Road Safety Case Studies

Adopting a Safe System Approach to Determine Safer Speed Limits: A Case Study from Iran

Mansour Ranjbar[1], Ali Tavakoli Kashani[2,3], Mohammad Mehdi Besharati[3], Moslem Azizi Bondarabadi[3], Hormoz Zakeri[4], Seyedali Hosseinizadeh[4], Gregory Chambers[5], Lori Mooren[6] and Ray Shuey[7]

[1] *NCD and Mental Health Unit Head, WHO Country Office, Tehran, Iran*
[2] *School of Civil Engineering, Iran University of Science and Technology, Tehran, Iran*
[3] *Road Safety Research Center, Iran University of Science and Technology, Tehran, Iran*
[4] *Iranian National Roads Safety Commission secretariat, Ministry of Roads and Urban Development, Tehran, Iran*
[5] *Context3sixty, Melbourne, Australia*
[6] *Safety and Communications, Sydney, Australia*
[7] *Strategic Safety Solutions, Melbourne, Australia*

Corresponding Author: Gregory Chambers, 28 Freshfield Avenue, Wantirna 3152, +61 4 1987 2938

Key Findings

- The Safe System Approach provides a valuable framework to review speed limits on duplicated rural highways and freeways
- The framework assists with quantifying safety risk and setting safer speed limits
- The framework provides evidence-based justification to reduce current speed limits
- Modelled framework-based speed limits generally reduce end-to-end travel times

Abstract

Speed management is one of the main dimensions of the Safe System Approach for reducing both the risk of crash involvement as well as injury severity. This study proposes a practical framework for setting safer speed limits on duplicated rural highways that has been applied to six pilot corridors (total carriageway length of approximately 1,250 km) in Iran. The safer speed limits determined from the proposed framework have been compared with the currently posted speed limits using several indicators and showed a considerable reduction in the total number of changes in speed limits while having very limited impact on reducing the mean travel speed and increase travel time along the study corridors. The study of the pilot corridors establishes that a clear approach and documented guidelines for setting speed limits provides a basis for quantifying engineering judgments about road hazards and determining more consistent speed limit values for similar conditions across Iran's rural highway network, legitimising speed limit reductions aimed at saving lives.

Keywords

Safe System Approach, Speed limit setting, Demonstration Project, Freeways, Multilane highways

Introduction

Road traffic fatalities and injuries are a major public health problem worldwide, especially in developing countries (WHO, 2018). This has led pioneer countries to move toward adopting a Safe System Approach (SSA) for reducing traffic crash fatalities and serious injuries (OECD, 2008). The SSA is central to reducing road crash trauma internationally, as emphasised in the Stockholm Declaration at the Third Global Ministerial Conference

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on Road Safety in February 2020. The Declaration also identified speed management as being vital to reduce road traffic deaths and injuries.

The SSA aims to create a road transport system in which human mistakes do not result in serious injury or fatality (Steinmetz, et al. 2015, Doecke, et al. 2018) and is increasingly becoming the foundation of road safety strategies in the developed countries (Hughes, et al. 2015), such as Sweden (Larsson, et al. 2010), United Kingdom (Department for Transport 2000), and Australia (Australian Transport Council, 2011).

These strategies provide a comprehensive overview of all the key components of a safe transportation system primarily with safer vehicles, safer road infrastructures, safer road users, and safer speeds (Hughes, et al. 2015). As vehicle speed is known to be an influential factor on both the likelihood of crash occurrence and the severity of injuries (Evans 1994, Kloeden, et al. 1997, Rosen, et al. 2011, Elvik 2013, Mackenzie, et al. 2015, Doecke, et al. 2018), "speeds must be managed so that humans are not exposed to impact forces beyond their physical tolerance." (WHO, 2018).

Reassessing the speed limits is considered an effective measure to align travel speeds with a safer environment and improve road safety. Speed limit changes have been shown to influence travel speed (Elvik, et al. 2004, Musicant, et al. 2016), which in turn is related to the number of fatal and injury crashes (Farmer 2017). As an example, Elvik, et al. 2004, found that when the speed limit is reduced by 10 km/h and no other action taken, the mean speed generally reduces by approximately 2.5 km/h.

These findings have influenced road transportation authorities to reassess speed limits on the road transport network. As a clear example, 110 km/h speed zones were reduced in South Australia with speed limits reduced to 100 km/h on 1,100 km of road in 2003 and a further 723 km in 2011 (Dua, et al. 2013). A follow up evaluation study indicated that the number of crashes in the after period was 27.4% lower than would have been expected if the higher speed zones had been maintained (Mackenzie, et al. 2015). Results also showed a 31% reduction in the number of injuries admitted to hospitals due to crashes on the subject road segments.

Background

Project Background

To facilitate formulation of SSA in the national road safety system of member states, the World Health Organization Regional Office for the Eastern Mediterranean (WHO EMRO) has developed a "Road Safety System Framework for the Eastern Mediterranean Region" and Iran has been nominated to demonstrate an applicable SSA-based model in the Region. With EMRO support a project has been launched jointly by WHO Iran Country Office and Iran's National Road Safety Commission (NRSC) in collaboration with national partners to demonstrate enhanced Safety Model Corridors focusing on speed management.

The project aims to demonstrate an effective SSA-based model for EMRO member states focusing on speed management, with the potential to extend over time to other SSA pillars and is structured around the UN's Results-Based Management approach.

Speed Management Background

Historically, the 85th percentile of the travelling speeds in a road segment has been used globally for setting the speed limit. Similarly, the following criteria is being used in Iran for setting speed limit:

1. 85th percentile speeds of free-flowing traffic
2. Roadway geometric characteristic (i.e., horizontal curve radius, sight distance, etc.)
3. Roadside prevailing land-use

However, studies have shown that the drivers' speed choice may not always be rational as drivers do not foresee all the potential road hazards (Elvik, et al. 2004). These hazards include unprotected guardrail ends, unsafe access points along a rural road, unsafe U-turns and unexpected pedestrian exposures. Indeed, preventing road users from being killed or severely injured due to traffic crashes should become the very first criterion for setting the speed limit. This provides a legitimate basis for limiting the freedom of speed choice and reassessing appropriate safer speed limits based on a more structured and scientific approach.

A review of the literature reveals that previous studies have focused on setting 'safe' speed limits based on the SSA (Jurewicz and Hall 2009, Doecke, et al. 2018). However, these studies have proposed safe speed limits based on only the tolerance threshold of the human body, and do not provide a practical tool for setting safer speed limits based on both the likelihood as well as severity of different potential crash types.

Therefore, the question remains as to "how to identify and set a safer speed limit that suits the road infrastructure and environmental conditions?" The aim of this paper is to document a framework for quantifying the potential safety issues on a road segment and setting safer speed limits along the road segment. The proposed framework is then applied to six corridors in Iran to assess its merits and demerits compared to the speed limits currently posted on these corridors.

Method

The study is part of a pilot project aimed at speed management based on the SSA, recognising its holistic nature and central role in reducing road crash trauma internationally[1].

To determine safer speed limits and associated road engineering treatments on pilot road segments, the following steps were followed: identification and adoption of pilot segments of road, collection of base pilot segment information, adoption of a speed limit setting framework, and application of the speed limit setting framework on the pilot segments.

Pilot segments

Potential pilot corridors were identified according to the following criteria:

1. the corridors having a primary role in the road network (movement, function and traffic volume),
2. the provinces having adequate capacity to conduct the project (budget allocation and experienced safety professionals),
3. the corridors having a relatively poor road crash and injury history.

The final six corridors in three Provinces were selected by Iran's National Road Safety Commission (NRSC) in consultation with Provincial authorities.

Base information

Base information collected for each of the six road corridors comprised traffic volumes, speed data from speed cameras and traffic detectors, as well as speed violations data. The information was provided by Provincial agencies from existing data sources, supplemented by some additional project-related data collection. Base information for the pilot corridors is included in Appendix 1.

Speed limit setting framework

The speed limit setting framework incorporated elements of "movement and place" to determine speed limits consistent with the function of the road (movement) and the human environment and activities that surround the road (place). The "safe system" principles were then incorporated to identify speed limits and associated road engineering treatments that prevent crashes resulting in serious injury or death having undertaken severe injury risk analysis.

Application of the framework involved the following steps: road safety inspection, importing the collected data on each corridor's map, identifying road segments with uniform environmental and safety conditions, scoring an "exposure-risk-severity" matrix, and identifying safer speed limits and associated road engineering treatments for each road segment.

A team of National specialists worked with Provincial counterparts to apply the framework on each of the pilot corridors, both providing consistency across all corridors and developing capacity at Provincial level. Progress evaluations were conducted to assess viability, benefits and potential outcomes of the framework.

Framework Application

This section describes how the SSA speed limit setting framework was applied to the pilot corridor segments to determine safer speed limits.

Road safety inspection

Road safety inspections of existing roads provide a mechanism to identify existing road and speed management characteristics that can influence crash likelihood and injury severity (WHO, 2018). In this first step, a team of experienced road safety engineers inspected the pilot corridors (total carriageway length of approximately 1,250 km) and documented the current condition by capturing geo-tagged videos (Figure 1).

Mapping of road safety inspection information

In this step, the captured videos were reviewed in the office, and all the data corresponding to each segment were located on a corridor map. Data elements included location and type of signs, road access points, roadside hazards, culverts, pavement condition and abutting development.

A total of 3,240 points were pinned and labelled on the maps, allowing the road safety engineering team to analyse the spatial distribution of road infrastructure, road hazards and safety issues along the corridors. This analysis identified a total of 148 road lengths with uniform safety and environmental conditions across the six pilot segments. An example of identified safety risk is shown in Figure 2

Evaluating serious injury risk

The road safety engineering team used an "Exposure-Likelihood-Severity" matrix based on the Austroads Safe System Assessment Framework (Austroads, 2016)

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[1] Although methodologies such as iRAP can be used to identify speed limits that will improve the safety along road corridors, Iran has limited experience with such methodologoes beyond the application of iRAP to improve pedestrian safety at a limited number of schools.
See https://irap.org/2020/07/new-star-rating-for-schools-case-study-tehran-mashhad-iran/

Figure 1. GPS tagged video captured from pilot road (Arak-Salafchegan Hwy)

Figure 2. Identified safety risk (unsafe U-turn)

to produce a quantified safety risk score for each uniform road length identified in the previous step. Road User Exposure, Crash Likelihood, and Crash Severity were scored on a scale of 0 to 4 for major potential crash types: Run-off-Road (ROR), Head-on (HO), Intersection (INT), Pedestrian (PED), Bicycle (CYC), Motorcycle (M/C), and other crash types (OTHER). An example of "Exposure-Likelihood-Severity" matrix completed for one of the pilot road segments is presented in Table 1.

Determining Safer Speed Limits

After quantifying the risk scores for each of the road segment, a Safer Speed Limit (SSL) was determined for each segment. These SSLs are the safer speed limits determined for each road segment based on the current safety condition of the segment.

The closer the safety risk score is to zero, the more the segment in question is in alignment with Safe System principles. However, as stated in the Austroads Safe System Assessment Framework, the scoring system should not be interpreted as a linear scale in which, for example, twice the score means twice the risk (Austroads, 2016). For this reason, the risk scores were divided into 5 ranges, 0, 1-100, 101-136, 137-170, and above 170. These ranges were determined by qualitatively checking and comparing the risk scores calculated for all the segments and identifying typical road segments based on safety conditions. Next, an SSL value was assigned to each score range. Table 2 shows the maximum safer speed limits identified for the safety risk score ranges. As seen in the second row of Table 2, for any unsafe condition (i.e., risk score being more than zero) the maximum safer speed limit was limited to 90 km/h.

Moreover, recognising that the Table 2 SSLs are not necessarily appropriate to all functional road types, the road safety engineering team considered *Movement and Place* principles to determine the maximum SSLs for functional road types in Table 3.This is inspired by the

Table 1. Exposure-Likelihood-Severity matrix template

	Crash Type						
	ROR	HO	INT	OTHER	PED	CYC	M/C
Road User Exposure (0 – 4)	High volume (4)	High volume (4)	Not applicable (0)	High volume (4)	With pedestrian volumes (2)	With cyclist volumes (2)	with motorcyclist volumes (4)
Crash Likelihood (0 – 4)	- (0)	Divided, wide/ raised median (0)	Not applicable (0)	slow moving entering/ leaving traffic (4)	No crossing facilities (4)	No Shoulder No lighting (4)	Mix of vehicles, some heavies (4)
Crash Severity (0 – 4)	High speed (4)	High speed (4)	Not applicable	High speed (2)	High speed (4)	High speed (4)	High speed (4)
Crash Type Product (Out of 64)	0	0	0	32	32	32	64
Safety Risk Score (Sum out of 448)	160						

Table 2. Safer speed limits based on safety risk scores

Safety Risk Score	Safer Speed Limit (km/h) [(1)]
0	Max. speed limit based on road type
1-100	90
101-136	80
137-170	70
Above 170 or significant Pedestrian safety risk score	50

Notes: [(1)] Limited to functional road type Maximum Safer Speed Limit (Table 3)

Table 3. Maximum safer speed limits for functional road types

Functional road types	Maximum safer speed limit (km/h)
Freeways	110
Semi-Freeways and divided multilane highways	100
Undivided main roads	90
Minor roads	80

results of Doecke, et al. (2018), which indicated that speed limits of 100 km/h or more would only meet the objectives of the Safe System where all crash types except rear end crashes are exceedingly rare, such as on a high standard divided road with grade separated junctions and a safe roadside design.

Evaluation using crash data

An integral component within the evaluation criteria will focus on crash data. The current crash investigation process primarily addresses compensation, retribution and fault. Further, there are extensive delays in converting the data analysis into strategic reform and productive interventions. As an initiative, a more analytical approach is to be adopted in the six corridors requiring the police investigators to identify primary, secondary and tertiary causes of any serious crashes and then make a recommendation as to how the risk of a crash of this nature can be prevented in the future. An expert review team led by the NRSC will fully analyse the causation factors and ensure the appropriate interventions are actioned. This conceptual approach is centred on current crash investigation reform (Shuey & Myers, 2021). As an evaluation strategy, it is intended to complement the SSA and address reform and interventions in a timely manner during the life-cycle of this project.

Results

The procedure described in the previous section for defining safer speed limits was repeated for each road length along the six pilot corridors. Results of SSA-based safer speed limits were compared with the currently posted speed limits based on several indicators. These include

Table 4. Maximum speed limit by corridor (km/h)

Corridor	Posted speed limit	Safer Speed Limit (based on SSA framework)	
		based on the roadway classification (see Table 3)	based on the current condition
Isfahan-Delijan (1)	110	100	90
Najaf Abad-Daran (1)	110	100	90
Neyshabur-Kahak (1)	110	100	90
Chenaran-Faruj (1)	110	100	90
Arak-Salafchegan (1)	110	100	90
Tehran-Saveh (2)	120	110	90

(1) Semi-freeway/divided multilane highway
(2) Freeway

Table 5. Lowest speed limit by corridor (km/h)

Corridor	Forward direction		Reverse direction	
	Posted speed limit	SSA-based speed limit	Posted speed limit	SSA-based speed limit
Isfahan-Delijan	40	50	40	50
Najaf Abad-Daran	60	50	40	50
Neyshabur-Kahak	60	50	40	70
Chenaran-Faruj	30	50	30	50
Arak-Salafchegan	40	50	20	50
Tehran-Saveh	40	50	80	50

reduction in maximum speed limits, differences in lowest speed limits, as well as changes in travel times and mean speed. The results of comparisons are discussed in the following subsections.

Reduction in maximum speed limits

Table 4 presents the maximum values of

1. posted speed limits,
2. safer speed limits based on roadway classification, and
3. safer speed limits based on current conditions.

Five out of six pilot corridors are classified as multi-lane highway, for which the maximum speed limit is currently 110 km/h. Also, the Tehran-Saveh corridor is classified as freeway, for which, the maximum speed limit is currently 120 km/h.

Table 6. Number of speed limit changes by corridor (both directions)

Corridor	Posted speed limit (no.)	SSA-based speed limit (no.)	% Change
Isfahan-Delijan	51	19	-63%
Najaf Abad-Daran	29	22	-24%
Neyshabur-Kahak	30	33	10%
Chenaran-Faruj	105	42	-60%
Arak-Salafchegan	40	16	-60%
Tehran-Saveh	17	8	-53%
All Corridors	272	140	-49%

Application of the SSA framework to the functional classifications across the six pilot corridors determined maximum safer speeds of 110 km/h for Freeways and 100 km/h for Multi-lane highways (Table 3). After further consideration of identified deficiencies in six pilot corridors and current road infrastructure and environmental conditions, the framework determined 90 km/h as the maximum safer speed limit for the corridors (third column in Table 5). Thus, if the authorities can improve the safety of the corridors, the maximum safer speed limit can be increased to 110 km/h for Tehran-Saveh freeway and 100 km/h for the other five multi-lane highways.

Differences in lowest speed limits

The Safer Speed Limits based on safety risks scores (Table 2) have been applied to determine the safer speed limit zones along each of the pilot corridors with the lowest SSL being 50 km/h. Further analysis showed considerable

Table 7. Mean travel speed by corridor (km/h)

Corridor	Forward direction		Reverse direction	
	Posted speed limit	SSA-based speed limit	Posted speed limit	SSA-based speed limit
Isfahan-Delijan	89	88	68	87
Najaf Abad-Daran	88	87	71	80
Neyshabur-Kahak	96	88	99	89
Chenaran-Faruj	74	84	79	85
Arak-Salafchegan	76	79	74	81
Tehran-Saveh	109	89	109	87

variation between the 50 km/h lowest safer speed limit zones and the current posted speed zones with the lowest values shown in Table 5.

Comparing the minimum values of posted speed limits along the six pilot corridors indicated that although having similar safety conditions, the lowest values of posted speed limits in these corridors are different and vary from 20 km/h to 60km/h, illustrating the lack of strict and consistent guidelines for setting speed limits in Iran. This is important because having a clear approach and documented guidelines for setting speed limits will result in more consistent speed limit values for similar conditions along roads all over the country.

Number of speed limit changes

As seen in Table 6, for each of the pilot corridors, the number of speed limit changes along the six pilot corridors is generally less when based on the SSA-based framework compared to the existing posted speed limits. Following application of the SSA-based framework to define safer speed limit zones, the total number of changes in speed limits across all six pilot corridors have reduced by 49%. As an instance, along the Chenaran-Faruj corridor, the posted speed limit currently changes 105 times, and the lowest speed limit is only 30 km/h. However, based on the SSA framework, the number of changes in the safer speed limit is decreased to 42, and the lowest safer speed limit is 50 km/h.

Reducing the number of changes in the speed limits along a corridor establishes a more credible connection between the safer speed limits and the road infrastructure and environmental conditions. Whether this more credible connection inclines drivers to obey the safer speed limits is a hypothesis that needs to be examined in a separate study.

Table 8. Approximate travel time by corridor (minutes)

Corridor	Forward direction		Reverse direction	
	Posted speed limit	SSA-based speed limit	Posted speed limit	SSA-based speed limit
Isfahan-Delijan	98	100	146	114
Najaf Abad-Daran	61	61	75	67
Neyshabur-Kahak	111	121	108	121
Chenaran-Faruj	76	67	70	65
Arak-Salafchegan	49	47	53	46
Tehran-Saveh	45	55	45	57
All Corridors (Average)	73	75	83	78

Changes in mean speed/travel times

Another interesting result of the comparison between current posted speed limits and SSA-based safer speed limits is the mean travel speeds and the relevant approximate travel times. The mean travel speeds and the relevant travel times are provided in Tables 7 and 8, respectively. Intuitively, the introduction of a 90 km/h maximum safer speed limit could be expected to decrease the estimated mean travel speed and increase the approximate travel time along the corridors. However, as seen in the Tables 7 and 8, the majority of the SSA-based speed limit mean travel speeds are similar or higher and travel times are similar or lower compared with the current posted speed limits. The reduced numbers of SSA-based speed limit changes (Table 5) are considered to be a factor given the correlation with similar or higher mean travel speeds and similar or lower travel times.

Conclusions

This study aimed to propose a practical framework, amongst other methodologies, for setting safer speed limits on rural roads based on both the likelihood as well as severity of different potential crash types. This framework has the following benefits:

1. Demonstrates this process as a practical tool for setting safer speed limits by accounting for the potential likelihood and severity of several crash types,
2. Reduces the effect of engineering judgment and unifies the procedure for setting safer speed limits.

The proposed framework was applied to six corridors in Iran and a set of parameters were used to compare the safer speed limits with the speed limits currently posted on the six corridors. Results of the comparison showed that the proposed framework can help to provide a more harmonic speed limit profile (i.e., similar speed limits for similar safety conditions), and fewer number of changes in the speed limits along a corridor. Furthermore, comparison results indicated that the safer speed limits have limited impact on reducing the mean travel speed and increase travel time along the study corridors. Also, by applying this framework, evidence has been obtained to legitimise speed limit reductions aimed at saving lives in the interim, while engineering infrastructure treatments can be implemented.

The study demonstrates the potential for SSA-based safer speed limits to reduce the likelihood and severity of several crash types without undue impact on current traffic speeds or travel times. The future potential of the approach is to increase safer speed limits over time as road infrastructure, vehicle and road user initiatives contribute to reduced risk of crash occurrence and injury severity on the continuing path to achieving a Safe System.

Finally, the following notes need further considerations (and perhaps be studied in future research):

1. Speed limit compliance is a crucial challenge especially when it comes to safer speed limits (Doecke et al. 2018). Speed limit compliance may vary due to factors such as perceived reasonableness of safer speed limits, and speed limit enforcement practices (Doecke, et al. 2018). Hence, increasing public awareness and social marketing activities aiming to increase the perceived reasonableness of safer speed limits, as well as more strict law enforcement of speed limit violations are vital for increasing the acceptance of safer speed limits among drivers.
2. Speed limits and infrastructure treatments are the flip sides of a coin. That is, if the infrastructure cannot assure safety at the speeds travelled, the speed limits must be reduced. On the other hand, where the road infrastructure is made safer through engineering treatments, the speed limits can often be raised from basic Safe System levels. Moreover, for a social acceptance perspective, improving road engineering safety standards and raising the safer speed limits on a number of road segments would legitimise lower safer speed limits with lower road engineering safety on other segments. However, this hypothesis needs to be investigated in a separate study.

Limitations

The focus of this paper was to report the application of Safe System Approach as a robust method to determine safer speed limits. The proposed framework was applied in six pilot zones in Iran. Certainly, the real effect of the proposed safer speed limits and engineering measures on the safety improvement can be demonstrated by comparing safety-related indicators (e.g., average speeds, speed violations, speed variances, crashes and injuries) in the six pilot zones before and after implementing the proposed safer speed limits and engineering measures. In the circumstances, a full evaluation could not be undertaken as the life cycle of the project is to be three years.

Also, regarding the risk scoring system and SSLs, it should be noted that no scoring system is ideal and subjectivity can affect the scores. Moreover, this was the first study in which the safety risk scores were banded and used for determining safer speed limits. The risk score ranges and the relevant safer speed limits were determined for the current case study, and providing a more general risk score and safer speed limit ranges would entail wider use of the framework and comparisons with actual safety performance.

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Appendix 1. Pilot Corridor Base Information

Pilot Corridor	Length (km)	Segment	Road Type (1)	Direction	AADT (2)	Heavy Vehicles (%)	Mean Speed (km/h)	Speed Violation (%)
Isfahan Province								
Isfahan - Delijan	125	1	Hwy.[1]	Forward	21,905	26	93	19.5
				Reverse	21,799	30	93	17.2
		2	Hwy.	Forward	12,910	45	84	9.4
				Reverse	12,656	44	90	10.4
		3	Hwy.	Forward	12,220	45	83	1.7
				Reverse	12,115	41	81	2.4
Najaf Abad - Tiran - Daran	100	1	Hwy.	Forward	22,182	11	84	3.9
				Reverse	21,526	13	85	8.1
		2	Hwy.	Forward	12,486	13	82	4.9
				Reverse	13,396	13	87	6.3
Khorasan Razavi Province								
Neyshabur - Sabzevar - Kahak	190	1	Hwy.	Forward	7,680	25	83	0.5
				Reverse	8,351	25	80	0.6
		2	Hwy.	Forward	7,924	28	95	16
				Reverse	8,616	31	87	4.8
Chenaran - Quchan - Faruj	65	1	Hwy.	Forward	12,883	11	91	7.2
				Reverse	12,255	12	91	8.3
		2	Hwy.	Forward	12,203	8	91	8.9
				Reverse	11,365	8	87	2.1
Markazi Province								
Tehran - Saveh Fwy.	77	1	Fwy.[2]	Forward	22,750	34	89	3.0
				Reverse	21,036	27	101	10.0
		2	Fwy.	Forward	14,613	35	93	10.8
				Reverse	11,314	36	74	2.9
Arak - Salafchegan	67	1	Hwy.	Forward	17,859	32	97	25.6
				Reverse	16,587	29	98	26.3

(1) Hwy. = Highway; Fwy. = Freeway
(2) Annual Average Daily Traffic