red traffic light was the primary outcome.
Johnson et al., 2011, Australia	C	A cross-sectional observational study was conducted using a covert video camera to record *cyclists* at 10 sites across metropolitan Melbourne, Australia from October 2008 to April 2009.	Observations of *cyclists* were made at 10 sites along the most frequently used on-road commuter routes in metropolitan Melbourne. All sites were within 5 km of the CBD, had 2 lanes of forward travel, 4 lanes of cross traffic, a pedestrian crossing and a tram line parallel to the right vehicular lane. 3 groups of predictor variables were recorded: location, cyclist characteristics, and other road users.

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Wu et al., 2012, China	C	A cross-sectional observational study on *cyclists* was conducted at 3 four-armed signalized intersections in Beijing. Two criteria were used to select the sites: 1. typical intersection design; 2. a high number of two-wheeled traffic.	The riders (both e-bike riders and cyclists) arriving during red light phases were videotaped and coded. The coded variables described the riders' individual characteristics (gender, age group, vehicle type), the riders' movement information and situational factors (cross traffic volume, group size, number of riders waiting upon arrival, and number of riders crossing against the red light).
Gates et al., 2014, USA	D	Naturalistic *driver* behavioural data were collected at 72 signalized intersection approaches selected from 4 regions of the US; data were collected with consumer-grade high definition video camera installed for 3 to 5 h at each of the 72 study approaches.	Data were obtained for 6,208 vehicles that were approaching a study intersection during the yellow interval, including 3,575 (57.6%) vehicles that stopped, 2,533 (40.8%) vehicles that entered the intersection before the end of the yellow indication, and 100 (1.6%) vehicles that committed RLR by entering after the end of the yellow indication.
Pai & Jou, 2014 Taiwan	C	The research used video cameras to collect the data (e.g., *bicyclist* attributes, temporal factors, roadway characteristics, and weather factors) at several selected junctions, Toayuan County, Taiwan.	12,447 observations on *bicyclists* crossings; the survey was carried out on 8 intersections, four 3-arm and four 4-arm, four with 50 km/hr and four with 60 km/hr speed limit, with crossing distance ranging from 23 to 43 meter, with peak hour traffic volumes of first stream (closest to bicyclists) ranging 2100 - 4000, and off peak hours 700 -2000)
Dommes et al., 2015 France	P	The study combined observational data with questionnaires answered by 422 French adult *pedestrians*. 15 urban crosswalks at 6 different signalized intersections in Lille (France) served as experimental sites. 13 behavioural indicators were extracted and demographical, contextual and mobility-associated variables were examined	All sites were on two-way streets, with no pedestrian refuge islands; all had zebra crossings, pedestrian and traffic lights, and a speed limit of 50 km/h on each road segment. Traffic density was available for each observed crosswalk in three categories (AADT): from 1500 to 6000 vehicles per day (4 crosswalks), from 6001 to 13,000 vehicles per day (4 crosswalks) and from 13,001 to 30,000 vehicles per day (7 crosswalks).
Richardson& Caulfield, 2015, Ireland, Dublin	C	An observational survey and an online questionnaire; 2061 *cyclists* (18+ yrs), completed an online survey with questions regarding the frequency with which respondents stopped at red lights and the reason(s) for cycling through red light.	4 intersections in Dublin, 2 with cycle track and 2 with cycle lanes; all 4 sites were surveyed on the same day; each site observed twice from 8 to10 am in half-hour intervals spread out over the eight surveys; thus, each site was surveyed for a total of 4h.
Wang, 2015, China, Changsha City	B	Observational study to record three types of traffic violations among *bus drivers* in Changsha City, China: illegal stopping at bus stations, violating traffic light signals, and distracted driving.	The study included 256 round-trip observations on 32 bus routes, recording the bus driver behaviour at 7,612 bus stations, 5,656 road intersections, and 14,384 road sections; the study collected valid records from 7,611 bus stations, 5,612 road intersections, and 14,277 road sections.
Yan, 2015, China	A	Portable digital devices were used to record red-light running violations at 5 selected intersections. In total, 162.124 vehicles and 31.649 pedestrians were recorded, including 117.557 cars, 11.946 coaches, 333 trucks, 27.974 motorcycles	Observations were conducted on 3 types of days (weekday, weekend, holiday). The selections of weekday, weekend and holiday were determined at random. For each selected day, the researchers conducted the observations in 4 time periods, including 2 peak hours (7:30–8:30

		and 4314 bicycles. *Cars, pedestrians, and motorcycles* were most observed accounting for 60.7%, 16.3 and 14.4%.	am and 5:30–6:30 pm) and two off-peak hours (9:30–10:30 am and 3:30–4:30 pm). In total, the traffic flows of 60 h were recorded at the five intersections.
Yang et al., 2015, China	C	A cross-sectional observational study was conducted at six signalized intersections in Beijing, China.	A total of 2322 two-wheeled riders approaching the intersections during red light periods were observed with hidden cameras. The overall proportion of riders' red-light running behaviour was 61.1% and varied from 46.4% to 72.1% across sites. Cyclists were less likely to cross against the red light than e-bikers (55% vs. 67%).

Description of main research methods

The direct effect of red light running on road safety has most often been studied in general or in-depth accident analysis. There are almost no studies that provide a relative risk estimate for red light running (exception King et al., 2009).

The prevalence of red light running is generally assessed in observational studies, with video cameras or human observers (Johnson et al., 2011; Rosenbloom et al., 2004, Rosenbloom, 2009; Wu et al.,2012; Pai & Jou, 2014; Dommes et al., 2015; Richardson et al., 2015; Yan et al., 2015). Many studies focus on the factors that influence red light running rates. The variables typically include characteristics of road users (e.g. age, gender), characteristics of intersections (e.g. traffic volume, signal phasing), social factors (e.g. presence and behaviour of other pedestrians/cyclists) and other circumstances (e.g. times and day, weather conditions).

Other research methods included the use of naturalistic driving data (Gates et al., 2014), observing bus driving behaviour along bus routes (Wang et al., 2015), combining cognitive and visual tests with driver behaviour data (West et al., 2010). Only one study investigated the extent to which red light running was associated with increased crash risk (King et al., 2009).

Most of the red light running studies have been conducted on a limited number of intersections in large metropolitan city areas. It should be noted that these intersections are often not representative for a city. Many studies focus on high-volume intersections in busy business or shopping areas. The types of intersections studied differ within one study and between studies which complicates comparing (discriminating or generalising) research findings.

2.2 RESULTS

- Red light running is fairly scarce amongst drivers (a few drivers per 1000 vehicles), but fairly frequent among both cyclists and pedestrians - percentages may run up to over 50% at specific locations, days and times.
- Most studies report considerable variation in red light running between intersections.
- The one study that linked red light running with crash risk found that pedestrians crossing against a red light had a crash risk that was eight times higher than crossing at a green light.
- An important cognitive function of drivers that is related to red light running is loss of attentional visual field (AVF).
- Pedestrian red light running is less clearly linked to demographic factors and traffic volume than cyclists and cars red light running.
- Besides traffic related factors, red light running of pedestrians and cyclists may be influenced strongly by social-cultural factors.

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Modifying conditions

Research on red light running of drivers, cyclists and pedestrians showed that in general red light running depends upon age, gender, visual function, type and time of day, weather conditions, and several static or dynamic characteristics (traffic volume, signal phasing) of the intersection.

Bonneson & Zimmerman (2004) summarised the engineering factors that influence the red light running as follows:

Category	Factor*	Red-Light violations tend to decrease when
Traffic characteristics	Approach traffic volume	...traffic volumes decrease.
	Approach speed	...speeds decrease.
	Heavy-vehicle percentage	...fewer trucks are present.
Signal operation	<u>Signal cycle length</u>	...cycle length increases, provided the *v/c ratio*** is less than 0.65. ...cycle length decreases, provided the *v/c ratio* is more than 0.65.
	<u>Yellow interval duration</u>	...yellow interval is increased (provided it does not exceed 5.5 s)
	<u>Phase termination by max-out</u>	...advance detection for green extension is used, provided it does not frequently extend to the maximum green limit (i.e., max-out).
Motorist information	Signal visibility	..signal visibility is improved (e.g., better signal head location, more heads, line of sight between signal and driver is improved)
	Signal conspicuity	...signal conspicuity is improved (e.g., use LED indications, 12" lenses, signal back plates, or dual red indications).
	Advance warning	...advance warning signs are added, especially if used with flashers that are active during the last few seconds of green.
Traffic operation	Approach delay	...delay decreases, especially if the *v/c* ratio is high.
	<u>Signal coordination</u>	...progression bands are adjusted so platoons do not arrive near the end of green.
Geometry	Approach grade	...grade is increased.
	Clearance path length	...distance travelled through intersection is short.
Enforcement	Threat of citation	...it is perceived that a violation is likely to result in a citation.
*** Underlined factors typically have an effect only on violations occurring just after the onset of red. ** "v/c"ratio = volume-to-capacity ratio.**		

Furthermore, studies show that drivers seem to be more likely to run a red light when they:

- were unbuckled (Porter, 2000),
- suffered from loss of AVF (West et al., 2010),
- drove as part of a platoon (Gates et al, 2014),
- encountered signals with shorter yellow duration (Gates et al., 2014),
- encountered good weather conditions (Wang et al., 2015).

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Cyclists seem to be more likely to run a red light when they:
- were male (Pai & You 2014; Richardson et al., 2015; Wu et al., 2012),
- were younger (Rosenbloom et al., 2004; Wu et al., 2012),
- encountered low traffic volume (Johnson et al., 2011; Pai & Jou, 2014),
- encountered fine weather (Pai & Jou, 2014),
- did not wear a helmet (Pai & Jou, 2014),
- cycled alone (Wu et al., 2012),
- had to cross a T/Y-intersection (Pai & Jou, 2014).

Pedestrians seem to be more likely to cross against a red light when they:
- were male (Rosenbloom et al., 2004; Rosenbloom, 2009),
- were part of an ultra-orthodox environment (Rosenbloom et al., 2004),
- crossed alone (Dommes et al., 2015).

On a number of variables studies showed contradictory results, for example:
- Some studies have found age and gender effects for pedestrians crossing red lights (Rosenbloom et al., 2004; Rosenbloom, 2009), other studies have not (Dommes et al., 2015).
- Wu et al. (2012) found no effect of cycling an electric bike (versus normal bike) on red light running, Pai & You (2014) found that riders on electric bikes engage in more red light running.

Besides the physical environment, the social-cultural environment also exerts considerable influence on red light crossing. Rosenbloom (2004) found that pedestrians in an orthodox environment were more like to cross against red than those in a secular area. In a later study, Rosenbloom (2009) found that a larger group of pedestrians waiting for red light decreased the prevalence of red light running.

An important theoretical distinction is the distinction between red light running by cyclists as risk taking and opportunistic behaviour. The risk-taking cyclists are those who ignore the red light and travel through the junction without stopping (perhaps slowing down); the opportunistic cyclists originally wait at a red light, but become too impatient and subsequently cross the junction by seeking gaps among crossing traffic.

Conclusions

- The relative crash risk of red light violation for pedestrians is 8 times higher than that for legal crossing at signalised intersections. Relative risk estimates for red light running by drivers and cyclists have not yet been made.
- Whereas red light running by car drivers is infrequent – a few drivers per 1000 vehicles – cyclists and pedestrians have been shown to be frequent red light violators – with percentages running over 50% at specific days, times and locations.
- Red light running is associated with various static and dynamic characteristics of intersections, personal characteristics, day, time and weather, and with social-cultural factors.
- Red light running by drivers is increased by driving in platoon and by shorter yellow duration of signals.
- A strong human function/competence predictor for red light running by drivers is loss of attentional visual field (AVF) (especially in the vertical meridian).
- Red light running of drivers, cyclists is promoted by good weather.
- Both cyclists and pedestrians waiting for a red light, or cyclists and pedestrians transgressing a red light, can influence red light running behaviour of others.
- The red light running of cyclists can be theoretically distinguished into risk taking red light running where the cyclist does not stop at all when the light is red, and opportunistic red light running where the violation occurs after the cyclist has stopped.

3 Supporting Documents

3.1 LITERATURE SEARCH STRATEGY

The literature on red light running and traffic risk was searched for in the international database Scopus on 23 March 2016. Scopus is the largest international peer-reviewed database. The literature was searched over the period 1999-2016; the search terms were searched in title, abstract and keywords. **Table 2** describes the search terms and logical operators and the number of hits for three searches on red light running and risk for drivers, cyclists and pedestrians.

Database: Scopus, Date: 23 March 2016

Table 2: Used search terms and logical operators

	Search terms/logical operators/combined queries	hits
1	The search for red light running and drivers used the following combination of key words: (TITLE-ABS-KEY ("red light running" OR "red light infringement" OR "red light negation" OR "red light violation" OR "red light offence" OR "red light crossing" OR "cross red light" OR "traffic light") AND TITLE-ABS-KEY (driver)) AND PUBYEAR > 1999	590
2	Search red light running and cyclists: This search used the following combination of keywords: (TITLE-ABS-KEY ("red light running" OR "red light infringement" OR "red light negation" "traffic light") AND TITLE-ABS-KEY (bicycle OR cyclist OR cycling OR riding OR "cyclist behaviour")) AND PUBYEAR > 1999	67
3	Search red light running and pedestrians: This search used the following combination of keywords: (TITLE-ABS-KEY ("red light running" OR "red light infringement" OR "red light negation" OR "red light violation" OR "red light offence" OR "red light crossing" OR "cross red light" OR "traffic light") AND TITLE-ABS-KEY (pedestrian OR "pedestrian behaviour")) AND PUBYEAR > 1999	231

In a first screening round, the 590, 67, and 231 references for drivers, cyclists, and pedestrians were screened on potential relevance for coding. **Table 3** presents the results from this first screening round. 42 studies were selected, of which two were duplicates, binging the final selection to 40 studies.

The main criteria for exclusion for coding were:
A = Paper concerns testing or evaluation of an intervention, method, or model.
B = Red light running is not directly investigated in the paper, is a side issue (if at all subject).
C = Non-English language or duplicate.

Table 3: Initial selection of studies after the first screening round

		Exclusion criteria			
Topic	**hits**	**A**	**B**	**C**	**Initially selected**
Red light running drivers	590	367	195	8	20
Red light running cyclists	67	20	33	3	11
Red light running pedestrians	231	99	112	9	11

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		Exclusion criteria			
Topic	**hits**	**A**	**B**	**C**	**Initially selected**
				Total	40 (42 minus 2 duplicates)

In a second screening round, the 40 references were checked with the same criteria on full-text copies of the papers. **Table 4** presents the results of the second screening round and describes the final decisions concerning coding of the studies. Eventually 14 studies were coded of which 3 concerned drivers, 5 cyclists, 4 pedestrians, 1 bus drivers and 1 all road users.

Table 4: Selection of studies for coding after the second screening round

	Full reference	Coding priority	Coded
1	Akaateba, M.A., Amoh-Gyimah, R., & Amponsah, O. (2015). Traffic safety violations in relation to drivers' educational attainment, training and experience in Kumasi, Ghana. Safety Science, 75, 156-162.	Given that the study was done in Ghana and that the study is self-report only this study has *low priority* for coding.	No
2	Bell, M.C., Galatioto, F., Giuffrè, T., Tesoriere, G. (2012). Novel application of red-light runner proneness theory within traffic microsimulation to an actual signal junction. Accident Analysis & Prevention, 46, 26-36	No. Study is too much theoretically oriented. Not suitable for coding.	No
3	Bendak, S.(2011). An in-depth analysis of red light crossing problem in Saudi Arabia. Advances in Transportation Studies, 25, 67-74.	An analysis of variance was done to determine if there were significant differences in red light crossing rates between the three regions of Saudi Arabia, between cities and country towns, between peak and off-peak times and due to differences in light cycle rates. Given that the study was done in Saudi-Arabia we do not rank it as among highest priority *(low priority*).	No
4	Cai, Y., Wang, X., Chen, X. (2009). Investigation of the relationship between red-light-running frequencies and intersection features. Proceedings of the 9th International Conference of Chinese Transportation Professionals, ICCTP 2009: Critical Issues in Transportation System Planning, Development, and Management, 358, 769-776.	This study is very technical, the specific method deviates from methods in earlier studies, the results have not been published in a peer reviewed scientific journal, the results are only based on 5 intersections in Florida. Low priority.	No
5	Chen, P.-L., Pai, C.-W., Jou, R.-C., Saleh, W., & Kuo, M.-S. (2015). Exploring motorcycle red-light violation in response to pedestrian green signal countdown device. Accident Analysis & Prevention, 75, 128-136.	This study focuses very specifically on motorcyclists response to green signal countdown device (GSCD) at intersections in Taiwan. Its results cannot be compared with most other studies. *Low priority.*	No
6	Elmitiny, N., Yan, X., Radwan, E., Russo, C., & Nashar, D. (2010). Classification analysis of driver's stop/go decision and red-light running violation. Accident Analysis and Prevention, 42, 101-111.	Although this study seems relevant for the subject, it is almost impossible to code since the results are analysed by a classification tree model. The results cannot be expressed in measures of effects. *Low priority*.	No

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	Full reference	Coding priority	Coded
7	Gates, T.J., Savolainen, P.T., & Maria, H.-U. (2014). Prediction of driver action at signalized intersections by using a nested logit model (2014) Transportation Research Record, 2463, 10-15.	Yes	Yes
8	Lu, G., Wang, Y., Wu, X., & Liu, H.X. (2015). Analysis of yellow-light running at signalized intersections using high-resolution traffic data. Transportation Research Part A, 73, 39-52	Main outcome variable is yellow light running rather than red light running. Therefore low priority.	No
9	Palat, B., & Delhomme, P. (2016). A simulator study of factors influencing drivers' behavior at traffic lights. Transportation Research Part F, 37, 107-118.	Main outcome variable is yellow light running rather than red light running. Therefore low priority.	No
10	Palat, B., & Delhomme, P. (2012). What factors can predict why drivers go through yellow traffic lights? An approach based on an extended Theory of Planned Behavior. Safety Science, 50, 408-417	Main outcome variable is yellow light running rather than red light running. Therefore low priority.	No
11	Porter, B.E., & England, K.J. (2000). Predicting Red-Light Running Behavior: A Traffic Safety Study in Three Urban Settings. Journal of Safety Research, 31, 1-8.	Yes	Yes
12	Rittger, L., Schmidt, G., Maag, C., & Kiesel, A. (2015). Driving behaviour at traffic light intersections. Cognition, Technology and Work, 17, 593-605.	This simulator study focused on specific driving behaviour when approaching traffic light intersections. The researchers measured driving speed and acceleration and deceleration behaviour as indicators for driving efficiency. Given the fact that the study was a simulator study and that the main outcome variables were related to speed changes, we accorded the study *low priority* for coding.	No
13	Schattler, K.L., & Datta, J.K. (2004). Driver behavior characteristics at Urban signalized intersections. Transportation Research Record, 1862, 17-23.	A series of evaluation studies were performed in Michigan to test the effectiveness of change and clearance intervals calculated according to ITE guidelines on late exits (LE) and red light violations (RLV) at nine signalized intersections in Detroit, Michigan. This study used 4 approaches at four test intersections where engineering treatments have been applied (16 total test sites) and 4 approaches at 5 control intersections. Basically this is a measure evaluation study belonging to measures part of SafetyCube.	No
14	Wang, Q., Zhang, W., Yang, R., Huang, Y., Zhang, L., Ning, P., Cheng, X., Schwebel, D.C., Hu, G., & Yao, H. (2015). Common traffic violations of bus drivers in urban China: An observational study. PLoS ONE, 10 (9), art. no. e0137954 .	Yes	Yes
15	West, S.K., Hahn, D.V., Baldwin, K.C., Duncan, D.D., Munoz, B.E., Turano, K.A., Hassan, S.E., Munro, C.A., Bandeen-Roche, K. (2010). Older drivers and failure to stop at red lights. Journals of Gerontology - Series A Biological Sciences and Medical Sciences, 65, 179-183.	Yes	Yes

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	Full reference	Coding priority	Coded
16	Yan, F., Li, B., Zhang, W., & Hu, G. (2014). Red-light running rates at five intersections by road user in Changsha, China: An observational study. Accident Analysis & Prevention, article in Press.	Yes	Yes
17	Yao, H.(2015). Common traffic violations of bus drivers in urban China: An observational study. PLoS ONE, 10 (9), art. no. e0137954	Is equal to Wang et al 2015 (mentioned above)	No
18	Yuan, L., Yuan, H.-W., & Wu, Z. (2009). The research of unintentional red running violation owing to dilemma zone 2009 2nd International Conference on Intelligent Computing Technology and Automation, ICICTA 2009, 4, art. no. 5288398, 708-710	This article includes a theoretical computational analysis. It does not present behavioural data. It cannot be coded in terms of effects.	No
19	Yousif, S., Alterawi, M., Henson, R.R. (2014). Red light running and close following behaviour at urban shuttle-lane roadworks. Accident Analysis & Prevention, 66, 147-157	This article concerns tailgating and red light running at temporary traffic lights near road zones. Low priority.	No
20	Zhang, L., Wang, L., Zhou, K., Zhang, W.-B., & Misener, J.A. (2010). Use of field observations in developing collision-avoidance system for arterial red light running. Transportation Research Record, 2189, 78-88.	No, this study is too much oriented towards specific measures (to be coded at later stage SafetyCube project that deals with measures)	No
21	Bai, L., Liu, P., Chen, Y., Zhang, X., & Wang, W. (2013). Comparative analysis of the safety effects of electric bikes at signalized intersections. Transportation Research Part D: Transport and Environment, 20, 48-54.	This paper studies traffic conflicts at signalised intersections. The main analysis concentrates on predicting traffic conflicts from number and type of roads u7sers on intersection and media type of cross streets. Basically the main unit of analysis is larger than red light running. Low priority.	No
22	Guo, Y., Liu, P., Bai, L., Xu, C., Chen, J. (2014). Red light running behavior of electric bicycles at signalized intersections in China. Transportation Research Record, 2468, 28-37.	Yes	No
23	Huan, M., Yang, X.-B., Jia, B. (2013). Red-light running behavior of non-motor vehicles based on survival analysis (2013) Beijing Ligong Daxue Xuebao/Transaction of Beijing Institute of Technology, 33, 815-819.	Paper not in English language (in Chinese).	No
24	Johnson, M., Newstead, S., Charlton, J., & Oxley, J. (2011). Riding through red lights: The rate, characteristics and risk factors of non-compliant urban commuter cyclists. Accident Analysis & Prevention, 43, 323-328.	Yes	Yes
25	Pai, C.-W., & Jou, R.-C. (2014). Cyclists' red-light running behaviours: An examination of risk-taking, opportunistic, and law-obeying behaviours. Accident Analysis & Prevention, 62, 191-198.	Yes	Yes
26	Richardson, M., & Caulfield, B. (2015). Investigating traffic light violations by cyclists in	Yes	Yes

Traffic rule violations - Red Light Running

	Full reference	Coding priority	Coded
	Dublin City Centre. Accident Analysis & Prevention, 84, 65-73.		
27	Wu, C., Yao, L.,& Zhang, K.(2012). The red-light running behavior of electric bike riders and cyclists at urban intersections in China: An observational study. Accident Analysis & Prevention, 49, 186-192.	Yes	Yes
28	Yang, X., Huan, M., Si, B., Gao, L., & Guo, H. (2012). Crossing at a red light: Behavior of cyclists at urban intersections. Discrete Dynamics in Nature and Society, 2012, art. no. 490810	The central variable in this research is waiting time of cyclists at signalised intersections. The analysis is done by a Cox proportional hazard duration model. Although the outcome variable is linked with red light running, the outcomes of this study are difficult to compare with other research.	No
29	Yang, X., Huan, M., Abdel-Aty, M., Peng, Y., & Gao, Z. (2015). A hazard-based duration model for analyzing crossing behavior of cyclists and electric bike riders at signalized intersections. Accident Analysis & Prevention, 74, 33-41.	Yes	Yes
30	Dommes, A., Granié, M.-A., Cloutier, M.-S., Coquelet, C., & Huguenin-Richard, F. (2015). Red light violations by adult pedestrians and other safety-related behaviors at signalized crosswalks. Accident Analysis & Prevention, 80, 67–75.	Yes	Yes
31	King, M.J., Soole, D., & Ghafourian, A. (2009). Illegal pedestrian crossing at signalised intersections: Incidence and relative risk. Accident Analysis & Prevention, 41, 485–490.	Yes	Yes
32	Koh, P.P., & Wong, Y.D. (2014). Gap acceptance of violators at signalised pedestrian crossings. Accident Analysis & Prevention, 62, 178-185.	No central variable is gap acceptance. No data on red light running.	No
33	Kroher, M. (2014). Should I stay or should I go? Deviant behavior at traffic lights [Should I stay or should I go? Abweichendes Verhalten im Straßenverkehr] Soziale Welt, 65, 201-220.	Not in English language (German language).	No
34	Li, B. (2013). A model of pedestrians' intended waiting times for street crossings at signalized intersections. Transportation Research Part B: Methodological, 51, 17-28.	Not relevant for SafetyCube purpose. The main outcome of this study is a statistical model of intended waiting times of pedestrians. The authors argue that a exponential distribution though often used is not the best model for waiting time.	No
35	Li, B. (2014). A bilevel model for multivariate risk analysis of pedestrians' crossing behavior at signalized intersections. Transportation Research Part B, 65, 18-30.	In this paper, the author proposes a multivariate method to investigate pedestrians' risk exposure associated with unsafe crossings. The proposed method consists of two hierarchically inter-connected generalized linear models that characterize two different facets of the unsafe crossing behaviour. Given the highly technical nature of the paper it is not suitable for coding.	No

	Full reference	Coding priority	Coded
36	Rosenbloom, T. (2009). Crossing at a red light: Behaviour of individuals and groups. Transportation Research Part F, 12, 389-394.	Yes	Yes
37	Rosenbloom, T. (2011). Traffic light compliance by civilians, soldiers and military officers. Accident Analysis & Prevention, 43 , 2010-2014.	The specific hypotheses from his study concerning differences red light running between civilians and military officers are not that interesting for the SafetyCube project. This study provides little new information compared with Rosenbloom 2009 on civilian crossing behaviour. Low priority.	No
38	Rosenbloom, T., Nemrodov, D., Barkan, H. (2004). For heaven's sake follow the rules: Pedestrians' behavior in an ultra-orthodox and a non-orthodox city. Transportation Research Part F, 7, 395-404.	Yes	Yes
39	Thouez, J.P., Lord, D., Bergeron, J., Bourbeau, R., Bussière, Y., Bélanger-Bonneau, H., Rannou, A., & Latremouille, M.E. (2003). Physical and environmental characteristics of signalized intersections and pedestrian behaviour. Advances in Transport, 14, 143-148.	This study provides rather weak description of analysis and of statistical results. Therefore we rank it as *low priority*.	No
40	Wang, Q., Zhu, S., Ma, Y., He, Q., Tan, A., & Hu, G. (2011). Investigation of traffic law violations among middle school students in Hunan province and the influencing factors. Journal of Central South University (Medical Sciences), 36, 229-234.	This paper is in Chinese language with only abstract in English.	No

3.2 BACKGROUND CHARACTERISTICS OF THE CODED STUDIES

The main study approach to investigate red light running by drivers, cyclists or pedestrians is an observational study with video cameras or human observers (Johnson et al., 2011; Rosenbloom, 2005, 2009; Wu et al.,2012; Pai, 2014; Dommes et al., 2015; Richardson et al., 2015; Yan et al., 2015). Most of these studies – in Australia, Europe, China and the USA - have been conducted on intersections in a large metropolitan city area. The variables in these studies typically include characteristics of road users (e.g. age, gender, type of vehicle), characteristics of intersections (e.g. traffic volume, signal phasing), social factors (e.g. presence and behaviour of other pedestrians/cyclists) and other circumstances (e.g. times and day of the measurements, weather conditions). Some other types of research into red light running included naturalistic driving data (Gates et al., 2014), observation of bus driving behaviour along bus routes (Wang et al., 2015), a study combining cognitive and visual tests with driver behaviour data (West et al., 2010), and a red light running relative risk study (King et al., 2009). Nearly all studies have focused on the personal or environmental factors that influence the prevalence of red light running. Only one study investigated the extent to which red light running was associated with increased crash risk (King et al., 2009).

It should be noted that in most studies red light running is studied at a limited group of intersections that cannot be regarded as representative for the city. Many studies focus on high-volume intersections in busy business or centre districts. The types of intersections studied differ within a study and between studies which complicates comparing (discriminating or generalising) research findings.

Only one study by King et al. (2009) quantified the increase in crash risk as a function of pedestrians running red light. The researchers describe their method as follows: "In this study, the risk per crossing event was calculated, i.e. number of crashes per unit time in that behavioural category divided by number of crossings per unit time for the category. Next, relative risk was calculated for each illegal behaviour by dividing its risk by the risk involved in legal crossing. Mathematically this was (crashes per crossing event for an illegal behaviour)/(crashes per crossing event for legal crossing), so that a result greater than 1 signified the multiplicative increase in risk associated with the illegal behaviour compared with the legal behaviour. Confidence intervals (95%) were calculated. Both sets of data were annualised (i.e. converted into a single year equivalent), which was straightforward for the crash data (simple division by 11), but required several steps for the observation data, as it slightly under-sampled the afternoon time slots, included 15 min breaks, and covered only 2 weekdays." (King et al., 2009; p . 487).

A few words on validity issues on this study are merited:

- Like most studies on red light running, the sites in the study were not representative; they were located in the Central Business District and having high volumes of pedestrians and vehicles.
- In this study different intersections are likely to have different patterns of illegal pedestrian behaviour, and different patterns for time of day. Since the researchers summed observation data across sites and times of day, this raises some doubts about validity. However the researchers note that their compositional analysis indicated that the breakdown of legal and illegal behaviours across the sites and times of day were consistent, which is reassuring concerning this validity issue.
- The study used a different approach to the typical measurement of pedestrian exposure, typically being the number of crashes per trip or per kilometre travelled. Instead the study used the observations of illegal crossing behaviour (i.,e. red light running) which were annualised (i.e. converted into a single year equivalent).
- Several factors considered to contribute to pedestrian crash risk were not taken into account in this study, e.g. intersection design, traffic concentrations, crossing distances, drinking and walking, vehicle speeds, and specific differences between red light running violations (the observations did not distinguish between pedestrians who crossed against the steady red man just before the green man vs. just after the flashing red man, and the crash data did not distinguish between flashing and steady red man violations).

All in all, despite certain limitations the study method seems robust and interesting enough to warrant application in further research. Somewhat surprisingly, to our knowledge the King et al. method has not been used to replicate red light running risk estimates in pedestrian research or to calculate red light running estimates for cyclists, motorcyclists, or car drivers.

Table 4 presented information on the main characteristics of the coded studies. Study sample characteristics are further described in **Table 5**.

Table 5: Background characteristics of coded studies.

Author, Year, Country	Study type	Sample/Measurement	Analysis
Porter & England, 2000, USA, Virginia	The study focused on RLR on 6 intersections in 3 Southeast Virginia cities. Appr. 44,000–115,000 vehicles enter each of these intersections daily. 2 four-	Observations were carried out between February and April, 1997. Weekday observations were scheduled so that of 6 intersections, one from each city, were observed daily during a continuous 2-hour	A hierarchical forward-step logistic regression model was used to test predictors of yellow- versus red-light runners. The demographic data were collected only for these drivers, and the test between yellow- and red-

	way intersections for each city were chosen. Other criteria for choosing the sites included: (a) distance apart (the sites had to be in different segments of the city); and (b) space at the intersection for data collectors to park their cars unobtrusively to watch traffic flow.	period between 3 p.m. and 6 p.m. These hours were those during which most weekday crashes occurred in Virginia. Each intersection was observed every other weekday, counterbalanced to account for differences in driving across the week.	light runners was thought to be more conservative to understand RLR.
Rosenbloom et al., 2004, Israel	This observational study investigated pedestrian behaviour, including red light running, as a function of gender, age, and type of cultural environment (secular city vs religious orthodox city).	The sample consisted of 1047 pedestrians who were observed at 2 busy urban intersections. The observations were conducted in 3 separate intervals at 2 busy intersections in Ramat-Gan (secular area) and Bnei-Brak (ultra-orthodox area) during the afternoon hours.	The effect of the location, gender and age was estimated by Chi square test for independence.
King et al., 2009, Australia, Brisbane	Observation survey of pedestrian behaviour at 6 signalised intersections in the Brisbane. The sites were located in the Brisbane Central Business District, having high volumes of pedestrians and vehicles.	Each intersection was observed for one half-hour period during 5 different time periods over the day; early morning (8 a.m.–10 a.m.), mid-morning (10 a.m.–12 p.m.), midday (12 p.m.–2 p.m.), mid-afternoon (2 p.m.–4 p.m.), and late afternoon (4 p.m.–6 p.m.), on Thursdays and Fridays in 2 successive weeks in November.	For calculation of relative risks, the two "red man" categories were combined, and the risk per crossing event was calculated, i.e. number of crashes per unit time in that behavioural category divided by number of crossings per unit time for the category. Next, relative risk was calculated for each illegal behaviour by dividing its risk by the risk involved in legal crossing.
Rosenbloom, 2009, Israel, Tel Aviv	An observational study that compared the road behaviour of individual pedestrians at an intersection with a traffic signal to that of groups of pedestrians (at the same intersection).	1392 pedestrians were unobtrusively observed in an urban setting at a pedestrian street crossing of undivided streets; 842 were female (60.5%) and 550 were male (39.5%). the observations took place between 7:30 and 8:30 in the morning.	RLR (crossed–did not cross) was analysed using a logistic regression, for the relative contributions of the pedestrian's gender, the number of pedestrians who were waiting at the crossing when the pedestrian arrived, the number pedestrians who joined afterwards, the traffic volume on the red-light phase, and the occurrence of another pedestrian crossing on a red light.
West et al.,, 2010, USA, Maryland	Multiple measures of vision and cognition were collected at the baseline examination of a population of 1,425 drivers aged 67-87 years in greater Salisbury, Maryland. Each driver had real-time data collected on 5 days of driving performance at baseline and again at 1 year. Failure to stop at a red traffic light was the primary outcome.	The researchers recruited participants from a complete listing of all Department of Motor Vehicle Administration (DMVA) licensees aged 67 – 87 years who resided in ZIP codes of the greater Salisbury metropolitan area. Of 8,380 registered licensees, 4,503 (54%) returned postcards. Of 4,503, 6.0% were no longer driving, 1.6% were deceased, and 2.3% were no longer living in the eligible area. Of the remainder, 42% agreed to participate and 83% of them were recruited to the clinic examination (N = 1,425).	The incidence rate ratio was used as the measure of association. Variables found to be associated with failure in measurement round 1 were used in predictive models of failure to stop at a red light in round 2.
Johnson et al., 2011 Australia,	A cross-sectional observational study was conducted using a covert video camera to record	Observations of cyclists were made at 10 sites along the most frequently used on-road commuter routes in metropolitan Melbourne. All sites	A single binary logistic regression analysis model was used; the model included all available predictor variables and selected interactions

Melbourne	cyclists at 10 sites across metropolitan Melbourne, Australia from October 2008 to April 2009.	were within 5 km of the CBD, had 2 lanes of forward travel, 4 lanes of cross traffic, a pedestrian crossing and a tram line parallel to the right vehicular lane. Morning observation sites were in-bound and afternoon observation sites were out-bound. Site gradient was flat with the exception of the continuous site (type 3) which had one downhill (morning) and one uphill (afternoon) site. 3 groups of predictor variables were recorded: location, cyclist characteristics, and other road users.	simultaneously. The location variables/categories were time (AM/PM), gradient (flat/downhill/uphill) and cycling facility type (standard/ centre/ continuous).The cyclist variables/ categories were: gender (male/female), bicycle type (road bike: drop handlebars; flat bar/ mountain bike; other: included recumbent bikes, folding bikes/ladies bikes) and clothing (full cycling: jersey and cyclist pants/half cycling: either jersey or cyclist pants / non-cycling: all other clothing), helmet use (yes/no), direction of travel (left/ straight); The road user variables/ categories were: nr. of other cyclists, nr. of cross vehicles (count from left and right), and presence/ absence of a vehicle at the intersection (yes/no); the traffic volume (count) was categorised (0, 1–10, 11–20, 21+).
Wu et al., 2012, China	A cross-sectional observational study was conducted at three four-armed signalized inter-sections in Beijing. Two criteria were used to select the sites: 1. the selected sites should represent the typical intersection design characteristics and traffic conditions of urban areas in Beijing; 2. there has to be a reasonably high number of two-wheeled traffic (both electric bikes and regular bicycles) during the observation period.	All road users who entered the intersection were recorded on video, but only the riders (both e-bike riders and cyclists) arriving during red light phases were coded. The researchers restricted the coding process to include only riders traveling through the intersection. Left-turners were excluded because of the limited field of view of the cameras, while riders making right turns were also ignored because they are not subjected to the traffic signal control according to the road rules in China. The first set of variables described the riders' individual characteristics, including gender, estimated age group, and vehicle type. The second set of variables focused on the riders' movement information, including the times of arrival at and departure from the stop line, the time when crossing is completed, and the status of the traffic light at each of these times. The last set of variables of concern were situational factors, including cross traffic volume, group size, number of riders waiting upon arrival, and number of riders crossing against the red light.	To analyse the factors that are associated with RLR behaviour, a logistic regression analysis was conducted. The model included all variables simultaneously. The outcome measure for was red-light compliance (yes/no). Non-compliance (RLR) was defined as riding across the stop line when the traffic light is red. The regression analysis included 10 predictor variables: 1. Rider type (E-bike riders vs. Cyclists), 2. Gender, 3. Age group Young vs. old, 4. Age group Middle-aged vs. old; 5. No. of riders waiting upon arrival, 6. No. of riders crossing against traffic light; 7. Intersection site (Y–Y vs. X–Z); 8. Intersection site (Z–X vs. X–Z), 9. Cross traffic volume Low vs. high, 10. Cross traffic volume Median vs. high.
Gates et al., 2014, USA	Naturalistic driver behavioural data were collected at 72 signalized intersection approaches selected from four regions of the United States. Data were obtained for 6,208 vehicles that were approaching a study	Driver behavioural data were collected by use of a consumer-grade high definition video camera installed for 3 to 5 h at each of the 72 study approaches. Data were obtained for a total of 6,208 first-to-stop or last-to-go vehicles, including 3,575 (57.6%) vehicles that stopped, 2,533 (40.8%) vehicles that entered the intersection	a nested logit model was estimated; the elasticity values for continuous variables may be interpreted to be the effect (in percentage) that a 1% change in the independent variable has on the probability of the respective driver action; (pseudo) elasticity values for the categorical variables may be interpreted as the

	intersection during the yellow interval.	before the end of the yellow indication, and 100 (1.6%) vehicles that committed RLR by entering after the end of the yellow indication.	effect (in percentage) that a change between levels (i.e., from 0 to 1) has on the probability of the respective driver action.
Pai & Jou, 2014 Taiwan	The current research used video cameras to collect the data (e.g., bicyclist attributes, temporal factors, roadway characteristics, and weather factors as independent variables) at several selected junctions, Toayuan County, Taiwan.	12,447 observations on bicyclists crossings; the survey was carried out on 8 intersections, four 3-arm and four 4-arm, four with 50 km/hr and four with 60 km/hr speed limit, with crossing distance ranging from 23 to 43 meter, with peak hour traffic volumes of first stream (closest to bicyclists) ranging from 2100 to 4000, and off peak hours from 700 to 2000).	A mixed logit model was assessed to explore the effects of various characteristics (characteristics cyclists, weather, speed limit, type junction etc.) on 3 behaviours (risk-taking, opportunistic, law-obeying). To uncover the marginal effect of the explanatory variables, the researchers examined the change in estimated probability of crossing behaviours when a variable changes its value from zero to one (= "the direct pseudo-elasticity of the probability with respect to the explanatory variable".
Dommes et al., 2015 France	The study combined observational data with questionnaires answered by 422 French adult pedestrians. 13 behavioural indicators were extracted (12 before and while crossing, and red light violation), and the roles of several demo-graphical, contextual and mobility-associated variables were examined	15 urban crosswalks located at 6 different signalized intersections in the city of Lille, in the north of France, were chosen as experimental sites. All were on two-way streets, with no pedestrian refuge islands. They all had zebra crossings, pedestrian and traffic lights, and a speed limit of 50 km/h on each road segment. Traffic density was available for each observed crosswalk in three categories (AADT): from 1500 to 6000 vehicles per day (4 crosswalks), from 6001 to 13,000 vehicles per day (4 crosswalks) and from 13,001 to 30,000 vehicles per day (7 crosswalks).	regression analysis was carried out to examine illegal crossings at red lights; for the logistic regression analysis, the predictive factors were automatically entered one at a time using the forward stepwise method, where non-significant predictive factors were removed until the final model yielded only the most significant effects
Richardson & Caulfield, 2015, Ireland, Dublin	An observational survey and an online questionnaire.	4 intersections in Dublin, 2 with cycle track and 2 with cycle lanes; all 4 sites were surveyed on the same day; each site observed twice from 8 to 10 am in half-hour intervals spread out over the eight surveys; thus, each site was surveyed for a total of 4h. 2061 cyclists, all aged 18 or older, completed an online survey with questions regarding the frequency with which respondents stopped at red lights and the reason(s) for cycling through a red light.	Multinomial logistic (MNL) regression was used to analysis the data since some of the dependent variables examined had more than two outcomes e.g. cyclist behaviour. MNL regression measured the extent to which each independent variable (e.g. age, gender) played a part in predicting the likely value of the dependent variable e.g. cyclists who broke the lights.
Wang et al., 2015, China, Changsha City	Observational study to record three types of traffic violations among bus drivers in Changsha City, China: illegal stopping at bus stations, violating traffic light signals, and distracted driving.	the study included 256 round-trip observations on 32 bus routes, recording the bus driver behaviour at 7,612 bus stations, 5,656 road intersections, and 14,384 road sections. After excluding rare missing records due to the crowded buses that prohibited valid data collection, the study had collected valid records from 7,611 bus stations, 5,612 road intersections, and 14,277 road sections.	Poisson regression examined factors that predicted bus driver violations. First, an ordinary logistic regression model was developed to identify the significant variables from the aspects of driver characteristics, driving conditions, and vehicle types. In order to account for unobserved heterogeneity among different types of intersections, a random effects logistic regression model was also adopted.

Yan et al., 2015, China	Portable digital devices were used to record red-light running violations at five selected intersections.	Observations were conducted on 3 types of days (weekday, weekend, holiday). The selections of weekday, weekend and holiday were determined at random. For each selected day, the researchers conducted the observations in 4 time periods, including 2 peak hours (7:30–8:30 am and 5:30–6:30 pm) and two off-peak hours (9:30–10:30 am and 3:30–4:30 pm). In total, the traffic flows of 60 h were recorded at the five inter-sections. In total, 162.124 vehicles and 31.649 pedestrians were recorded, including 117.557 cars, 11.946 coaches, 333 trucks, 27.974 motorcycles and 4314 bicycles. In general, cars, pedestrians, and motorcycles were most observed accounting for 60.7%, 16.3 and 14.4%.	the violation rate of RLR was calculated as the numbers of vehicles or pedestrians being observed running red light divided by total number of vehicles or pedestrians x 100%; also an adjusted violation rate ratio (VRR) was used to quantify the effects of type of day and time period based on an Poisson regression model.
Yang et al. 2015 China	A cross-sectional observational study was conducted at six signalized intersections in Beijing, China. Field observations with video recordings were used.	The cameras were hid behind the intersection stop line so that it would not be visible. The data collection was conducted on weekdays during the daytime (i.e., 7:00 a.m.–6:30 p.m.) in good weather conditions.	In this study, the length of time is the waiting duration of a rider who arrives at the intersection during the red light period. The waiting time for each rider was taken as the difference between the arrival time at the intersection and the departure time when he/she begins to cross the intersection. The waiting time can be classified into uncensored data and censored data. It is defined as uncensored data if the rider terminates the waiting duration to cross the intersection during the red light period. Otherwise, it is considered as censored data as long as the rider terminates the waiting duration to cross the intersection during the green light period. The Cox proportional hazards model is the most commonly used semi-parametric model in which exp(βX) is used as the function form of the covariate influence. The researchers expanded proportional hazards model to include an unobserved random effect, called a frailty, allows for modelling association between individual duration times within a group.

3.3 OVERVIEW OF THE RESULTS OF THE ANALYSED STUDIES

Table 6: Main results of coded studies

Author, Year, Country	**Main RLR outcomes and modifying conditions**
Porter & England, 2000, USA, Virginia	- Safety-belt use and ethnicity were the only demographic variables to predict RLR after controlling for contextual predictors; drivers who were unbuckled were 1.32 times as likely as those who were buckled to run the red light; non-Caucasians were 1.19 times as likely as Caucasians to run red lights. - Weather was not important, but the city and time factors were significant.

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	- City differences may likely have resulted from intersection size and volume differences (i.e., larger inter-sections and higher volumes seemed to be related to higher RLR rates). - Time represented RLR variations during the late afternoon and rush hour periods; the odds ratio for time was 0.9979: red-light running tended to decrease the later the observation became.
Rosenbloom et al., 2004, Israel	- Males were more inclined to RLR than women ($X2(1) = 19.78$, $p < 0.01$). - Pedestrians in Bnei-Brak (ultra-orthodox) were more likely to RLR than pedestrians in Ramat-Gan ($X2(1) = 48.962$, $p < 0.01$). - Age was a factor in the RLR rate in Ramat-Gan ($X2(2) = 6.939$, $p < 0.05$), but not in Bnei-Brak. In Ramat-Gan, the elderly and children appear to adopt safer patterns than adults (0%, 3.9%, 8.6%, respectively, for running a red light). - Beyond age and gender, pedestrians in the orthodox environment committed about three times more violations than those in the secular environment.
King et al., 2009, Australia, Brisbane	- The risk ratios showed that crossing against the lights and crossing close to the lights both exhibit a crash risk per crossing event approximately eight times that of legal crossing at signalised intersections (8.1 resp. 7.8).
Rosenbloom, 2009, Israel, Tel Aviv	- 13.5% of the pedestrians arriving in the red-light phase crossed the street on a red light. - The more pedestrians present at the curb, the lower was the rate of people crossing on red. - No evidence for the hypothesis of the study that the probability that someone will cross the street when the light is red is higher in a situation where another pedestrian is already crossing on red than in a situation where the other people on the curb are waiting for the green light. - A higher rate of males crossed the street on a red light than females, independent of whether they were individuals or in a group. - Traffic volume did not predict pedestrians' behaviour.
West et al.,, 2010, USA, Maryland	- Of those who encountered a traffic light at round 1, 3.8% of persons failed to stop appropriately (assessed over a 5-day period); offenders were modestly clustered, with 15% of offenders failing 10% or more of the traffic lights they encountered. - Mean failure rates for drivers encountering 1 – 6, 7 – 11, 12 – 17, 18 – 27, >27 traffic lights were 0, 0.0035, 0.0018, 0.0024, 0.0020. - At round 1; race, the cognitive measure of attention, and AVF (= attentional visual field) were significantly related to failure to stop at a red light. - In the multivariate analysis, ethnicity (black/whites), pain, and visual attention (AVF) were significant predictors of red light running at round 1. In neither round was age (between the ages of 67 and 87 years) or the measure of psychomotor speed significantly related to failure to stop at a red light. Loss of AVF was related to failure to stop at a red light at both rounds. - The stronger predictor of failure to stop at a red light was the loss of AVF in the vertical meridian. The researchers hypothesize that, as older drivers approach an intersection and are paying attention to surrounding cars and traffic flow; the loss of vertical attentional field would hamper detection of the high-hanging traffic signal, which may have changed colour.
Johnson et al., 2011 Australia, Melbourne	- The rate of red light non-compliance was 7% (n=4225 cyclists). - Cyclists turning left were 28.4 times more likely to RLR than cyclists riding straight. - Females had odds of RLR of 0.60 compared with males. - Cyclists at the centre facility had a 2.6 higher odds of RLR than cyclists at the standard facility site. - RLR was most likely when the cross traffic volume was low and decreased when cross traffic volume increased. - When compared to cyclists at the intersection alone, odds of RLR were 0.39 compared when a driver was present and 0.26 when other cyclists were present.
Wu et al., 2012, China	- More than half (56%) of the two-wheelers crossed the intersection against a red light. - A lower proportion of older riders ran against the red lights than that of the younger groups. - The RLR probability of a rider was higher when she or he was alone, when there were fewer riders waiting, and when there were riders already crossing on red. - Two-wheelers' crossing behaviour was categorised into 3 distinct types: law-obeying (44%), risk-taking (31%) and opportunistic (25%). - Males were more likely to act in a risk-taking manner than females, and so were the young and middle-aged riders compared with the old ones. - The rider type (e-bike riders vs. cyclists) did not predict RLR decisions after the effects of other variables were statistically controlled.
Gates et al.,	- Drivers were 125.5% more likely to commit RLR when they approached signals with yellow durations

2014, USA	of less than or equal to 4.5s than when they approached signals with longer yellow durations. - Drivers were 41% more likely to commit RLR if they were traveling as a part of a platoon of vehicles. - RLR was also found to be 21% more likely to occur at locations with speed limits ≤ 40 mph. - Drivers were more likely to commit RLR when they were located a greater distance from the intersection at the onset of the yellow indication. The elasticity for this variable suggests that for drivers traveling through the intersection, each 1% increase in distance from the intersection at the onset of the yellow indication results in a 9% increase in the likelihood that RLR will be committed. - Go-through drivers approaching the intersection at a lower rate of speed before the yellow indication were also found to have a greater likelihood of RLR, likely because of the greater travel time to the intersection. A 3% increase in RLR was estimated for every 1% decrease in approach speed.
Pai & Jou, 2014 Taiwan	- Off-peak hours were associated with an increase in the probability of RLR risk-taking behaviours (19%). - Male cyclists are associated with an increased probability of RLR risk-taking behaviours (46%). - Bicyclists of pupils in uniform (6-18 yrs.) were found to be more likely to have risk-taking and opportunistic behaviours (79% and 85% respectively) than the other age groups. - Bicyclists carrying passengers were less violation-prone (89% and 81% for risk-taking and opportunistic behaviours). - Riders of electric bicycles were more likely than those of traditional bikes to engage in RLR risky behaviours (i.e., 33% and 41% for risk-taking and opportunistic behaviours). - Un-helmeted cycling was associated with an increase in the probability of RLR risk-taking and RLR opportunistic behaviours, 76% and 79% respectively. - Fine weather was found to result in an increased likelihood of RLR risk-taking behaviours (9%). - Roadways with speed limits of 60 km/h increased the probabilities of risk-taking and opportunistic behaviours (72% and 76% respectively). - Roadways with red lights that endure 30s had higher probability of opportunistic behaviours (74%). - Bicyclists travelling through T/Y intersections tended to engage in more risk-taking behaviours (113%). - There appears to be an increased likelihood of risk-taking and opportunistic behaviours when traffic volume is low (<15 min–1), resp. 69% and 53%. - Countdown signals with duration of 30s were associated with bicyclists' RLR opportunistic behaviours (41%).
Dommes et al., 2015 France	- Demographic factors, age and gender, did not explain RLR; neither did traffic density or variables linked to individual mobility. - Two of the contextual factors explained RLR: the probability of crossing against the light was larger when pedestrians crossed alone rather than in groups, and when vehicles were parked near the crosswalks. - The probability of RLR was associated with 3 precursor behaviours: pedestrians who crossed against the signal were more likely to look toward the traffic before crossing but less likely to look toward the light or toward the ground before crossing. - RLR was associated with three behaviours during the crossing phase: pedestrians who crossed against the light where more likely to run while crossing, to look toward the traffic while crossing, and to cross diagonally.
Richardson & Caulfield, 2015, Ireland, Dublin	- An average of 61.9% of cyclists break the lights in Dublin City Centre (n = 3064). - An average of 97.8% of cycle track users broke the lights with the large majority of violations occurring during the pedestrian green phase (n = 1677). - The average RLR rate by cycle lane users was significantly lower at 18.6%, with the majority breaking the lights during a motorist phase (n = 1387). - Males were the most likely to break lights.
Wang et al., 2015, China, Changsha City	- Of 5,612 observations at road intersections, 2.2% were coded as the bus driver 'running traffic lights' (95% CI: 1.9%- 2.7%) . - The incidence rate of RLR was lower on cloudy days compared to sunny days (adjusted Incidence Rate Ratio (IRR): 0.60).
Yan et al., 2015, China	- The overall violation rates were much higher for motorcyclists, bicyclists and pedestrians than for motor vehicle drivers (18.54–18.74 vs. 0.14 per 100 vehicles/pedestrians). - The violation rate for motor vehicle drivers on holiday was 1.89 times that on weekday (95% CI: 1.33–2.70). - The violation rate of RLR for motorcyclists was higher in off-peak hours than in peak hours (adjusted VRR: 1.11; 95% CI: 1.06–1.18), but lower on weekends and on holiday than on weekdays (adjusted VRRs: 0.80, 95% CI: 0.75–0.85; 0.65, 95% CI: 0.61–0.69). - The violation rate was 32% lower on weekends than on weekdays (adjusted VRR: 0.68; 95% CI: 0.57–

	0.81) for bicyclists. - For pedestrians, the violation rates were higher on weekends and on holiday and in off-peak hours than those on weekdays and in peak hours, having adjusted VRR of 1.09, 1.67 and 1.30, respectively.
Yang et al. 2015 China	- 2322 two-wheeled riders approaching the intersections during red light periods were observed in Beijing, China. - The RLR behaviour of most riders was dependent on waiting time; they were inclined to terminate waiting behaviour and run against the traffic light with the increase of waiting duration; over half of the observed riders could not endure 49s or longer. 25% of the riders could endure 97s or longer. - Rider type, gender, waiting position, conformity tendency and crossing traffic volume were identified as having significant effects on riders' waiting times and RLR violation hazards.

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