EFFECTS OF ROAD DESIGN AND BUILT ENVIRONMENT ON ROAD SAFETY IN DEVELOPING COUNTRIES: THE CASE OF ESKISEHIR (TURKEY)

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ABSTRACT

This paper explores effects of network design and built environment on traffic accidents. Basic objective of this study is to test simple and practical models that can predict traffic accidents in a developing country context employing similar factors used by studies conducted in developed country contexts. Data collected at 107 road segments between 2008 and 2010 in Eskisehir (Turkey) include accidents with fatalities and injuries. Two model groups are developed accordingly. The first group of models uses Binary Logit models of traffic safety. Three Binary Logit models estimated probe into distinguishing elements of road segments with no accidents in three years. The second group of models uses Count Data regression models to estimate occurrences of different accident types. For both model groups, accident types are pedestrian-vehicle, vehicle-vehicle and all accidents combined. Explanatory variables used in both group of models are derived from ambient land use characteristics, road segment properties, and traffic flow characteristics. They are slope, number of minor crossings/exits/side roads, number of lanes, type of land uses, shape of road segments, length of road segments, building coverage and number of stations, speed, and volume. Two of the direct policy implications developed from the results and accompanying discussion consider regulating public transit and improving traffic conditions and street network.

INTRODUCTION

Traffic accidents pose a real threat to the modern life in both developed and developing countries. More than 1.2 million people die and 20–50 million people get injured or handicapped in traffic accidents annually (*1*). By the year 2030, post-injury death in a traffic accident is expected to become the fifth frequent cause among all causes of death; but for the youngster (10–24 age group), it will rank the first (*1*). Injuries and disabilities caused by traffic accidents lead to further widespread problems that increasingly traumatize not only the people involved in traffic accidents but the people who depend on them too (*2*).

In Turkey, developing country on a fast track, a daily total of 2886 road traffic accidents causes 12 people die and 552 more get injured on a daily basis (according to the statistics compiled for 2009). Of special attention, 90 per cent of these accidents occur in urban areas, which is typical in a fast motorizing and urbanizing background. Among total deaths and injuries, urban areas account for four deaths and 300 injuries, 33 and 54 per cents, respectively (*3*). As a typical developing country, in Turkey, number of cars is increasing fast, thereby households and individuals travel more. While drivers lack experience and proper education, together with pedestrians, rules in urban areas followed loosely in the face of lax controls and poor institutional organization. However, vehicle kilometers travelled is steadily increasing along with uncontrolled urban sprawl too. Development of urban areas poses more risks considering the layout of the land uses, road structure along with other urban amenities. Therefore, risks associated with transportation safety in Turkey are expected to increase more in urban areas during the years ahead. Therefore, it is important to locate those risks in urban areas and devise policies that minimize them.

Studies concerning road safety in urban areas can be traced back to 1950s in developed country settings. For example, Marks (1957) is one of the first dealing with the relationships between road network type and the traffic accidents (*4*). By comparing these two road network systems (i.e., limited access (disconnected residential subdivisions) and grid system (connected residential subdivisions) in terms of annual number of traffic accidents over a five year period, Marks (1957) found the grid system is riskier than the limited access system (*4*). In terms of junctions, he found that accidents concentrate around four-armed junctions, while three-armed (T) junctions lead to fewer accidents (*4*).

Although Marks (1957) has been criticized for failing to consider the severity of accidents and for not considering the ratio of accidents as a whole, the basic findings of his study are confirmed by recent (developed country) studies conducted too (*5−9*). Lovegrove and Sayed (2006) finds that areas with more lane miles of arterials have significantly higher accident rates than areas with more local street mileage (*5*). Also, areas four-armed junctions have higher accident rates than those with three-armed (T) junctions (*5*). Similarly, Ladrón de Guevara et al. (2004) reports a positive relationship between percentage of roadways classified as arterials or collectors and rates of total and injurious crashes (*10*).

Risk factors associated with road geometry, road environment, etc. can be estimated in several ways. The most dependable method is by use of controlled 'before–after' cases. However, 'before–after' studies need more sampled sites and elongated study periods. An alternative is to make multidimensional cross-tabulation of accident rates by different safety factors, depending on with- or without- cases (e.g., accident rates for junctions with or without signal control). However, cross-tabulation is possible for a limited number of discrete variables. Furthermore, dully comparing accident rates at different sites might ignore intervening variables such as geometry, design, existence of amenities such as transit stops, etc. (*11*).

Nevertheless, a number of previous studies have managed to investigate road safety in urban areas (e.g., *12−14*). Recently, accident prediction models identifying factors affecting road safety in urban areas have become popular due to their advantages over other methods. Kim et al. (2006), Lovegrove and Litman (2008), Lovegrove and Sayed (2006), Greibe (2003), Dumbaugh and Rae (2009), Kim and Yamashita (2002) are some of the examples of accident prediction model applications based on factors affecting traffic accidents in urban areas (*5*, *8*, *11*, *15−17*).

Basic objective of this study is to test simple and practical models that can predict traffic accidents in a developing country context employing similar factors used by studies conducted in developed country contexts. Unlike models based on traffic flows only, this study considers additional contributing factors of traffic accidents, similar to those mentioned above. This objective comes with a plea of change for designing proactive measures instead of reactive measures as given in (*18*) for developing country contexts. As urban areas are changing fast along with motorization in urban areas of developing countries, by defining contributing factors of accidents, it will be possible to take proactive countermeasures by planning and urban design policies, instead of waiting accidents to take reactive measures, which is the general way of doing business (at least in Turkey).

TRAFFIC ACCIDENT PREVENTION POLICIES IN TURKEY (ESKISEHIR)

Road safety has been addressed by the United Nations General Assembly as a major global issue especially for developing countries. Recently, the General Assembly adopted Resolution 64/255 "Improving Global Road Safety" to improve road safety and reduce road traffic deaths by 50 per cent till 2020 in the "Decade of Action for Road Safety" from 2010‒2020 and called on member states to declare their own action plans for the decade. Accordingly, the Road Safety Action Plan was developed by the Turkish National Police Agency in cooperation with the relevant institutions and agencies to prevent road traffic accidents, minimize fatalities and injuries, and mitigate their impacts in Turkey. One of the main tasks defined in the action plan is to decrease risks at accident black spots. As most of the accidents occur in urban areas as stated above, it is important to find ways to account for black spots in urban areas and identify possible routes of proactive measures.

In this manner, Eskisehir (Turkey), a fast growing mid-sized metropolitan city supplies suitable backdrop for developing country context. Eskisehir is situated in North-Western part of Mid-Anatolia region of Turkey. Eskisehir is one of the industrial and educational centers of Turkey associated with heavy industries along with two state universities. The city has a compact urban form, and a population size around 700,000 with high rates of pedestrian and bicycle trips. Public transit in the city relies on two light rail lines along 76 public bus transit lines covering all the metropolitan area. Private car ownership rate is around 155 per thousand people, which makes Eskisehir the third among the metropolitan cities of Turkey. In eight years, private car ownership in Eskisehir has increased 55 per cent from 100 to 155 per thousand people (*19*, *20*), which inevitably increased traffic accident risks.

From 2005 to 2010, traffic accidents in Eskisehir had increased by 28 per cent (with an annual compound of 4.23 per cent) from 857 in 2005 to 1099 in 2010. Although number of deaths in traffic accidents monotonously decreased from 22 in 2005 to 16 (28 per cent decrease), number of injured increased by 30 per cent from 1246 to 1623 (with an annual compound of 4.50 per cent)—it should be noted that although emergency responses regarding traffic accidents improved a lot in Turkey, however, there are cases that heavily injured at accident site is generally coded as injured without no follow-up of his/her well-being, the person might die because of his/her injuries, so caution is required when interpreting number of deaths.

Steady increase in urban traffic accidents can partially be attributed to fast motorization and the urban backdrop. Besides, urban road safety is neglected as road safety concerns are generally restricted to inter-urban roads. This inevitably causes capacity deficiencies in urban areas to tackle accident risks (*2*).

DATA

Data on traffic accidents with fatalities or injuries had been retrieved from Traffic Information System (TIS), which is operational since 2003 is a centralized computer-based accident database based on paper-based traffic accident reports filled at accident sites by attending officers. A typical record includes date, time of day, location, type of the accident, number of the vehicles involved in the accident, code of the highway, GPS measurements, age, sex, intoxication of the driver, weather conditions, lighting conditions, vehicle type, and number of persons injured/killed.

Approximately, more than 100,000 traffic accidents worth of data are stored in TIS annually. Therefore, it is possible to use spatial as well as non-spatial analyses to compare effects of traffic accident prevention policies. Accordingly, data used in this study are organized in three steps. Firstly, traffic accident data are queried from TIS, and points of traffic accidents are created in GIS environment by using GPS measurements. Secondly, the locations of these data are cross-checked with locations and false recordings are corrected if there is any unfitting condition—nearly 25 per cent of the data come with wrong geospatial coordinates. Digital maps and satellite images of the study area are used to determine ambient land use characteristics of road segments under scrutiny. Lastly, all pertinent variables are merged under a single working data set.

In this study, traffic accident data regarding 107 road segments with a total of 110.98 km with 1,415 traffic accidents have been assembled in the research database. Of these 107 road segments, 38 road segments have 4 lanes (35.5 per cent), 37 have 3 lanes (34.6 per cent), 20 have 6 lanes (18.7 per cent), and 12 have 2 lanes (11.2 per cent). Considering ambient land use characteristics, 37 road segments are in mixed-use (CBD) environment (34.6 per cent), the remaining of the road segments fall in single (monotonous) land uses: 34 are in residential (31.8 per cent), 15 are in light industry (14.0 per cent), 13 are in non-urban (12.1 per cent), and 8 are in industrial areas (7.5 per cent).

As regards fatal or injurious accidents at 107 road segments, it is found that 2005 is the year of minimum values, 2007 is the year of maximum values (Table 1). Although we have annual data of traffic accidents from 2005 to 2010, the independent variables compiled are available only for the last three years, i.e., 2008−2010. Therefore, we have used accident data for the combined 2008−2010 period in the models developed in this study. Note that accidents at 107 road segments generally account for more than 40 per cent of all (fatal and injurious) accidents in Eskisehir annually.

TABLE 1 AROUND HERE

The data compiled for the models for the three year period at 107 road segments give use 46 % of all accidents in Eskisehir (Table 1), which is a reasonable amount for deriving inferences about traffic accidents. For the dependent model variables, we rely on the TIS database for accident classification that considers accident involvements such as Pedestrian-Vehicle (P-V) and Vehicle-Vehicle (V-V) accidents (Table 2).

TABLE 2 AROUD HERE

For the 2008−2010 term, P-V accidents are mostly confined to the immediate vicinity of the city center, which is mostly pedestrianized and served by newly built LRT. The first three of most frequent P-V accident road segments that constitute 20 per cent of all P-V accidents are near the city center. These three most frequent road segments are followed by a road segment on the intercity by-pass road. When peeked, we run into a residential area neighboring the road segment that might be the cause of congregation of P-V accidents there. Therefore, an early conclusion can be made that P-V accidents generally occur when pedestrians are abundant regardless of the road type—three types of road types are identified in this study, i.e., straight, curved and warped (Figure 1).

FIGURE 1 AROUND HERE

As regards V-V accidents, we come across a congregation of accidents on the intercity by-pass road. 25 per cent of 1027 V-V accidents occur on any of the road-segments of this road, which represent 11 per cent of sampled road segments (or 16 per cent in terms of their total length). One of the reasons why by-pass road has become risky in terms of traffic accidents is that the road has assumed the role of an intra-urban arterial road too. Therefore, mix of the traffic on the road including pedestrians has increased the risk of traffic accidents on the road. Most of the cities in Turkey have such kind of by-pass roads that has assumed these dual purposes in time. This is mainly because of the urban expansion encroaching on the bypasses.

MODEL DEVELOPMENT

Of special interest in this study may be the locations where no traffic accident happened. In three years from 2008−2010, 36 and 16 of the 107 sampled road segments witnessed no P-V and V-V accidents, respectively—only at 14 road segments, there was no traffic accident at all (Table 2). A Binary Logit Models are used to unearth the factors of road safety at these road segments in terms of different classifications: *Model 1A: P-V, Model 1B: V-V, Model 1C: All*.

The rest of the models are used to account for the number of accident occurrences. Data regarding these accidents are suitable for count data models of various types depending on the frequency distribution; besides, previous research support use of count data models for accident predictions (*18*, *21−29*). In line with the previous research, extensions to the norm model, the Poisson regression model, are also utilized to account for any diversions from the norm distribution of the data generation process (i.e., the Poisson distribution). The models estimated are given as follows (selected models in terms of model fit are given in bold characters):

Model 2A1: Poisson regression model of P-V Accident Occurrences
Model 2A2: Zero Inflated Poisson regression model of P-V Accident Occurrences
***Model 2A3*: Negative Binomial regression model of P-V Accident Occurrences**
Model 2A4: Zero Inflated Negative Binomial model of P-V Accident Occurrences

Model 2B1: Poisson regression model of V-V Accident Occurrences
Model 2B2: Zero Inflated Poisson regression model of V-V Accident Occurrences
Model 2B3: Negative Binomial regression model of V-V Accident Occurrences
***Model 2B4*: Zero Inflated Negative Binomial model of V-V Accident Occurrences**

Model 2C1: Poisson regression model of All Accident Occurrences
Model 2C2: Zero Inflated Poisson regression model of All Accident Occurrences
Model 2C3: Negative Binomial regression model of All Accident Occurrences
***Model 2C4*: Zero Inflated Negative Binomial model of All Accident Occurrences**

The norm Poisson regression model assumes that the conditional frequency of traffic accidents at the i^{th} urban road segment, y_i is independently and identically distributed with the Poisson probability mass function given mean parameter, μ_i, as follows (*21, 30−32*):

$$p(y_i|\mu_i)_P = \frac{e^{-\mu_i}(\mu_i)^{y_i}}{y_i!} \quad \text{(1a)}$$

The independent variables used in the Poisson regression model are associated with the mean and variance parameter via the exponential mean function (Eq. 2a). Negative Binomial regression model assumes that variance differs from mean as in Eq. 2b.

$$E(\mu_i|\mathbf{x_i})[= V(\mu_i|\mathbf{x_i})] = exp(\boldsymbol{\beta}'\mathbf{x_i}) \quad \text{(2a)}$$

$$E(\mu_i|\mathbf{x_i}, \varepsilon) = exp\left(\boldsymbol{\beta}'\mathbf{x_i} + \varepsilon\right) \quad \text{(2b)}$$

Parameter $exp(\varepsilon)$ in Eq. 2b has Gamma Distribution with mean 1 and variance equal to α which changes the probability density function as in Eq. 3.

$$p(y_i|\mu_i, \varepsilon)_{NB} = \frac{e^{-\mu_i exp(\varepsilon)}(\mu_i e^{\varepsilon})^{y_i}}{y_i!} \quad \text{(3)}$$

Integrating ε out of Eq. 3 gives the probability distribution function of Negative Binomial regression as in Eq. 4.

$$p(y_i|\mu_i)_{NB} = \frac{\Gamma(\theta + n_i)}{\Gamma(\theta)n!} u_i{}^{\theta}(1 - u_\iota)^{n_i} \quad (3)$$

where $u_i = \theta(\theta + \mu_i)$ and $\theta = 1/\alpha$. Negative Binomial regression model relaxes the equality of mean and variance parameters by changing variance to $V(\mu_i|\mathbf{x_i}) = E(\mu_i|\mathbf{x_i})[1 + \alpha E(\mu_i|\mathbf{x_i})]$.

Zero Inflated extension of both Poisson and Negative Binomial models (ZIP models) depends on a selection process to distinguish true zeros from excess zeros. The separation depends on the probability q_i such that $y_i = 0$ with probability q_i. This separation process depends on a Binary Logit model of true zeros.

$$p(y_i = 0|\mu_i)_{ZIP} = q_i + (1 - q_i)p(y_i = 0|\mu_i) \quad (3a)$$

$$p(y_i = j > 0|\mu_i)_{ZIP} = (1 - q_i)p(y_i = j > 0|\mu_i) \quad (3b)$$

where left hand side probabilities, *p*, in Eq. 3a and Eq. 3b might be Poisson or Negative Binomial depending on the model. The models are estimated by LIMDEP 9.0 econometric software. The remaining sets of equations including log-likelihood functions and variances of estimators in the models can be found in (*21*–*23*).

FINDINGS OF THE MODELS

How Risky are The Road Segments?

Three Binary Logit models are estimated to account for pedestrian, vehicle and all accidents, i.e., *Model 1A: P-V, Model 1B: V-V, Model 1C: All*. The results of the models are given in Table 3. All models indicate significant departures from restricted models with only the constant variables. Results of *Model 1A: P-V* highlight four variables that are effective on pedestrian accidents on the positive side: Traffic Volume, Number of Links (per 100 mt.) and Number of Transit Stops (per 100 mt.) and Mixed Land Use. All these variables are proxies for possible pedestrian and vehicle conflicts. In a typical developing county like Turkey, where motorization trend is on the brink of exponential surges, future seems bleak in this respect. In the near future, unless extensive proactive measures to control vehicle flows are taken, pedestrian accidents are expected to rise.

TABLE 3 AROUD HERE

Number of links that merges with the road segment and transit stops are the remaining sources of pedestrian and vehicle conflicts—significance of parameter estimate for transit stops is on the edge though. Both of the variables affect number of pedestrians and/or vehicles in the road segment positively. Links that merges with the road segment are for left or right turns increase risks of accidents. In the case of transit stops, existence of passengers crossing the street to reach transit stops is an incessant source of traffic accidents in the developing countries. This is mainly due to the lack of (local) expertise to locate transit stops and to take necessary precautions around transit stops (*26*, *27*). A plain solution to this might be to reduce the number of transit stops. But this solution has to be ruled out given the heavy usage of transit systems in the developing countries.

Combining with the early conclusion given above, we may further say that especially road segments near pedestrianized area in the city center are prone to P-V accidents due to increased volumes serving car-free areas. Because city center consist of mixed-land uses predominantly, we expect all kinds of traffic congregating around pedestrianized area for a multitude of purposes.

Three variables seem to increase safety in terms of P-V accidents: Two Lane Roads, Residential Land Use and Straight Roads. The city areas characterized by these variables generally shoulder mixed land use areas in the city center. This characteristic can be generalized to almost all of the mid-sized cities and metropolitan areas in Turkey. However, the analyses here misses one important point that road segments does not include unsignalized (four-armed) intersections, which cause traffic accidents (*4*–*9*)—number of links counts minor links for diverges from or merges to the road segment.

Regarding the vehicle accidents accounted by *Model 1B:V-V*, safety is related to fewer variables: after controlling for land uses, two and four lane roads promotes safety. Risk increasing variable is the number of transit stops in this category. That might seem counter-intuitive in the case of vehicle only accidents. A possible explanation is the mix of the traffic and the existence of the paratransit aggressively looking for passengers especially, who are generally gathered around transit stops. The similar result obtained for pedestrian accidents suggest a closer look into the transit stops when traffic accident related safety policies are being prepared.

On the contrary, two and four-lane roads turn out to be safe havens for vehicular traffic—both coefficient estimates are significant and positive. Two separate reasons can be developed for the effects of these variables. Four-lane roads are supplied with median refuge that separates traffic in opposite directions. This is supposed to increase safety on four lane road sections. For two lane roads which are abundant in dense and predominantly residential areas, driving comes to a more considerate level, possibly by psychologically driven instincts. The result obtained for two lane roads is also supported similar result obtained for pedestrian accidents. *Model 1C: All* reveal results no different from the results and variables used for *Model 1B: V-V*. Probably, the similar result can be explained by very few number of no accident road segments.

What are the Contributing Factors behind Accidents?

Three groups of count data regressions are carried out with different variation, as given in the previous section. The results of best performing models are presented in Table 4. According to *Model 2A3: P-V* results, traffic volume, number of links connected to the road segment, and mixed land use turn out to be significant factors increasing pedestrian accidents. These variables were also found to increase vehicle-vehicle and all accidents too—(positive and significant) results of *Model 2B4: V-V* and *Model 2C4: All* confirm this. The reasons well discussed above are also valid here. However, these results should not give way to policies that decrease number of links, transit stops. Nor should we suggest policy makers to change mixed land uses to monotonous land uses, which increase trip lengths, private car usage, thereby unsustainability in transportation. Instead, results imply that precautions should be taken in areas associated with increasing values of these accident-increasing variables. Especially, around transit stops and connections of minor roads to major roads, traffic calming policies are advised to decrease risks of accidents.

TABLE 4 AROUD HERE

As for the road structure, straight and four-lane roads are found to decrease pedestrian accidents. Reasons for these results might be related to better visibility and presence of median refuge that protects pedestrians—nearly all four-lane roads have median refuges in Turkey. However, care has to be taken here as median refuge is not a natural extension of accident prevention strategy. There are examples of median refuges that cause traffic accidents too. According to field studies conducted by the second author, in Ankara, the capital of Turkey, when road segment with median refuge popular for pedestrian accidents is closely inspected; cause of accidents is found to be bushy trees blocking visibility for both drivers and pedestrians. Therefore, care must be taken, especially for micro design elements of the road infrastructure that cause all kinds of accidents. When this result is combined with the similar result for vehicle only accidents—four-lane roads also decrease vehicle only accidents too—one may say that four lane roads installed with refuges increase overall safety.

Further notices should be given to median refuge that is used for both separating opposing traffic flow and supplying safe passage for passengers in urban areas. Intercity by-pass road (a six lane road) has also a median refuge, which was intended to separate opposing flows only, not for supplying a safe ground for pedestrians who find themselves in-between opposing flows. When urban development encroaches the by-pass road—this is not unusual in developing countries as the urban development is on the fast track too—number of pedestrians trying to cross wide by-pass roads increase; any accident on these roads generally end up with fatalities.

CONCLUSION AND DISCUSSION

In general, variables of speed, road segment length, and number of transit stops are related to traffic accidents. Monotonous land uses such as industrial and residential land uses are less related to traffic accidents, whereas mixed-use (CBD) land uses are more related. While straight road segments improve road safety due to better visibility, two and four lane roads are found to improve road safety.

A strong internal correlation within the data is a major problem for this study. Variables describing speed tend to correlate strongly with other variables like traffic volume, number of lanes, etc. Therefore, the safety effects from a single explanatory variable were difficult to estimate since it may be affected by other variables in the model.

Studies conducted in developed country contexts find significant effects of speed and volume as well as built environment on traffic accidents (e.g., *15*, *24*, *25*). Similar results obtained in a developing country context point to universality traffic accident causes in terms of these variables. This further suggests that similar precautions should be adopted in developing countries in terms of road structure.

In terms of built environment and transportation, it is for sure that developed and developing countries differ a lot (*26*, *27*). Whereas developing country context is dense, fast urbanizing, developed country context is less dense and urbanizing slowly. One of the main contributing factors to traffic accidents in developing countries is the urbanization rate which should be disciplined to increase road safety in urban areas.

Studies conducted in developed country contexts (e.g., *6*, *7*, *8*, *18*, *21*-*29*, *33*, *34*) obtain similar results as this study conducted in a developing country context produce: roadway characteristics such as curvature and slope are found to affect traffic accidents ubiquitously. Therefore, one may say that given that drivers follow traffic rules, the basic findings in terms of roadway characteristics obtained in developed country contexts can be used for developing countries.

Departures from models developed and estimated in the developed countries context (although mainly in USA) are related to idiosyncratic characteristics of a developing country regarding urban transportation systems (*35*, *36*). Two of the most important variables in this context are number of transit stops and number of minor roads linked to road segments. In Turkey, transit stops are instituted by municipalities according to demand for the transit system. There is no rule of interspacing transit stops; one may come across transit stops interspaced shorter than 200 mt. in the city center without much respect to ambient traffic conditions and roadway characteristics. In terms of reactive safety measures, the usual practice in Turkey as in all developing countries, location of a transit stop usually changes if an accident causing death or injury occurs.

Another finding states that mixed land use increases traffic accidents. Generally, city centers and their immediate vicinities are associated with mixed land uses. Mixed land use attracts more traffic during the day in addition to pedestrians, therefore, traffic in these areas become dense (road segments in mixed land use areas averages second in terms of average hourly traffic volumes in Eskisehir). Moreover, in the city center where parking are generally unregulated at roadsides, accident risk increases when some of the vehicles try to park, transit vehicles make frequent stops for passengers, and while others try to maintain their courses.

One must also take into consideration the paratransit vehicles without no designated stops. Paratransit which is partially regulated (in terms of route and vehicle size) is another source of risk especially in city centers. Paratransit vehicles which assume stop-go cycles for taking or dropping passengers are more inclined to make risky maneuvers around transit stops (location of which are risky) for prospective passengers. In a fast changing urban setting and heavy patronage of public transit, location of transit stops and design of minor links come without no safety precautions. In this manner, proactive perspective for road safety is badly needed in developing countries.

Policy Implications

True, when it comes to the backstage, developing countries deserve more thoughtful and thorough approach in terms of variables developed for traffic accidents, thereby safety. As WHO and Aeron-Thomas and Jacobs stress, till 2030, expected deaths are mostly will be observed in low-income countries, which will be followed by lower middle-income countries (*1*, *2*). Although results of this study conducted in a developing country confirms results obtained in developed country setting in terms of roadway characteristics, nature of the traffic, their communication with the immediate environment deserves a lot more in terms of policies. While mixed land use is tagged as sustainable for creating shorter vehicular trips and endorsed in developed country setting, mixed land use in developing countries seem to cause traffic accidents. Solution to this is not to decrease mixed land uses, instead proactive stance is needed to remedy deficiencies by using design and control elements simultaneously. Some of the direct policy implications can be summarized as follows:

1. *Regulating public transit*: Two policy areas seem to be appropriate under this category. The first one is the location of transit stops. Although the current study reveals results about the number of transit stops—as the number of transit stops increase in a road segment, accident risk accidents increase. This result is corollary to the risks associated with the location of transit stops—however this has to be verified by additional empirical researches. Location of transit stops is not restricted to city centers. According to daily news in Turkey, there are numerous traffic accidents in which vehicles overrun transit stops, thereby causing fatalities and injuries.
2. *Improving traffic conditions and street network*: In an environment where traffic is associated with different kinds of vehicles in terms of type, size, quality and age in addition to unregulated street space and fast motorization, control of traffic (in terms of signalization) and safety-improving (or risk decreasing) design are crucial. However, urban planning, street design and transportation planning activities are practiced independently. Coordination between these related areas in developing cities is critical in terms of road safety. Therefore capacity building for a more unified and coordinated ways of urban governance can be the most significant policy area in terms of rad safety.

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LIST OF TABLES AND FIGURES

TABLE 1 Accidents on 107 Road Segments (2005−2010)

Year/Period	Number of Accidents at 107 Road Segments (per cent of all accidents in the year or the period)	Summary Statistics of Accidents			
		Median	Av.	Max.	Std. Dev.
2005	350 (41 %)	2	3.27	26	4.14
2006	446 (50 %)	3	4.17	22	4.87
2007	584 (54 %)	3	5.46	30	6.16
2008	482 (49 %)	2	4.50	25	5.55
2009	447 (44 %)	3	4.18	28	5.16
2010	486 (44 %)	4	4.54	23	4.84
2008−2010	1415 (46 %)	9	13.22	75	14.38

TABLE 2 Model Variables

Variables	%	Mean	Median	Std. Dev.	Min.	25%	75%	Max.
No P-V Accidents (36 Road Segments)	33.6							
No V-V Accidents (16 Road Segments)	15.0							
No Accidents (14 Road Segments)	13.1							
# of Accidents (P-V Accidents)		3.62	2	5.55	0	0	5	38
# of Accidents (V-V Accidents)		9.60	5	10.28	0	2	14	46
# of Accidents (All Accidents)		13.22	9	14.44	0	3	21	75
Length (km.)		1.04	0.89	0.50	0.24	0.71	1.33	3.48
Speed (km/h)		32.18	27	16.94	12	21	39	102
Traffic Volume (# of 2-way pcu per hour., *ln*)		5.17	5.47	1.36	0.62	4.41	6.14	7.08
Slope (x100 %)		0.01	0.01	0.02	0.00	0.00	0.02	0.15
# of Transit Stops per 100 mt.		0.48	0.00	0.86	0	0	1	4
# of Links per 100 mt.		0.04	0.00	0.08	0		0.07	0.30
Building Coverage (%)		58.54	60.39	32.48	0.00	30.66	90.95	100
Land Use #1: Light Industry	14.0							
Land Use #2: Mixed Use	34.6							
Land Use #3: Residential	31.8							
Land Use #4: Industrial	7.5							
Land Use #5: Non-urban	12.1							
Road Type #1: Straight	51.4							
Road Type #2: Warped	29.9							
Road Type #3: Curved	18.7							
# of Lanes: 2	11.2							
# of Lanes: 3	34.6							
# of Lanes: 4	35.5							
# of Lanes: 6	18.7							
Sample Size					107			

TABLE 3 Results of No Accident Binary Logit Models

Variables	*Model 1A: P-V*		*Model 1B.V-V*		*Model 1C: All*	
	Coeff.	*p*	Coeff.	*p*	Coeff.	*p*
Constant	2.26	0.12	-3.42	0.00	-3.52	0.00
Length (km.)						
Speed (km/h, *ln*)						
Traffic Volume (*ln*)	-0.53	0.03				
Slope (x100 %)						
# of Transit Stops per 100 mt.	-8.95	0.15	-15.19	0.08	-19.41	0.08
# of Links per 100 mt.	-0.60	0.08				
Building Coverage (%)						
Land Use #1: Light Industry						
Land Use #2: Mixed Use	-1.99	0.05				
Land Use #3: Residential	1.35	0.09				
Land Use #4: Industrial	1.69	0.18	2.76	0.07	3.19	0.00
Land Use #5: Non-urban						
Road Type #1: Straight	1.49	0.03				
Road Type #2: Warped						
Road Type #3: Curved						
# of Lanes: 2	3.44	0.03	2.69	2.62	0.01	0.11
# of Lanes: 3						
# of Lanes: 4			2.44	0.01	2.17	0.02
# of Lanes: 6						
Log-Likelihood with Constant	-68.34		-45.14		-41.51	
Log-Likelihood (Model)	-37.32		-30.98		-27.4	

TABLE 4 Results of Count Data Regression Models

Variables	*Model 2A3: P-V* *Neg. Binomial R.*		*Model 2B4:V-V* *ZIP Neg. Binomial R.*		*ZIP Model*		*Model 2C4:All* *ZIP Neg. Binomial R.*		*ZIP Model*	
	Coeff.	*p*	Coeff.	*p*	Coeff.	*p*	Coeff.	*p*	Coeff.	*p*
Constant	-2.88	0.03	1.12	0.16	-4.37	0.01	0.70	0.41	-4.85	0.01
Length (km.)	0.72	0.00	0.90	0.00			0.96	0.00		
Speed (km/h, *ln*)	0.09	0.75	-0.21	0.35			-0.17	0.47		
Traffic Volume (*ln*)	0.38	0.00	0.18	0.00			0.24	0.00		
Slope (x100 %)	-11.08	0.24	-8.39	0.25			-7.77	0.29		
# of Transit Stops per 100 mt.	1.49	0.31	-0.13	0.92			0.46	0.72		
# of Links per 100 mt.	0.35	0.01	0.20	0.03			0.21	0.02		
Building Coverage (%)	0.00	0.82	-0.01	0.03			-0.01	0.07		
Land Use #1: Light Industry										
Land Use #2: Mixed Use	1.33	0.00	0.75	0.00			0.94	0.00		
Land Use #3: Residential										
Land Use #4: Industrial									3.72	0.07
Land Use #5: Non-urban										
Road Type #1: Straight	-0.43	0.10	0.26	0.26			0.10	0.41		
Road Type #2: Warped			0.23	0.30			0.18	0.79		
Road Type #3: Curved							-0.29	0.47		
# of Lanes: 2	-0.51	0.32	-0.37	0.31			-0.41	0.10	3.88	0.11
# of Lanes: 3	-0.19	0.59	-0.46	0.05			-0.70	0.00		
# of Lanes: 4	-0.58	0.06	-0.59	0.01					1.55	0.33
# of Lanes: 6										
Alpha	0.48	2.64	0.25	0.00			0.32	0.00		
Log-Likelihood with Constant	-436.68		-720.17				-942.85			
Log-Likelihood (Model)	-232.35		-407.28				-482.56			
Log-Likelihood (Over-Dispersion)	na		-312.27				-338.84			

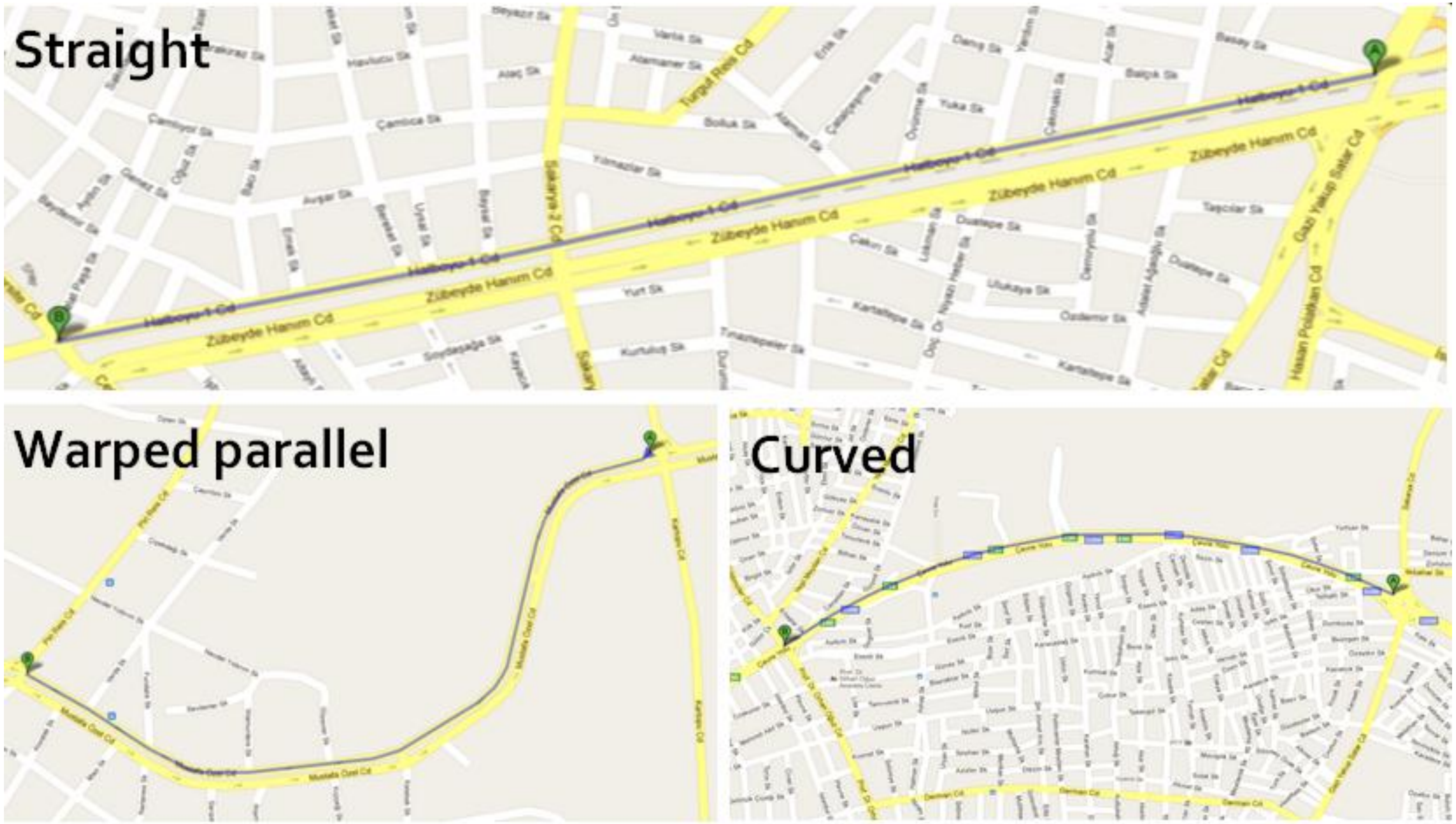

FIGURE 1 Classification of road segments.