A Controlled Trial to Allow Motorcycles on Bus Lanes in Tel Aviv: An Assessment of Mobility and Safety Impacts

**ABSTRACT**

While motorcycles or powered two-wheelers (PTWs) provide mobility benefits in densely urban areas, their riders are exposed to a high risk of high injury. Bus lane use by PTWs has been implemented in some locations internationally as a measure for improving motorcycle safety and mobility. However, the impact of this practice has rarely been examined, with results reported mostly in the United Kingdom. It is anticipated that allowing PTWs to use bus lanes would better separate PTWs from other traffic, thus reducing PTW conflicts with other vehicles and improving PTW travel conditions. However, concerns have been raised regarding possible disturbances to bus traffic and the safety level of bus lanes. In Israel, a pilot project on the use of bus lanes by motorcycles was introduced in Tel Aviv on two major traffic routes of the city. The pilot included an observational study examining changes in traffic and road user behavior on the routes before and during the trial in order to assess the mobility and safety impacts of the measure. In addition, a comparison was made of road accidents during the trial compared to previous years. The study observations were collected by means of video recordings on road sections, traffic cameras at junctions, and mobile cameras attached to motorcycle helmets worn by a group of volunteer observers. The findings showed that during the trial, the rate of motorcycles using bus lanes increased by 4–5% when traffic was flowing, and by 6–8% when traffic was congested. Nonetheless, PTWs continued to be observed travelling on other traffic lanes. The rate of traffic incidents between PTWs and other vehicles did not change along the course of the routes, and actually decreased near junctions. The number and severity of conflicts between PTWs and other vehicles on the bus lanes did not increase, and the passage times of buses and PTWs along the routes did not change. Accident numbers did not change substantially on either route during the trial, yet signs of a decrease in accidents involving motorcycles were observed. Overall, allowing PTWs on the bus lanes in Tel Aviv resulted in slight improvements in motorcycle mobility, without any detrimental effects on bus travel times or safety. The absence of substantial changes during the trial indicated that the measure “regulated” the already existing traffic situation.

**1. Introduction**

Various methods for reducing motorcycle accidents can be found in the literature, including: technological means to prevent collisions; travel speed limitations; improvements to motorcycle stability; driver training and information; traffic law enforcement; improvements in motorcyclists’ protective gear; improvements in carriageway maintenance; and more (ETSC, 2008). One method for reducing injuries to motorcyclists is associated with traffic management. Asian countries, with high rates of motorcycle traffic, have traffic arrangements for motorcycles, including specially-designated lanes for them (ITF, 2016). In contrast, in European cities, including London, Stockholm, Paris, Vienna, and Barcelona, motorcycles are permitted to travel in bus lanes (2-Be-Safe, 2012).

* 1. **Previous research on the use of bus lanes by PTWs**

During rush hours, motorcycles tend to weave between lanes and even move into oncoming traffic lanes to bypass standing traffic. Such behavior gives rise to several dangers, including colliding with traffic in the oncoming lane or with the opening of doors of stationary cars, or hitting a pedestrian seeking to cross the standing traffic (IHE, 2015). Allowing motorcycles to travel in bus lanes is thought to prevent such dangers. Similarly, it is assumed that two-wheeled vehicles using bus lanes will not interfere with bus traffic because they can clear the road by moving into adjacent lanes when necessary. Additionally, collision risks with other vehicles is thought to be reduced by opening bus lanes to motorcycles, as the motorcycles are not forced to crowd within lanes shared with other vehicles, thereby reducing collision and accident risks (2-Be-Safe, 2012). On the other hand, concern has been raised that motorcycles travelling in bus lanes will exacerbate safety problems as the result of increased friction or competition between buses and others using the bus lane and motorcycles. Additionally, there are those who claim that adding motorcycles to the bus lane will interfere with bus schedules. Nonetheless, according to assessments of programs implemented in various European experiments, as a rule, permitting motorcycle travel in bus lanes did not cause any deterioration in safety or any considerable change to bus schedules (2-Be-Safe, 2012).

In England, a series of studies were conducted to examine the effect of motorcycle use of bus lanes. For example, the Transport for London Authority (TfL) (2004) summarized the experimental results for allowing two-wheeled vehicles to use three London bus lanes. The pilot project was conducted over a two-year period. The research found that during the experimental period: there was a decrease of all accidents and accidents with two-wheeled vehicles; the number of motorcycles in the bus lanes increased significantly but decreased in other traffic lanes; and bus travel speed increased after the change was implemented.

Subsequent research by TfL (2008) performed a broad assessment of the above traffic arrangement’s effect over a period of 36 months, using a number of methods to analyze the changes in traffic incidents. It was found that the new traffic arrangement was associated with an improvement in safety according to most assessments of accidents involving motorcycles. Nonetheless, the results were not statistically significant. Additionally, in 2008, TfL (2008) presented a summary of previous experiments conducted in England in which motorcycles were permitted on bus routes, including:

* An experiment on the M4 in London in which there was a decrease in accidents involving motorcycles as well as in all accidents during the new traffic arrangement period;
* An experiment carried out in in three London districts: Westminster, Kingston, and Richmond. There, following permission for motorcycles to use bus lanes, a decline was observed in accidents with vulnerable road users, namely, motorcycles, pedestrians, and bicycles. However, the calculations were carried out without control groups;
* An experiment carried out in Bristol along a 16 km stretch of bus lanes, in which no accidents involving motorcycles, pedestrians, and bicycle riders were observed during the first six months of the new traffic arrangement’s initial implementation, and a decline in accidents involving motorcycles was observed for the duration of the trial period.

York et al. (2008) examined changes in traffic patterns and safety following permission granted for motorcycle travel in bus lanes in the Westminster City area in London. In this research, a “before and after” assessment was carried out at eight chosen sites, which were characterized by features that could increase the chances for conflicts between various road users, such as: bus stations along the route; crosswalks; junctions with side roads; and more. To examine the implications of the new traffic arrangement, the data collected included: traffic counts with vehicle classification; video films documenting motorcycle behavior and the conflict situations; documentation of bus and motorcycle license plates at the entrance and exit points to calculate travel times; and an analysis of accident data. The research found that: the percentage of motorcycle use of bus lanes doubled during the new traffic arrangement period; most motorcycles kept to their lane; the number of conflicts between motorcycles, buses, and pedestrians declined; travel times for buses slightly increased; and the number of accidents did not change and even decreased during the “after” period.

In January 2009, motorcyclists were allowed to travel in most of the bus lanes in Metropolitan London. In research by York et al. (2010), findings were presented from the first 10 months of the implementation of the new traffic arrangement. Among the assessment criteria were: use of bus lanes by different vehicles; travel times of buses and motorcycles in PTRs; analysis of conflicts in bus lanes; analysis of road accidents. Most of the traffic and behavioral data were collected by video cameras with two static cameras placed at the entrance and exit of each site. Camera data was used to produce segment travel times, to classify vehicles using the lane, and to analyze the interaction between motorcycles and other road users. In the York et al. (2010) study, it was found that:

* The scope of motorcycle use of public transportation lanes rose by a range of 0–35% (with an average of 6%), during the “before” period, and up to 27–80% (with an average of 51%), during the period of permissible use of PTRs;
* The amount of traffic did not change, and even a slight rise of 4% of motorcycles in PTRs was observed;
* Bus speeds did not change, but there was a rise in motorcycle speeds;
* The conflict rate at intervention sites declined from about 3% to about 1%, although most were at a low severity level, thus, having no practical implications on safety.

Nonetheless, an analysis of accidents found a rise of accidents with motorcycles in roads with permanent traffic recorders (PTRs) during the period of the new traffic arrangement’s implementation. Therefore, when continuing the experiment in London, the designated speed limit for motorcycles was set at 30 mph, speed limits were enforced, and a public campaign to increase safety awareness was launched. In a continuing study by York, et al. (2011), an additional assessment was carried out on safety levels at sites with permissible motorcycle travel, both at the traffic grid level and at the group of sites according to the level of enforcement presence, in contrast with control groups. In the York, et al. (2011) study, it was found that both at the grid level and at selected traffic routes, the accident rate with motorcycles in segments with bus lanes did not change in comparison with control sites. The study concluded that the motorcycle accident rate in segments allowing motorcycle travel within bus lanes was not different than that of other routes in Metropolitan London. Following two experiments (York, et al., 2010; 2011), the London Department of Transportation announced permission for motorcycle travel in most bus lanes (IHC, 2015).

The 2-Be-Safe (2012) study reported on the experimental application of a new traffic arrangement in a number of bus lanes in Vienna, finding it to be successful, with no increase in accidents involving collisions between buses and motorcyclists. Among the benefits of allowing motorcycles to use the bus lane, this study pointed to improvements in motorcycle mobility without disturbing other road users and the prevention of motorcyclists weaving in and out of lines of vehicles, which reduced the chances for collisions between motorcycles and other vehicles.

The European 2-Be-Safe (2012) research presents motorcycle travelling in bus lanes as a method for mainly improving motorcycle mobility, while the European eSUM (2012) research project, analyzing experiments conducted in England, confirms that motorcycle use of bus lanes is a technique for improving motorcycle safety.

According to 2-Be-Safe (2012), motorcycle use of bus lanes is appropriate for application in urban areas and is considered to be efficient in countries with a high degree of compliance with the law. Factors to be taken into consideration when implementing this are the road environment, bus speeds, and bus density in the lane. According to 2-Be-Safe (2012), following permission for motorcycles to travel in bus lanes, a rise in the number of motorcycles travelling in PTRs and a decrease in motorcycle travel time can be expected, and motorcycle presence in bus lanes is not expected to influence bus travel times. However, care must be taken to ensure that there is no worsening in the number of accidents involving motorcycles after such a traffic arrangement is implemented compared to the preceding period.

* 1. **The Israeli study**

With the increasing density of urban traffic and increased awareness of the need for improved motorcycle mobility and safety, more cities around the world are considering the possibility of permitting motorcycle travel in bus lanes.

While such a measure has been introduced in a number of countries, there are few detailed examinations of its impacts, and those that exist have been reported mostly in the United Kingdom.

In Israel, following a decision by the Ministry of Transport and the Tel Aviv-Yafo Municipality, the use of bus lanes by motorcycles was introduced in the city of Tel Aviv, initially in the form of a trial on two major traffic routes, with a total length of 5.5 km (Figure 1). The measure was initiated in the middle of February 2016. The public was informed of the change through the media and new traffic signs installed on the roadsides showing that motorcycles had permission to use the bus lanes. The trial was planned for six months and was accompanied by an evaluation study to examine the mobility and safety impacts of the measure, comparing road user behavior indicators and accident changes on the two routes before and after implementation of the measure.

1. Methodology
	1. **The study framework**

The study included two urban thoroughfares, Ibn Gvirol Street (Route 1), and Namir Road (Route 2) (see Fig.1). Both streets are divided roads with a built median, curbside bus lanes, and two to three lanes of general traffic in each direction. The bus lanes were operated in the morning and evening hours on Route 1 and on the northern part of Route 2, and for the entire day on the central part of Route 2.

Based on international experience, the shared use of bus lanes by PTWs was expected to improve PTW mobility and to reduce conflicts between PTWs and other vehicles. In addition, it was not anticipated to have a detrimental impact on the travel times of buses or safety levels in the streets involved. All these factors, as well as changes in accident levels, were to be examined in the study based on field observations of traffic components and road user behaviors during the trial in comparison to the period prior to the trial.

The review of the state of mobility relating to travel times in selected test segments by motorcycles and buses in PTRs is based on an analysis of the behavior of motorcyclists and other road users in PTRs and adjacent traffic lanes, and subsequently, on the analysis of road accident data in street segments where the new traffic arrangement was implemented. The changes in mobility and safety were examined while considering the background metrics of the scope and composition of vehicle traffic in PTRs and adjacent traffic lanes in test streets. Thus, an examination of the implications of the new traffic arrangement took into consideration the following factors:

* The scope of motorcycle traffic and other vehicle types in PTRs and adjacent traffic lanes;
* Motorcyclists’ behavior: keeping to travel lanes; PTR use by motorcycles; creation of conflicts between motorcycles and other road users;
* Creation of conflicts between buses and other road users during travel in PTRs;
* Motorcycle travel time in the experimental segments;
* Bus travel time in the experimental segments;
* Creation of dangerous conditions in sensitive areas, such as near bus stations located on the PTR.

The experiment would be considered successful if the following changes were observed:

* A rise in the percentage of use of the PTRs by motorcycles and a decline in the number of motorcycles travelling in adjacent lanes;
* An increased percentage of motorcycles keeping within the traffic lane while travelling in the segment and a lower percentage of conflicts between motorcycles and other road users;
* A decline or no change in the percentage of conflicts between buses and other road users during travel in PTRs;
* A decrease of motorcycle travel time on routes with PTRs;
* No change or decline in average bus travel times in PTRs;
* No change or decline in creation of dangerous conditions in sensitive areas.

The experiment would be considered a success if it revealed a decline or no change in road accident rates during the experimental period in comparison to the period prior to the experiment.

* 1. **Data collection and analysis**

To determine the impact of the new traffic arrangement, several measurements and observations were carried out of traffic behavior before permitting motorcycles to travel in bus lanes, in the first two weeks of February, 2016 and three months after implementing the change in traffic arrangements, during May and the beginning of June of that year.

Several methods were used to collect data on traffic and behavior on the trial streets: fixed video cameras at different segments; video cameras at intersection control centers; mobile video cameras on motorcycles; and data on the Dan company bus travel times.

1. **Fixed video cameras** were placed at five segments on the trial streets. At each segment, two video cameras were installed at a distance of approximately 150 m from each other which filmed the activities on the PTRs and adjacent lanes for seven to ten hours. For each segment, the films produced traffic and behavior data, including:
	1. Traffic data: traffic volume and composition in each lane;
	2. Behavioral data of motorcycles travelling the segment;
	3. Behavioral data and conflicts in the PTRs;
	4. Behavioral data of motorcycles observed behind buses stopping at stations (if relevant);
	5. Identification of motorcycles at segment entrances and exits for evaluating segment travel time;
	6. Identification of buses at segment entrances and exits for evaluating segment travel time.
2. **Video cameras at control centers in Tel Aviv provided data from four intersections on the trial streets.** At each intersection, the films were made during a weekday for the duration of eight hours. For each intersection, the films served to produce traffic and behavior data, including:
	1. Traffic data: traffic volume and composition in each lane;
	2. Behavioral data of motorcycles for a short travel segment before and after the intersection;
	3. Behavioral data and conflicts in the PTRs;
	4. Behavioral data of motorcycles observed behind buses stopping at stations (if relevant).
3. **Mobile video cameras on motorcycles** worn by bike-club riders collaborating with the test activity, with some travelling on Route 1 and others on Route 2. The cameras were attached to the rider’s helmet or leg. The films were made during weekdays on each route when PTRs were active. Based on the video films, data were collected for calculating motorcycle travel times on the test streets. Likewise, motorcyclist behavior while travelling over the test segments was inspected, determining the travel lane upon entry and lane change while travelling.
4. **Data for bus travel time** on streets with PTRs were derived from the Dan bus company’s geographic data systems. The data was collected for both routes, in two travel directions, during the hours of bus lane operation.

Figure 2 presents a general view of placement of equipment used for collecting traffic and behavioral data of road users on the trial routes.

The video footage was decrypted manually by research team investigators. A selected researcher decrypted the same sites during an entire observation period. Forms were developed and uniform activity rules were defined for recording the data.

**A. Fixed video cameras at segments**

Two cameras were fixed at each segment, with one camera documenting traffic at mid-segment (the main footage). The second camera was placed at the end of the segment (closing footage). The main footage served for collecting traffic and behavioral data at the site and identifying motorcycles and buses at the entry or exit from the segment. The closing footage was used for repeat identification of motorcycles and buses by calculating segment travel times. For decryption, the main footage was marked by two aerial lines, and the final footage by one aerial line.

For example, Figure 3 shows aerial lines marked on the films from Site 2. At Site 2, a single line in the main footage served to count vehicles and identify motorcycles and buses entering the segment for calculating travel times, and identifying motorcycles and buses for documenting motorcycle and vehicle behavior in the PTR (“beginning segment follow-up”). The second line in this film marks the second boundary of the area for behavioral documentation (“end of segment follow-up”). The third line in the closing footage for Site 2 marks the line for identifying motorcycles and buses exiting from the segment (for calculating travel times).

The following criteria were used for documenting traffic and behavior:

* + - *Traffic counts* were made for all traffic lanes according to seven vehicle types. The counts were arranged over quarter-hour periods, after each half-hour of observations. The values were aggregated for hourly approximations. Each site received average values of traffic volume and traffic composition in each lane.
		- *Regarding motorcycle behavior* while travelling through the segment, the following data was documented:
	+ Traffic status (not in PTR) when the motorcycle appeared: traffic was moving, crawling or standing;
	+ Location: motorcycle travelling lane at the identification line;
	+ During moving or crawling traffic: did motorcycles change lanes while travelling (did not change, changed once, changed numerous times); did the motorcycle travel faster than the vehicles (yes, no); did the motorcycle travel in the PTR (no, partially, fully);
	+ During standing traffic: did the motorcycle change lanes while travelling; did the motorcycle weave between the vehicles in order to get ahead (yes, no); did the motorcycle travel in the PTR;
	+ Was a conflict observed between the motorcycle and another vehicle or between the motorcycle and a pedestrian? A conflict was defined as changing speed (braking) and/or a motorcycle changing travel direction in order to prevent a collision with another vehicle or pedestrian or changing speed (braking) and/or another vehicle changing direction to avoid colliding with the motorcycle.

Following the York, et al. (2010) study, four conflict levels were defined: 1) Preventative caution; 2) In control; 3) Near accident; and 4) Accident. Conflicts at levels 1 and 2 actually reflect states of interaction between the motorcycle and another vehicle or pedestrian, without creating risky situations.

Documentation of motorcycle behavior during segment travel was made for the first 15 motorcycles during each half-hour of observation.

* + - *Behavior in the PTR* was documented for buses travelling in the PTR and included the following data:
* Traffic status (not in PTR) when the bus appeared: moving, crawling or standing;
* Was there a lane change by the travelling bus;
* Was a conflict observed between the bus and other vehicle, or between the bus and a pedestrian while travelling in the PTR? Also, for this case, four levels of conflict were defined, but only for documenting event details.

Documentation of bus behavior in PTRs was made for the first 10 buses during each half-hour of observation.

* + - A specific documentation was made for instances when the motorcycle was behind *a bus that had stopped at a station on the PTR*. For characterizing such situations, the following data was collected:
* Documentation was made of each bus stopping at a station at stop time and time of travel resumption;
* If the motorcycle appeared behind the bus during its stop at a station, the time of its appearance was recorded; the state of road traffic when the motorcycle appeared; did the motorcycle make a lane change and if so, where did it go; was a conflict created between the motorcycle and other vehicle (with four severity level definitions as described above)?

This information was documented for each bus that stopped at a station. The total number of buses stopping at stations facilitated the examination of the frequency of instances when a motorcycle appeared behind a bus stopping at a station. This figure subsequently was used to examine the risk level in such situations (creation of conflicts).

* + - *Travel times* of motorcycles and buses were calculated following the completion of observation of each motorcycle/bus identified beforehand by aerial line 1 by adding travel time for that motorcycle/bus at the closing aerial line.

Travelling time was documented for the first five motorcycles and buses during each half-hour of observation.

A summary of metrics of behavior was obtained from each film footage.

**B. Video cameras at intersection control centers**

Using video cameras at intersection control centers, four intersections along the test routes were filmed: three on Route 1 and one on Route 2, while at three intersections, it was possible to film both travel directions oncoming and moving away. For each travel direction at the intersection, two aerial lines were drawn for documenting motorcycle travel along the segment and of buses in the PTR. Figure 3 presents the aerial lines marked on films at Intersection 77 on Route 1 for both travel directions. Documentation of motorcycle and bus behavior was made during their travel between lines 1 and 2, and 3 and 4 respectively.

Rules similar to those described above were used for documenting traffic and behavior caused by fixed video cameras in the segments.

**Accident analysis**

In addition, road accident changes were examined during the trial period in comparison to previous years, with regard to total accidents resulting in injury, severe accidents and accidents involving buses and motorcycles. Accident data for both routes were extracted from the national accident files for the period between January 2014 through August 2016.

The analysis of the accident data referred to the following two comparisons:

1. Between the “after” period from February through August, 2016 (seven months) and the “before” period from January from January, 2014 through January, 2016 (25 months);
2. Between the adjusted periods (to diminish seasonal effects): the “after” period of March through August, 2016 (six months) and the “before” period of March through August, 2014 and March through August, 2015 (12 months).

The analysis included a metric assessment of monthly accidents in road segments and intersections on two routes and compared them with the “before” and “after” periods.

The significance of differences in accident values was estimated using a T-statistic analysis.

3. Results

**3.1. Use of bus lanes and other lanes by motorcycles**

Table 1 presents a summary of the percentage of motorcycles in the traffic volume for each lane in the test segments, before and after implementing the new traffic arrangement (based on data from segment video cameras). One can observe that after implementing the new traffic arrangement, motorcycles constituted 14–26% of the vehicles observed in the bus lane on Route 1, and 5–14% on Route 2. Nonetheless, motorcycles were observed in lanes adjacent to the Public Transportation Route (PTR). For example, in nearby lanes, in segments on Route 1, between 6–15% of the vehicles were motorcycles, with 4–7% on adjacent lanes in Route 2. That is to say, the percentage of motorcycles travelling in adjacent lanes was lower than in the PTRs. However, motorcycle usage of adjacent lanes did not cease following implementation of the new traffic arrangement. In the “after” period, , there was a rise in the motorcycle presence in PTRs at most of the sites in comparison to the “before” one. In some of the PTRs, the change was significant and indicated an additional 5–6% of motorcycles in the PTRs. On average for all the segments, the proportion of motorcycles in the PTRs rose from 11% to 14% (a significant change, p<0.01). The rise in PTR usage by motorcycles under the new arrangement’s conditions was in accordance with expectations.

Nonetheless, the proportion of motorcycles in traffic during the “after” period also rose in adjacent lanes. This finding is contrary to expectations about the arrangement based on findings from international literature, where permissible motorcycle travel in PTRs was meant to reduce motorcycle travel in other lanes. Examining the total traffic volume and its composition during the “after” period in comparison to the “before” one (see table T1-b) shows that although the total amount of buses and their proportion in traffic did not change, the number of motorcycles passing through the test streets did increase, so that their proportion of the total traffic rose from 6% to 7%. The total number of motorcycles in traffic during the “after” period could possibly explain the lack of decline in motorcycle presence in adjacent lanes.

Table TJ1 summarizes the proportion of motorcycles in the traffic volume in each lane during both periods based on video footage at intersections. (As noted in Section 2, photos from four intersections were received from the Tel Aviv Municipality Control Center, which enabled an examination of traffic patterns and behavior in seven traffic lanes). The findings show that during the “after” period, the percentage of motorcycles in the PTR was at a 12–25% level on Route 1, and 8–10% on Route 2 (except for one site, J81, during morning hours, when the proportion of motorcycles was abnormally low). During the “after” period, the proportion of motorcycles observed in PTRs rose at all sites compared to the “before” period, with the exception of Site 81. In some cases, the increase was significant (see Table TJ1). As an average among all the sites in this grouping, the proportion of motorcycles in the PTR rose from 10.5% to 12.5% (significant change, p<0.01). Nonetheless, during the “after” period, motorcycles were observed in other traffic lanes. In total, the findings derived from an analysis of intersection camera data were similar to those from segment camera data presented above, showing an increased PTR use by motorcycles under the new traffic arrangement conditions, but accompanied by a continued presence of motorcycles in other lanes. This appears to be associated with the growth in volume of motorcycle traffic during the “after” period.

Table T2 contains a summary of traffic conditions during motorcycle travel in the test segments and motorcyclists’ use of PTRs, based on a sampling of motorcycles gathered by segment video cameras. In many cases, during both periods, the motorcycles were travelling in flowing or crawling traffic conditions, while there were only a few cases of congested conditions observed, mostly on Route 1, and the proportion of congested traffic declined during the “after” period. During the “after” period, at the identification line for motorcycles in the segment, 38–39% of them were observed in the PTR at Sites 1 and 2, with 22–24% at Sites 4 and 5. The extent of PTR use by motorcycles was lower at Site 3 (one can also discern a similar finding in Table T1). In a comparison between the two periods, there were no outstanding changes in the proportion of motorcycles observed in PTRs at segment entrance lines.

In the “after” period, during travel in a segment with flowing or crawling traffic conditions, between 24–60% of the motorcycles used the PTR at most of the sites (see Table T2). Similarly, during the “after” period, there was a significant increase of PTR use at Sites 2–4 in comparison with the “before” period. In contrast, at Site 3, a decline in PTR use was observed during the “after” period (up to 14%). During travel in a segment under congested conditions, most motorcycles used the PTRs at Site 1. There was a significant increase in the number of motorcycles travelling in the PTR observed during the “after” period compared to the “before” period. In summary, during the “after” period there was a rise in PTR use by motorcycles compared to the “before” period. On average, between the test segments, an increase of 4% was obtained in PTR use by motorcycles in flowing or crawling traffic conditions; 6% during congestion; although, as said, the changes were not uniform at all sites.

Also, according to intersection camera data (Table TJ2) most of the motorcycles were observed in flowing or crawling traffic conditions, while congestion was observed mainly at two intersections (J77 and J81, in the same travel direction); the proportion of congested conditions in intersection areas rose during the “after” period. In travel segments near intersections, during the “after” period, at the identification line for motorcycles (at segment entry in the film footage), 32–35% of them were observed in the PTR on Route 2, 17–40% on Route 1 in the southerly direction, and 7–16% on the same route in the northerly direction. In comparison with the “before” period, at most sites, there was a marked increase in the proportion of motorcycles observed in the PTRs during the “after” period. This was significant at all sites. The estimated average proportion of motorcycles observed (at the identification line) in the PTRs rose by 3.8%.

During flowing or crawling traffic conditions, most motorcycles did not travel on the PTR. During the “after” period, at all sites except for one (J81 in the northerly direction), a rise in PTR use was observed in comparison with the “before” period. This was significant in many of the cases. According to an estimated average of all sites, the proportion of motorcycles travelling in the PTRs rose by 4.7%. During congested conditions, most motorcycles travelled in the PTR; for example, 54–77% during the “after” period. During the “after” period, there was a marked increase in the proportion of motorcycles observed in the PTRs compared to the “before” period. This was significant in a number of cases (see Table TJ2). As an estimated average, the proportion of motorcycles travelling in the PTRs rose by 8% during congested periods.

It is to be noted that according to video films taken by dynamic cameras of motorcycles passing through the test segments during the “after” period, the percentage of PTR use by motorcycles rose. Nonetheless, motorcycles did not cease also travelling in other lanes according to the segment traffic situation.

**3.2. PTW behavior: Keeping in lane and conflict occurrence**

Other behaviors that the new traffic arrangement was supposed to influence were: motorcycles keeping in traffic lanes while travelling in the segment; motorcycles weaving around other vehicles during congested conditions; and creation of conflicts between motorcycles and other road users. Table T3 presents findings regarding these issues (based on segment video footage). One can see that in flowing or crawling traffic conditions, inconsistent changes were observed for keeping within traffic lanes by motorcycles travelling in the segment during the “after” period compared to the “before” one. There was a significant rise in the proportion of motorcycles changing traffic lanes at Sites 2 and 4, but a significant decline at Sites 3 and 5 and no change at Site 1. Comparing data from the motorcycle sampling during congested conditions at Site 1 in the “after” period to the “before” period, it can be seen that fewer motorcycles changed lanes or weaved in between vehicles to get ahead (p<0.05). This effect was less observable at all the other sites.

Both before and after implementing the new traffic arrangement, conflicts between motorcycles and other vehicles were rare occurrences. Comparing the “after” and “before” periods, there was a rise in the extent of conflicts at Site 4, from 0–4.5%. However, all the occurrences were of Level 1 type (“precautionary”), which actually reflects the interaction between the various road users without any real danger. In comparison to the “before” period, during the “after” period, Level 2 type conflicts were not observed. Serious Level 3–4 conflict occurrences were not observed at any test sites. Likewise, in all traffic situations during the “after” period, no conflicts between motorcycles and pedestrians were observed in any of the test segments.

Table TJ3 presents a summary of findings for the above issues for travel areas close to intersections (based on intersection cameras). The findings show that in flowing traffic conditions, during the two periods, most of the motorcycles (61–83%) did not change traffic lanes. In the “after” period compared to the “before” period, there was a rise in motorcycles keeping to their lanes was noted at most of the sites, while in two cases, the rise was significant. In traffic jam conditions, at most of the sites during the “after” period, more than half the motorcycles (52–64%) did not change traffic lanes, while in a comparison between the “before” and “after” periods, mixed changes were recorded for this behavior. At most of the sites, during traffic jam conditions, most of the motorcycles weaved between vehicles in order to move ahead. However, at intersection J81, there was a decline in the extent of weaving motorcycles during the “after” period compared to the “before” period.

In the “after” period, in flowing traffic conditions, almost no conflicts were observed between motorcycles and other vehicles (see Table TJ3). Those observed cases were of the type of interaction between various road users without any collision risk. Also observed was an “almost accident” between a motorcycle and a pedestrian (at Intersection J151), where the pedestrian crossed at a red light. In traffic jam conditions, at all intersections in the study, no conflicts were observed between motorcycles and other vehicles or pedestrians.

It can be added that according to video films taken by dynamic cameras of motorcycles passing through the test segments, during both periods, no conflicts were observed between motorcycles and other vehicles. Nonetheless, during the “after” period, the lane change phenomenon by motorcycles did not decline.

To summarize; the findings show that when travelling through a segment, most motorcycles kept to their traffic lane, especially near intersections. However, during the new traffic arrangement period, no consistent improvement was found in this behavior. Similarly, in congested conditions, most of the motorcycles tended to weave between vehicles. Still, signs of a decline in the extent of motorcycle weaving around were observed during the new traffic arrangement period. During the “after” period, as compared to the one before, there was no significant difference in the occurrence of conflicts between motorcycles and other road users. The conflicts did not disappear, but they actually reflect the already existing level of interactions between motorcycles and other vehicles and do not point to a rise in risk.

Additionally, special attention must be devoted to conditions where the motorcycle appears behind a bus stopping at a station (see example in Figure 4). There is nothing to be found in the literature about this topic, but in the opinion of bus operators involved in the test, such situations can become dangerous because of the bus driver’s limited field of view which prevents the driver from being able to see the motorcycle behind the bus. Thus, permitting motorcycles to travel in the PTRs could increase that risk. For a focused examination of this issue, several special samplings of data from sites with bus stops (Sites 2, 3, and 4) were collected concerning motorcycle behavior when stuck behind a bus. It was found that such occurrences were common only at Sites 2 and 4. Table T4 contains a summary of findings at those sites. It is to be noted that at Site 2, the bus stop was on the PTR curbside (no bay), while at Site 4, the bus stop was in a bay.

In Table T4, one can observe that during the “after” period, in conditions where the motorcycle appeared behind a bus stopping at a station at Site 2, the motorcycle changed traffic lanes in most cases, while at Site 4, in half the cases, the motorcycle waited and did not change travel lanes. At both sites, if the motorcycle chose to continue travelling, it mostly chose to travel between the PTR and the adjacent lane. This behavior during the “after” period compared to the “before” period shows there was no change at Site 2, while at Site 4, more motorcycles chose to wait and did not weave between lanes. Likewise, during the “after” period, compared to the “before” period, in such situations, the prevalence of conflicts between motorcycles and other vehicles at Site 2 diminished. All conflict situations observed were without risk. Most of the cases were of the Level 1 (“precaution”) type, with only a few of the Level 2 (“under control”) type. To summarize, after implementing the new traffic arrangement, no dangerous situations were observed with respect to buses stopping. The number of interactions between motorcycles and other vehicles diminished or remained unchanged change where sufficient caution was taken by the parties involved in these incidents.

3.3. Travel times through the routes

Table T5-a presents a summary of travel times for buses in the test streets; the times were derived from the Metropolitan Tel Aviv bus operator’s geographic data system for a number of bus lines passing through the test routes. The findings show that during the period of the operation of the new traffic arrangement, no increase in bus travel time was observed. On Route 1, in the southerly direction, bus travel times were shorter during the “after” period than during the “before” period. In other cases, the differences between travel times during both periods were insignificant.

Table T5-b lists motorcycle travel times on test routes obtained from dynamic camera data on motorcycles. It can be seen that during the period of the new traffic arrangement compared to the “before” period, there was no change in motorcycle travel time on Route 1 in both directions and on Route 2 in the northerly direction, while on Route 2, there was an increase in the southerly direction.

It can be seen from these findings that the implementation of the new traffic arrangement for motorcycles did not cause an increase of bus travel time but also did not improve motorcycle travel times on the test routes.

**4. Discussion**

Table T9 presents a summary of the main changes observed in traffic characteristics and behaviors of road users along the test routes during the “before” period and after it, including a note as to whether the new traffic arrangement fulfilled or did not fulfill the expectations based on existing to international literature about the new traffic arrangement. It was found that:

* As expected, the new traffic arrangement caused an increase in PTR usage by motorcycles. However, this increase was not large since the motorcycles continued using the other lanes. Similarly, improvements in motorcycle travel use of the designated traffic lane was partial. As a result, interactions in traffic along the test routes between motorcycles and other vehicles did not disappear.
* For all traffic situations examined — travelling in street segments, near intersections, in the area of bus stops — the new traffic arrangement did not bring about any essential change in the incidence of conflicts between motorcycles and other road users. Indeed, there was no decline in interactive situations between motorcycles and other vehicles. Nonetheless, all the incidents observed ended without any actual danger of collision. Observational findings show that the examined new traffic arrangement was not associated with a worsening of traffic safety in PTRs.
* Because of small changes in motorcycle behavior, the new traffic arrangement did not bring about a decrease in motorcycle travel times along the test routes, but neither did it hinder bus traffic nor increase their travel times.

In summation, the Tel Aviv experiment displayed mixed results. The test findings show that integration of motorcycle travel within PTRs is associated with signs of slight improvements in motorcycle traffic without impairing bus travel and without signs of deteriorating safety for road users. Traffic and behavior characteristics of motorcycles under the new traffic arrangement conditions were very similar to the metrics existing in the previous period before implementing the new traffic arrangement. Therefore, it can be concluded that the experiment in Tel Aviv actually “regulated” the actual traffic behaviors observed.

The absence of substantial behavior changes during the trial indicated that the measure essentially “regulated” the situation that was already present in traffic patterns.