Free-Flow Travel Speed Analysis and Monitoring at the National Level Using Global Positioning System Measurements

Shlomo Bekhor[1]; Tsippy Lotan[2]; Victoria Gitelman[3]; and Smadar Morik[4]

Abstract: Among the main factors affecting road crash injuries, speed is considered as a leading cause and contributing factor. There are numerous studies linking travel speeds and road crashes. Hence, an essential part of road safety plans and interventions is devoted to speed management. However, to manage speed, actual travel speeds have to be systematically and consistently monitored and analyzed. In this study, a system for the collection and analysis of free-flow travel speeds on the road network is presented, enabling speed monitoring at the nationwide level. The paper focuses on the collection and analysis of travel speeds on different road sections. Using the information gathered through advanced technologies combined with geographical information systems, a comprehensive speed database in space and time is provided allowing visual presentation and comparison of the results. This analysis can identify the road sections with significant excesses of travel speeds relative to the speed limits. It can also serve as a baseline to evaluate the impact of various counter-measures employed to reduce speeds. **DOI:** 10.1061/(ASCE)TE.1943-5436.0000607. © *2013 American Society of Civil Engineers.*

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Introduction

Speed is a key factor in road safety. The correlation between speed and road crashes has been extensively studied and established both as a causal factor and as a factor that increases the severity of crashes (Aarts and van Schagen 2006; Hauer 2009; Shinar 1998). Specifically in Israel, several safety-related speed studies were conducted (Gitelman and Hakkert 2003; Gitelman et al. 2010). The overall conclusion of the scientific research clearly proves high correlation between high speeds and high crash severity as well as excessive level of actual travel speeds. In light of these findings, a need for speed management was stated [Organization for Economic Co-operation and Development (OECD) 2006]. The main method used in the world to manage speed is to impose speed limits by law, accompanied by law enforcement, publicity, and driver education. There are a few other methods, such as infrastructure changes (e.g., traffic calming) that are mainly suited for local roads, use of advanced technologies for self-enforcement (e.g., intelligent speed adaptation), and more. Although existing methods to manage speed do influence actual speeds, in practice, it is typically to a limited extent and relies heavily on enforcement. Studies of different locations show different compliance rates with the speed limits, depending on road types (e.g., Goldenbeld and van Schagen 2005).

To manage speed, it is of utmost importance to keep track of actual speeds over time. The monitoring of speed and its relationship with road crashes constitutes a major challenge and can be done in various ways. One method measures individual vehicle speed, and interviews the drivers (through mail based on license plate matching, or when they are asked to pull over) with a self-report questionnaire about road crash history and their severity (Quimby et al. 1999). Another method restores the speeds of vehicles before the crash (by different physical methods) and compares them with speed distribution of the overall vehicles in every road section (Kloeden et al. 2001). A third method uses the statistic correlation between the overall vehicles speed in a variety of road sections and the number of crashes by severity in each road section (Baruya 1998). A fourth method relies on "before and after" studies of speed and road crash changes on the same road sections (Elvik et al. 2004).

Past studies indicate a large variation with respect to speeding. In Israel, a speed survey conducted in 17 interurban road sections in July 1998 demonstrated that the percentage of vehicles exceeding the speed limits (in the free-flow hours) varied between 10% and 96%, with an average value of 58% (Hakkert et al. 2001). On the basis of the information from some 15 countries, OECD (2006) reported that 15–80% of drivers exceeding speed limits.

The National Road Safety Authority conducts a speed survey every year in Israel (Gitelman et al. 2010). The survey focuses on speed distribution during free-flow conditions, and it is held at 135 measurement sites on a nationwide basis. The measurements are derived from mechanical counters in interurban roads and major arterials urban roads and from laser guns in small urban streets. The speed indicators include average speed, 85th percentile, standard deviation, and percentage of drivers over the speed limit. According to these surveys, for instance, the 85th percentile of the speed on

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freeways is higher than the speed limit by 15–16 km/h, where the percentage of vehicles above the speed limit was around 50%.

All of the conventional methods to measure speed are based on the deployment of equipment in the measured road sections, whether temporary or permanent (OECD 2006). Because of the relatively high cost of the equipment and its deployment/installation, speed measurements are typically conducted at a low frequency in road locations that are selected for different purposes and cover only a small part of the road network. (In Israel, permanent measurement equipment exists on two roads only: the Ayalon Highway—a suburban freeway—and Road 6—a trans-Israel freeway.) Such specific measurements allow performing targeted speed examinations, but they do not supply systematic databases for evaluation of actual speed distributions in time and space.

In recent years, with the development of cellular technologies and vast penetration of global positioning system (GPS) devices, several attempts were made to develop sampling methods on the basis of the speed assessment of vehicles equipped with cellular phones or GPS to characterize speeds in the road network. The main activity in this field so far focused on characterizing the average speed in congested conditions and the assessment of delays in driving duration, mostly for navigation purposes. Results of these studies indicate a great potential of these technologies to provide accurate estimates of actual and current traffic conditions (Ygnace et al. 2000; Bar-Gera 2007; Krause et al. 2008). In particular, a study in Germany using floating car data collected from vehicle fleets showed the ability to detect congested situations and provide reliable travel time information (Brockfeld et al. 2007). From the work that was done so far, it is reasonable to assume that similar methods can be used to receive estimates of speed distribution during free-flow conditions, which are needed to monitor, analyze, and manage road safety.

The advantage of these methods stems from the availability of the data without a need to install or deploy equipment of any sort. Therefore, having defined the methods required for data processing, it is possible to receive assessments of the speed distribution on every road section in the road network as well as to evaluate trends of the changes in speed throughout time or because of various intervention activities.

A pilot study conducted in 2008 in Israel for the first time collected free-flow speed data on all interurban roads in Israel (approximately 8,000 km). The speed measurements were collected through cellular phone technology (Lotan 2008). The technology enables handover events for which control of a presently used phone is handed over from one cell to another. Typically, handovers occur about once a minute, and phone calls last 3–10 min. The system observes all handovers for every phone that is on during a conversation, and their time stamps. The accuracy of the system is dependent on the number and duration of calls. However, in free-flow conditions, the number of vehicles was relatively small, and the correspondent share of conversations was too small to obtain reliable estimates.

To monitor road infrastructure characteristics, road user behaviors, and injury data, it was decided to establish a geographic information system that would allow visual as well as analytical monitoring and analysis of data related to traffic safety. In particular, the system will be capable of receiving data from various sources such as detailed infrastructure data (e.g., number of lanes, signs), traffic counts, travel speed data, data from in road-installed sensors, speed camera data, driving events obtained from advanced technologies [e.g., in-vehicle driver recorder (IVDR)], and road crash and injury databases.

The main objective of this study is to create a national database that integrates several data sources in a geographical information system (GIS) environment. This paper focuses on the analysis of free-flow travel speeds at different road sections. The current research provides a comprehensive speed database in space and time by using the information gathered through advanced technologies combined with a geographical data system that allows visual presentation of the data. This analysis can identify the road sections with significant excesses of travel speeds relative to the speed limits. It can also serve as a baseline in evaluating the effects of various countermeasures employed to reduce speed.

Methodology

This section describes the research methodology. First, an examination of the accuracy of the GPS measurements is presented. Then the data processing and map matching of the speed data into the GIS road database are specified.

Speed Measurement Accuracy

Given the large penetration of GPS in both fleet and private cars, the present study makes use of commercial data available from GPS measurements. The travel speeds used in this study were provided by Decell Technologies, which stores speed measurements from both GPS and cellular phone technologies. For this research, the speed measurements were extracted from GPS data only. This study benefits from the fact that, because of insurance policies in Israel, not only are company vehicle fleets equipped with GPS, but also a certain share of private cars. According to the information provided by Decell Technologies, the share of vehicles equipped with GPS is more than 40% for buses and trucks in the data set and around 5% for private cars. Given that there are over 2 million private cars, 30,000 buses, and 50,000 trucks in Israel (Central Bureau of Statistics 2012), the overall sample contains 12,000 buses, 20,000 trucks, and 100,000 private cars, which is large enough for estimating travel speeds.

To assess the reliability of the GPS speed measurements, the data collected were compared with an independent data source coming from the Ayalon Highway, a north-south freeway crossing the Tel Aviv metropolitan area. Magnetic loop detectors permanently installed in the highway provide speed and occupancy data every 5 min, for each lane and direction. Fig. 1 shows the location of the loop detectors on the Ayalon Highway and the definition of the road sections.

Ayalon speed data are obtained from averages taken in 5-min intervals. The data are classified into five categories of different vehicles, and for each category, average speed and amount of vehicles traveling is provided. The loop detectors are placed every 500 m; the raw results received from the Ayalon Highways Company contain flow data and speed data for each loop detector, for each lane, in 5-min intervals (more refined data could not be obtained). The GPS data are not precise enough to compare data at the lane level. Therefore, the loop detector data were aggregated by section for all lanes to allow for comparison with the GPS data.

Because the study focuses on free-flow travel speeds for safety applications, it was necessary to locate the relevant highway sections. Fig. 2 shows the variation of the speed measurements on Ayalon Highway. The spatiotemporal dynamics representation follows Celikoglu (2013a, b) and Treiber and Helbing (2002).

According to the results presented in Fig. 2, for the purpose of examining speed anomalies, it is reasonable to use data from segments between 6.0 and 1.6 km and from 2200 to 0600 hrs. Therefore, data collected from two different sources during night hours (between 2200 and 0600 hrs.) in March 2011 were compared: Ayalon loop detectors and GPS observations. The data

Fig. 1. Magnetic loop detector placement and road section definition on Ayalon Highway (Map data © OpenStreetMap contributors, CC BY-SA)

collected from the GPS observations were matched to the same road sections provided by the Ayalon detectors.

Table 1 presents the results of comparison of the mean speeds estimated using the Ayalon data and the GPS data.

The results presented in Table 1 show a relatively good fit between speeds measured by the two methods, with a downward bias for the GPS speeds. The main explanation for this discrepancy is the way the average speeds are calculated: the loop detectors provide point estimates (time mean speed), whereas the GPS speeds are calculated for the vehicles passing each section (space mean speed). It is known that time mean speeds are typically greater than space mean speeds, where the literature shows that the free-flow time mean speed is 1% to 5% higher than space mean speed (May 1990; Han et al. 2010). In addition, GPS speeds were collected during a longer period (6 months) to provide sufficient observations.

Data Processing and Network Matching

The road network used for the analysis includes the 2011 Israel Traffic Message Channel (TMC) road network. This network contains most interurban roads and major arterial urban roads in main metropolitan areas (Haifa, Tel Aviv, and Jerusalem). The network comprises 1,593 road segments (between adjacent intersections) with an overall length of about 8,960 km. Out of the 1,593 segments, 1,383 relate to interurban roads and 210 to urban arterials.

The preprocessed observations contain raw speed data that were not manipulated in any way. To estimate the speed distribution in free-flow conditions only, traffic load has to be identified and filtered out. Traffic load is identified when post-processed data show road speed below 80% of average free-flow speed. To provide the population homogeneity, only private cars' observations are kept. Also, to avoid slow traffic in the proximity of traffic lights, vehicles within 40 m from traffic lights are filtered.

Thus, the overall analysis was performed with two main filters: (1) removing observations for which the average hourly speed section is 20% lower than the free-flow speed and (2) removing observations close to junctions. Because average hourly speeds are used for filtering, there might still be individual observations with low speeds.

In line with previous studies in Israel and international practice, different time periods were defined in which free-flow travel speeds are to be analyzed. A total of six different periods were defined: workdays (Sunday to Thursday), Fridays and Saturdays, and two hour periods: day (from 0600 to 2200 hrs.) and night (from 2200 to 0600 hrs.). Friday and Saturday correspond to weekend days in Israel, and Sunday is a workday.

The raw data were collected for 6 months, from February to July 2011, and after filtering, included over 30 million GPS free-flow speed observations. More than 90% of the 1,593 road segments have more than 1,000 observations. For privacy reasons, there is no information about the driver or the vehicle, so the same segment

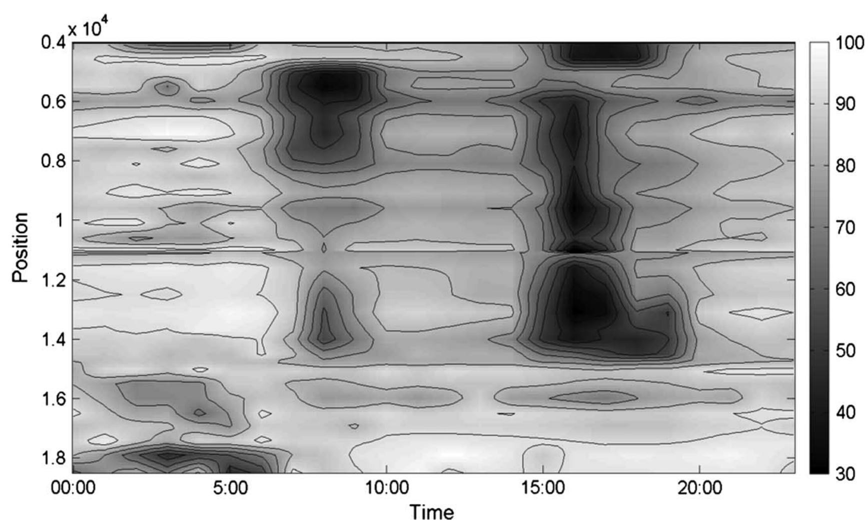

Fig. 2. Spatiotemporal variation of speed measure on Ayalon Highway

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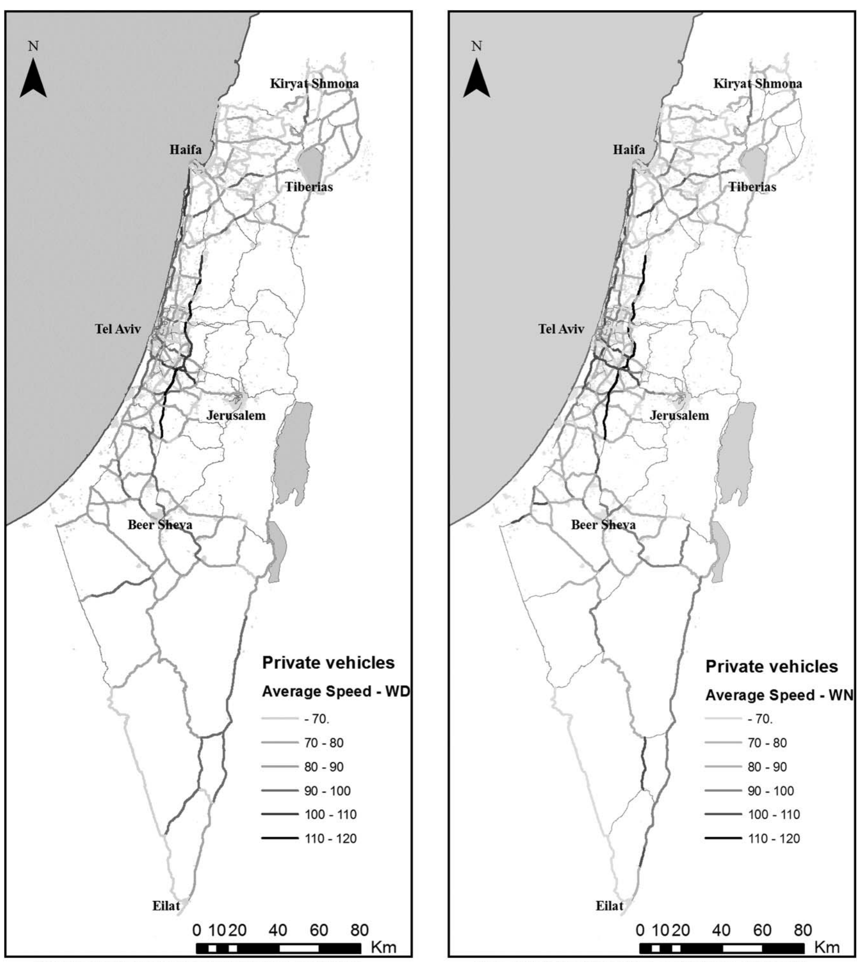
Table 1. Free-Flow Speed Comparison between Loop Detectors and GPS Speed Data

Direction	From junction	To junction	Loop detector speeds		GPS speeds		Relative difference in mean speeds (%)
			Mean (km/h)	Standard deviation (km/h)	Mean (km/h)	Standard deviation (km/h)	
North	Kibutz Galuyot	La Guardia	92.8	6.9	92.8	7.0	0.0
	La Guardia	Hashalom	99.5	5.8	98.7	5.3	−0.8
	Hashalom	Harakevet	96.0	3.9	95.7	6.2	−0.3
	Harakevet	Halacha	99.3	3.3	99.6	4.8	0.4
	Halacha	Rokach	103.2	2.4	103.4	7.0	0.2
	Rokach	Kakal	100.7	3.0	98.4	9.8	−2.3
	Kakal	Glilot	104.8	5.2	102.6	3.7	−2.1
	Glilot	Shevat Hakochavim	103.8	1.5	100.2	1.6	−3.5
South	Shevat Hakochavim	Glilot	104.5	2.8	98.2	4.6	−6.1
	Glilot	Kakal	107.3	2.2	102.0	4.0	−5.0
	Kakal	Rokach	108.9	2.8	101.5	3.6	−6.9
	Rokach	Halacha	105.0	4.3	95.3	4.4	−9.2
	Halacha	Harakevet	103.0	4.3	94.4	4.7	−8.4
	Harakevet	Hashalom	95.2	4.3	93.8	5.4	−1.6
	Hashalom	La Guardia	100.7	3.9	91.4	4.2	−9.2
	La Guardia	Kibutz Galuyot	94.1	4.3	93.9	11.2	−0.2
Average			101.2	3.8	97.6	5.5	−3.5



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(a)

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(b)

Fig. 3. Free-flow speeds on the national network for workday, day period: (a) average speeds; (b) 85th percentile speeds (Map data © OpenStreetMap contributors, CC BY-SA)

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might contain more than one observation for the same vehicle. Since the average segment length is about 6.0 km, and a GPS reading is recorded every 30 s on average, this means that a vehicle traveling at 90 km/h will give, on average, 4 GPS readings per segment.

Aside from GPS data, there was a need to gather information about the speed limit that enables calculating statistical speed indicators. Different data sources have different attributes: geographical (road segments and GPS data), alphanumeric (speed limits by road and junction), and numeric (distribution of the speed for each road section). Thus, as a preprocessing phase, there was a need to create a common geographical database that would join different data sources and allow the direct transition between them. Linking those different data sources constitutes a spatial topological problem of matching a set of points (which represent junction names) to lines (road segments). Positional accuracy, dimensional atrophy in geometrical representation of road as a line and junction as a point, and nonuniform spelling of junctions and road names pose a challenge in combining those data sources to create a geographical information system.

The GPS data containing the distribution of the speed for each road section at 5 km/h intervals were matched to the road segments. A mechanism for automating the process of statistical measures was developed (Bekhor et al. 2012). For each road section, the following statistics were estimated: mean speed, standard deviation, percentage of observations over the speed limit, the 85th percentile speed, and the excess speed (a difference between the 85th percentile speed and speed limit).

Results

Overall Statistics

This section presents selected results of the main statistics estimated. The study focuses on excess speeds at interurban roads. Figs. 3(a and b), respectively, illustrate the average speed and the 85th percentile speed at the national level, for the weekday–day period. Table 2 presents overall results for all road sections, classified by speed limits and periods of day.

In general, the results are in line with previous studies, indicating that about 50% of the drivers are speeding. The average speeds at night are significantly higher compared with the day average speeds. In addition, the average speeds on weekends are significantly higher compared with weekdays.

The tables also shows that for roads with a speed limit of 110 km/h, the excess speed is lower compared with 100-km/h speed limit roads. This might be explained by the fact that both cases are related to roads, with relative similar infrastructure characteristics, and therefore the average differences between the two cases are relatively small (6–7 km/h) compared with the difference in the posted speed (10 km/h). Nowhere in Israel does a speed limit of more than 110 km/h exist.

Mapping of Excess Speeds

Because the GPS data were matched to the Israeli Transverse Mercator (ITM) network, it is possible to show the excess speeds in the network. Figs. 4(a and b) show the excess speed for workdays and nighttime, respectively, in the central region of Israel.

The visual comparison between Fig. 4(a) and Fig. 4(b) clearly shows more road sections with high excess speeds at night. For example, roads Nos. 4, 232, 3, and 6 at the bottom side of Fig. 4(b) are in excess of more than 20 km/h at night. Looking closely at the figures, it is possible to see that Road No. 6,

Table 2. Average Statistics for Each Period and Speed Limit

Period	Speed limit (km/h)	Mean speed (km/h)	Standard deviation (km/h)	Percentage above speed limit (%)	85th percentile speed (km/h)	Excess speed (km/h)
Workday-day	70	55.4	18.4	29.4	72.6	2.6
	80	70.9	20.8	39.3	89.9	9.9
	90	80.5	20.5	39.0	99.1	9.1
	100	100.4	16.6	54.7	116.1	16.1
	110	104.2	16.5	38.5	119.8	9.8
	Average	75.9	20.1	38.4	94.3	8.9
Workday-night	70	64.0	18.9	39.5	81.5	11.5
	80	74.2	22.0	45.1	94.5	14.5
	90	85.6	20.9	48.3	104.7	14.7
	100	102.3	19.6	61.2	119.7	19.7
	110	108.5	18.5	48.7	125.7	15.7
	Average	81.0	20.9	46.6	100.2	14.4
Friday-day	70	58.2	19.0	32.5	75.9	5.9
	80	72.6	20.4	42.8	91.3	11.3
	90	82.9	20.9	43.7	102.1	12.1
	100	101.3	17.3	57.4	117.4	17.4
	110	107.0	16.5	44.9	122.7	12.7
	Average	78.2	20.2	42.5	96.8	11.3
Friday-night	70	65.0	19.6	42.4	83.2	13.2
	80	72.8	21.1	43.9	92.5	12.5
	90	87.4	20.1	51.4	105.8	15.8
	100	102.2	16.8	60.0	118.1	18.1
	110	108.5	17.2	47.9	124.8	14.8
	Average	83.0	19.9	48.6	101.5	14.7
Saturday-day	70	60.7	18.9	35.0	78.2	8.2
	80	72.4	20.5	41.6	91.3	11.3
	90	84.5	19.9	46.0	102.8	12.8
	100	101.6	17.1	58.4	118.3	18.3
	110	108.4	16.0	48.0	123.4	13.4
	Average	79.2	19.7	43.6	97.4	11.9
Saturday-Night	70	65.7	19.2	43.6	84.2	14.2
	80	77.6	21.0	52.0	97.4	17.4
	90	88.4	20.6	53.2	107.2	17.2
	100	102.2	18.9	60.2	119.8	19.8
	110	109.5	16.2	50.7	124.6	14.6
	Average	84.9	20.2	51.8	103.6	16.8

a north-south freeway with a speed limit of 110 km/h, has few sections with excess speed during the day period but high excess speeds at night.

The average results presented in Table 3 mask the effect of speeding on specific sections. Fig. 5 shows the distribution of the excess speeds for each time period. The figure also shows the first four moments—average, standard deviation, skewness, and kurtosis—for each time period.

The results presented in Fig. 5 show similar patterns for the excess speed distribution in each time period. All distributions are negatively skewed and exhibit positive kurtosis. This means that relatively few observations were with very high excess speeds.

Given the nationwide coverage of the vehicle fleet equipped with GPS, it is possible to pinpoint the roads and specific sections with high excess speeds. Table 3 presents the top 10 road sections with excess speed.

The table shows that the highest excess speeds are on Ayalon Highway sections where the speed limit is 70 km/h. In most sections of this highway, the speed limit is 90 km/h, but in short sections with entrance and exit ramps, the speed limit drops to

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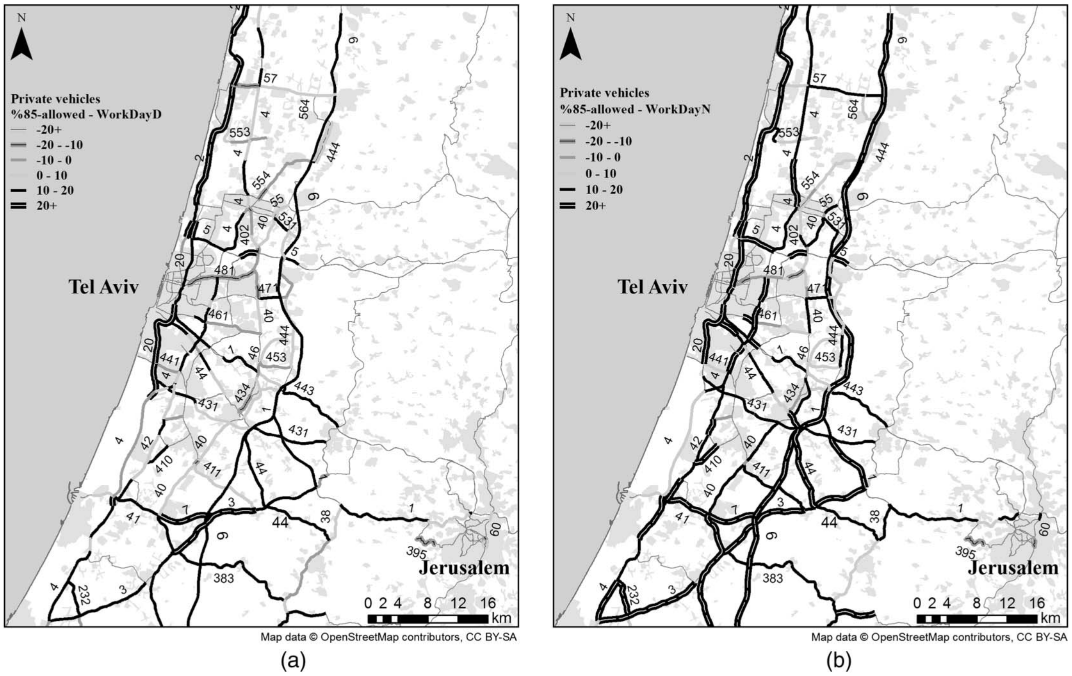

Fig. 4. Excess speeds in the central region, workday: (a) day period; (b) night period (Map data © OpenStreetMap contributors, CC BY-SA)

Table 3. Top 10 Road Sections with Excess Speeds

Traffic message channel road	From junction	To junction	Region[a]	Length (km)	Average speed (km/h)	Standard deviation (km/h)	Percent above speed limit (%)	85th percentile speed (km/h)	Speed limit (km/h)	Excess speed (km/h)
Ayalon South	Moshe Dayan	Mevo Ayalon	C	2.1	99.8	16.8	97	116.1	70	46.1
Ayalon North	Holot	Mevo Ayalon	C	2.8	99.0	16.4	97	115.0	70	45.0
Road 12	Shizafon	Ovda	S	14.0	97.8	28.6	80	125.0	80	45.0
Road 211	Shivta	Ktsiot	S	15.2	98.8	20.3	84	121.1	80	41.1
Road 40	Tzichor	Shizafon	S	26.5	97.7	21.6	86	117.7	80	37.7
Road 13	Tzichor	Menucha	S	11.4	94.1	27.2	84	115.9	80	35.9
Road 241	Maon	Urim	S	8.3	90.7	24.6	77	113.9	80	33.9
Road 258	Tzafit	Hatrurim	S	22.4	90.8	23.0	76	112.7	80	32.7
Road 4	Alenbi	Hagana	N	1.7	79.1	17.8	71	100.7	70	30.7
Road 234	Reim	Urim	S	10.7	86.5	25.3	68	110.1	80	30.1

[a]C = central; N = north; S = south.

70 km/h (see the first two lines of the table). Similarly, for Road 4, in most sections the speed limit is 90 km/h, whereas entering the metropolitan Haifa area there are sections with 70 km/h speed limit where actual speeds are still high.

Apart from these three cases, all other extreme cases refer to roads in the south region. These sections correspond to rural two-lane highways, in which the speed limit in Israel is 80 km/h. The explanation for very high speeding in these cases is related to the fact that the roads are in the Negev desert area, with low traffic in most hours of the day and little law enforcement.

Fig. 6 compares the top 30 excess speeds for each workday period: day [Fig. 6(a)] and night [Fig. 6(b)], using the GIS tool developed. Fig. 6(c) shows the superposition of Figs. 6(a and b), to illustrate that not all sections are consistent with respect to excess speed.

In addition to the excess speeds in the south region, the results presented in Fig. 6 show excess speeds in road sections with infrastructure characteristics resembling freeways with higher speed limits. For example, in Road 2 and Road 70 in the north region, the allowed speed is 90 km/h, but the road alignment is similar to Road 6 (a trans-Israel freeway with 110 km/h speed limit).

Excess Speeds by Vehicle Type

The data set contains information about vehicle type in three main categories: private cars (up to 3.5 t), trucks, and buses. The speed limits in Israel are different for trucks; on most roads the maximum allowed speed is 80 km/h. The speed limit for buses is identical to the limit for private cars. Table 4 shows average results for the workday-night period for each region and vehicle type. The excess speed was calculated separately for each road segment, and the table shows the average excess speed for all speed limits.

The average speeds in the center region are higher than other regions because of the higher share of multilane highways (with correspondent higher speed limits). The excess speeds of private cars are higher in comparison with trucks and buses. However, in the north and center regions, what is noticeable is the high excess

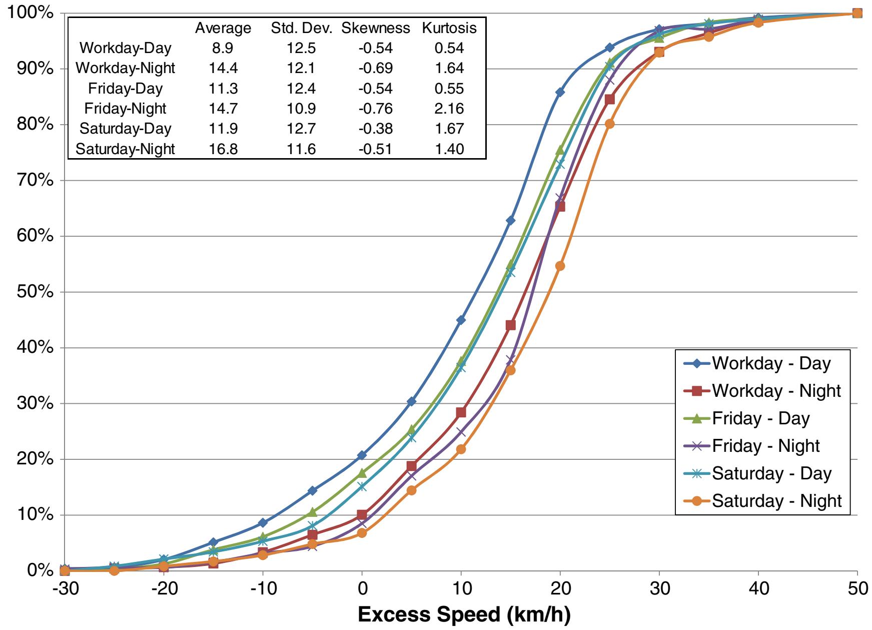

Fig. 5. Distribution of excess speeds by time period

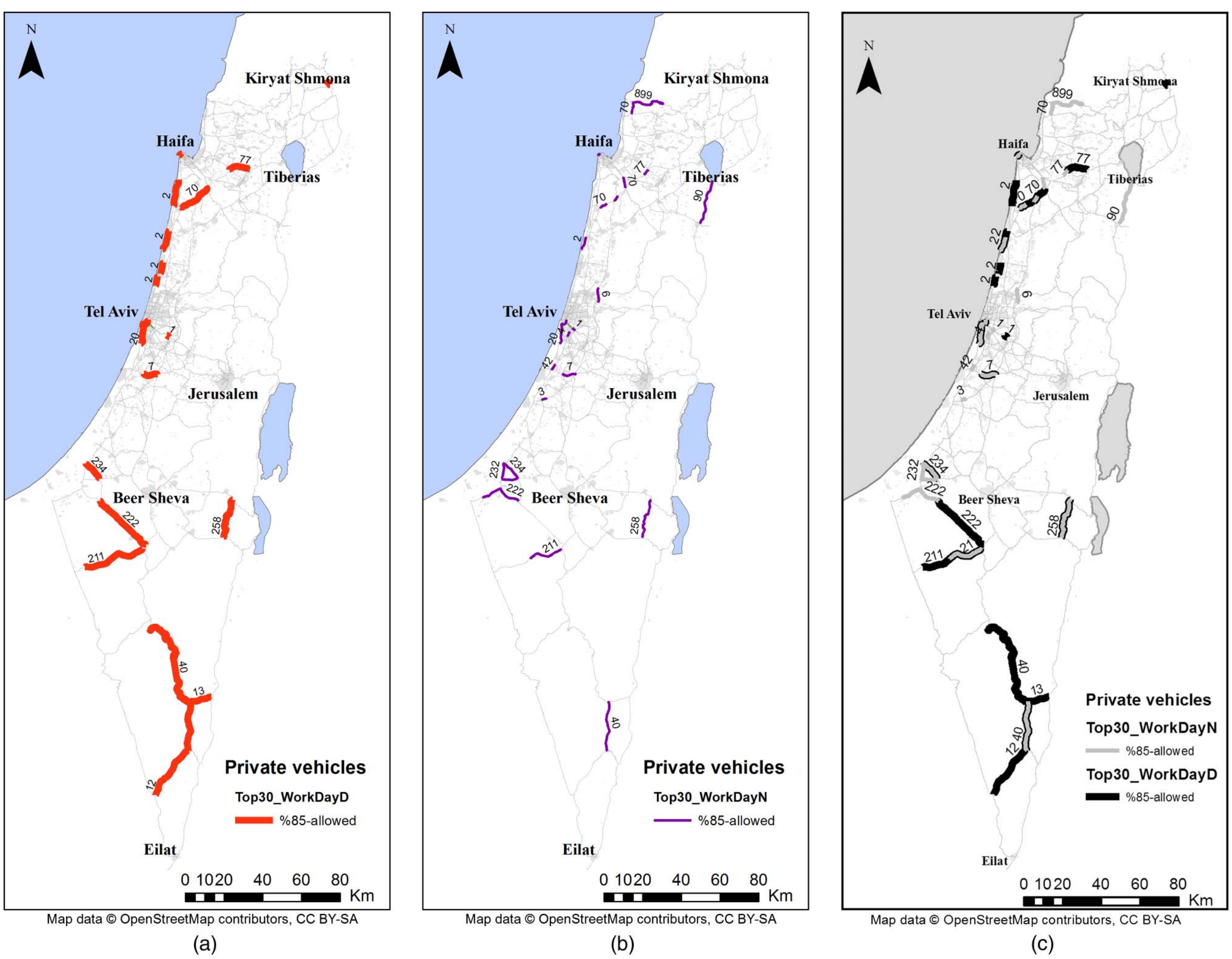

Fig. 6. Top 30 excess speeds: (a) workday-day; (b) workday-night; (c) superposition (Map data © OpenStreetMap contributors, CC BY-SA)

Table 4. Average Statistics by Vehicle Type and Region—Workday-Night Period

Vehicle type	Region	Mean speed (km/h)	Standard deviation (km/h)	Percentage above speed limit (%)	85th percentile speed (km/h)	Average excess speed (km/h)
Private car	North	80.7	21.5	47	100.1	14.6
Truck	North	71.1	20.0	31	87.4	7.4
Bus	North	84.5	16.5	45	100.6	13.6
Private car	Center	95.7	19.8	56	114.1	19.0
Truck	Center	80.3	15.9	29	90.9	10.9
Bus	Center	93.2	16.1	41	110.4	12.6
Private car	South	87.8	22.8	59	108.1	20.3
Truck	South	73.5	22.1	28	89.5	9.5
Bus	South	81.3	12.8	27	93.2	4.1

speeds for buses. Excess speeds for trucks are relatively low, which might be explained by speed limiters installed on trucks.

Summary and Conclusions

This paper illustrates the application of a GIS tool to analyze GPS free-flow speeds at a national level. The paper presents selected results, which can be easily derived from the system. These results can serve as a decision support tool for speed management. In particular, stakeholders and road safety organizations can use this system to monitor, evaluate, focus, and maintain measures related to speed management.

The data collected can be used to calculate speeds on roads, provided that the number of observations is large enough. Results from the comparative analysis of GPS data from floating sources with sensor data on fixed locations show that there is a good fit. To reduce variance and receive representative estimates it is recommended to gather at least 300 GPS observations for every road section.

The paper analyzes free-flow speed of private cars in interurban road sections, without the influence of junctions. The analysis is done on different days, during day and night hours without traffic congestion. The results clearly show that in most roads in the country, around 50% of the drivers in private vehicles drive above the speed limit. This percentage is higher during weekends compared with weekdays (excluding rush hours).

The GIS system that was built for this research enables the research to expand in various directions. Additional data will enable researchers to identify excess speed by region (urban/interurban) and will provide further analysis about speed distributions of trucks and buses.

The research is still ongoing, and GPS data is continuously being collected, thus allowing the monitoring of trends in observed speeds. In particular, in January 2013, the Israel Road Safety Authority in cooperation with the police initiated speed camera program in several interurban road sections. The cameras can provide detailed speed data, but only at specific locations. The database described in this paper can be applied to perform before–after studies not only on the specific road sections, but also on the nearby sections. Furthermore, the data provides a comprehensive baseline for the "before" intervention period, which was automatically collected.

Further research related to safety applications will combine information of road crash data with the speed data, which will allow analysis of correlations between actual speeds and crashes. Another direction of research will identify spatial speed patterns by overlaying speed information with buildings location, which allows the examination of excess speeds in urban areas. Further analysis will incorporate GPS-based information from Intelligent transport systems (ITS) technologies (such as IVDR, distance-keeping devices) into the system to analyze multidimensional effects on road crashes.

The database can be extended to include travel times and speeds in congested situations. However, given the large variance in travel speeds during congested hours, further research is needed to verify if the data are accurate enough to monitor and analyze travel speeds for all time periods.

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