An Investigation to Determine the Minimum Acceptable Roadway Condition for Iran's Highways

Hamid Behbahani[1], S. Mohammad Elahi[2]

[1]Professor of Civil Engineering, Iran University of Science and Technology, Tehran, Iran
[2]Traffic Engineer, City of Waterloo, Waterloo, Iowa, U.S.A.

Abstract:*To properly plan for construction, repair, maintenance, and reconstruction of highways the minimum acceptable roadway condition is needed information. This, along with other pavement management tools, will help select the most desirable roadway alternatives. In this research the minimum acceptable conditions are developed based on an opinion survey of non-technical but high-level decision makers. Roadway roughness, expressed as international roughness index (IRI), is used as the measurement criteria. Because IRI is a widely known, acceptable, and a uniformly measurable index, it is used for the purpose of this research. The minimum IRI values developed here will help managers, planners, and engineers in prioritizing their plans and projects. Iran has a central planning system, hence having a minimum acceptable IRI will help in producing homogeneity in decision making. A questionnaire is sent to top level and influential management-level officials who have a decisive input in highway matters. The officials are asked to choose the minimum acceptable service level of different types of roadways and classifications. Naturally, roadways with higher levels of importance would require higher service levels. The answers to the survey questionnaires are investigated to determine a preferred minimum acceptable roadway condition. The IRI is computed using a mechanical device enabling a more uniform data collection. The IRI was first proposed by The World Bank as a standard roughness statistic. Extensive research has proven that the IRI can be related to pavement condition. The result of the opinion survey is investigated to determine the minimum levels acceptable for each category. The responses show distinct preference patterns for most of the roadway types. Survey results are investigated by plotting and analyzing them. Based on road user's perception of roadway condition using guidelines from AASHTO, the Corp of Engineers, and related research work. The appropriate IRI limits and ranges are determined for Iran's highways. These values are adjusted to obtain final values for Iran. The result, shown in a table, gives upper and lower IRI values accepted and recommended for Iran's highways. The result of this research work is specifically useful in developing specifications for new pavement design, accepting new pavement from contractors, pavement management, highway planning, and in roadway life cycle cost analysis decision making. The results are subject to refinement over time.*

Keywords: *pavement condition, highway planning, pavement management, IRI, minimum acceptable, LCCA, decision making, pavement service level, roadway roughness, management tool, Iran's highways.*

Introduction

When making decisions, using the appropriate tools can help decision makers select the most desirable alternatives. This is also true for highways. Tools and information will help in making better decisions. Development of a basic tool for Iran highways is presented here. This is the minimum acceptable roadway condition.

This is needed to help keep the nation's pavement on a consistent level of service, and in making decisions regarding pavement maintenance, replacement, and reconstruction. Minimum acceptable conditions are developed based on an opinion survey of non-technical high level decision makers, those who affect the budget and planning of highways. A methodology based on the roadway roughness is used to

determine values for minimum acceptable conditions. These values are expressed in terms of IRI, the international roughness index that was originally developed by the United Nations. The following sections contain the problem statement, methodology, results and recommendations.

Problem Statement

There is no management support tool for decision making regarding Iran's highways. An important management support tool needed for making decisions is the minimum acceptable service level that pavement should provide. Using such minimum standards, the decision makers can select projects or plan improvements and construction that are in-line with other decision makers and according to a more homogenous view of the needs. Not all roadways and pavements must provide the same quality of service. Depending on their usage and significance, pavements need different service ratings. Homburger, et al, mention that one of the requirement of long-range transportation planning is giving emphasis to those, which serve important national and regional transportation systems.

By determining these levels, decision making across the country would more harmonious and equitable. Keeping particular roadways under a certain minimum and uniform standard condition will keep a uniform level of service throughout the nation. At the same time money is spent where it is needed, and guess work is reduced. This is one of the tools of a life cycle tool box. There is no life cycle tooling available in Iran to the decision makers. Iran has a central planning and budgeting system for its national level highway network. The provinces also receive budgets to plan their roadway construction

and maintenance activities over a five year period. The planners and managers at both levels do not have any decision support tools to come up with the most desirable decisions. Interviews with high level officials who substantially influence the decisions revealed that there is no systematic and scientific approach to decision making for highways. The officials acknowledged a need for tools to help select highway projects for budget allocation and scheduling. A survey of the leading consultants involved in roadway planning and design also revealed a lack of existence of any tools for decision making and revealed a need for such tools. The most important of these tools is determining a minimum acceptable level of service for the pavements. A minimum acceptable pavement condition must be determined and agreed on as a basis before an LCCA can be implemented. This is needed to determine when work must be planned or scheduled. Having a national uniform consensus on the minimum acceptable levels is important. There are many other benefits to having a uniformity regarding pavement surfaces. The minimum acceptable condition can help planners and engineers to rank and prioritize projects. A variation of surface conditions on a stretch of a roadway can result is speed differentiation. Design practices incorporate the concept of speed consistency. Uniform minimum levels for same type of roadways, regardless of jurisdictional supervision, will help maintain a more desired uniform speed. Bad surface conditions can reduce speed, which will lower the traffic level of service and cause delays.

Determining the Minimum Acceptable Level

To determine the minimum acceptable pavement service levels for Roadways a

Table 1. Minimum Acceptable Service Levels in Alphabetic Form

Visual and Movement Condition	Condition in Alphabetic Presentation
Completely smooth; appears to be uniform; no visible patching or deficiencies	A
Completely smooth; some discrepancies in appearance	B
Almost smooth; some discrepancies in appearance	C
Not very smooth and non uniform appearance	D
Many bumps, pot holes, cracks, and inappropriate appearance	E
Many bumps, pot holes, cracks, severe pavement deterioration; unacceptable appearance	F

questionnaire is sent to those top level management officials. These are individuals who can influence and have a say in deciding what should be the minimum pavement service levels. They include the Iranian Minister of Roads and Transportation, deputies to the Minister, and those people holding positions in the Iran Management and Planning Organization who influence planning and budgeting of transportation systems. A questionnaire and a cover letter is mailed. The participants are asked not to forward the letter to their technical staff for response, because their own opinions as managers were needed. The questionnaire package points out that roadways are different according their operation and geometric characteristics, and that as a result, the minimum acceptable levels for roadways vary accordingly. Roadways with higher levels of importance would require higher service levels. This should decrease as the importance of the roadway decrease. The questionnaire is in the form of a table. It has different types of roadways, with functional classification and area serviced listed horizontally, and the minimum acceptable service levels in the form of alphabetic assignments listed as vertical column headings. A separate table explains what

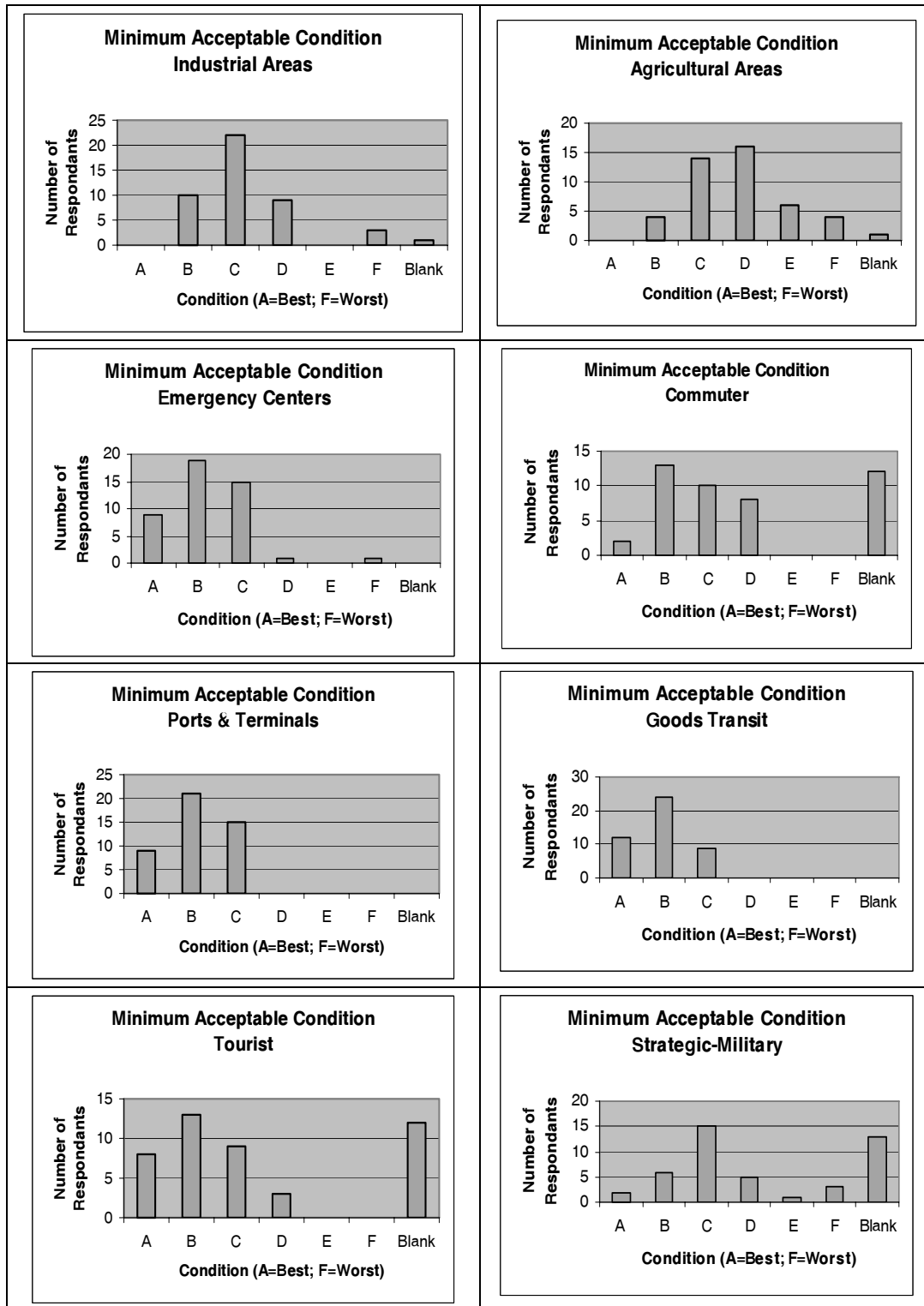each alphabetic letter stands for. Table 1 shows this latter table.

The answers from the questionnaires are investigated to determine a preferred minimum acceptable roadway level of service. The response received was overwhelming. All those who were sent the questionnaire responded. The next step is to translate the common language descriptions into technical and measurable equivalents. A combination of works done by Montenegro and Mink, AASHTO, and the Corps of Engineers were used to convert the above mentioned alphabetic nominations into acceptable IRI limits for Iran. *International roughness index* (IRI) is a number that represents the amount of roughness in a measured longitudinal profile. The IRI is computed using a mechanical device. The authors of this paper recommend the use of IRI. Consistency of data and uniformity of data collection is very important for the purpose or comparing and ranking pavements. Manual methods are cumbersome and may result is variances. To bring the data collected by raters closer to reality and to one another many efforts have been taken. The SHRP has had accreditation training programs for pavement distress

Table 2. Summary of the Result of the Opinion Survey

Pavement condition	Type of Route														
	Two Lane	Four Lane	Expressway	Freeway	Villages & Minor Access	s'Dignatory	High Level Officials	Strategic-Military	Tourist	Transit of Goods	Ports and Terminals	Commuter	ncy CentersEmerge	Agricultural Areas	Industrial Areas
A	4	14	21	30	1	27	6	2	8	12	9	2	9	0	0
B	14	18	18	13	1	7	24	6	13	24	21	13	19	4	10
C	23	12	5	1	7	1	2	15	9	9	15	10	15	14	22
D	3	0	1	1	1	0	1	5	3	0	0	8	1	16	9
E	1	1	0	0	1	0	0	1	0	0	0	0	0	6	0
F	0	0	0	0	0	0	0	3	0	0	0	0	1	4	3
No Answer	0	0	0	0	34	10	12	13	12	0	0	12	0	1	1
Total	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45

raters as far back as the early nineties. The IRI was first proposed by The World Bank as a standard roughness statistic. The World Bank was looking into a means through which to compare the roughness data from different parts of the world. The IRI was developed as a statistic which, when used with stable methods and standard equipment could produce consistent results. In 1982, the World Bank initiated a correlation experiment in Brazil to establish a correlation and a calibration standard for roughness measurements. In processing the data, it became clear that nearly all roughness measuring instruments in use throughout the world were capable of producing measures on the same scale, if that scale were suitably selected. From that point on, an objective of the researchers was to develop the IRI. The IRI is reproducible, portable, and stable with time. Today almost every automated road profiling system includes software to calculate a statistic called the International Roughness Index (IRI). The Federal Highway Administration (FHWA) in the United States has made it a requirement since 1990 for all the states to report road roughness on the IRI scale for inclusion in the Highway Performance Monitoring System (HPMS). That is why IRI is recommended. IRI can be consistent since a mechanical means is used to collect the data. The mechanically collected data can be uniformly applied to rank projects. Extensive research has proven that the IRI can be related to the pavement condition. One such work was conducted to establish the relationship between the International Roughness Index (IRI) and asphalt pavement condition. The IRI values for roadway pavement sections in the North Atlantic region was studied with the Pavement
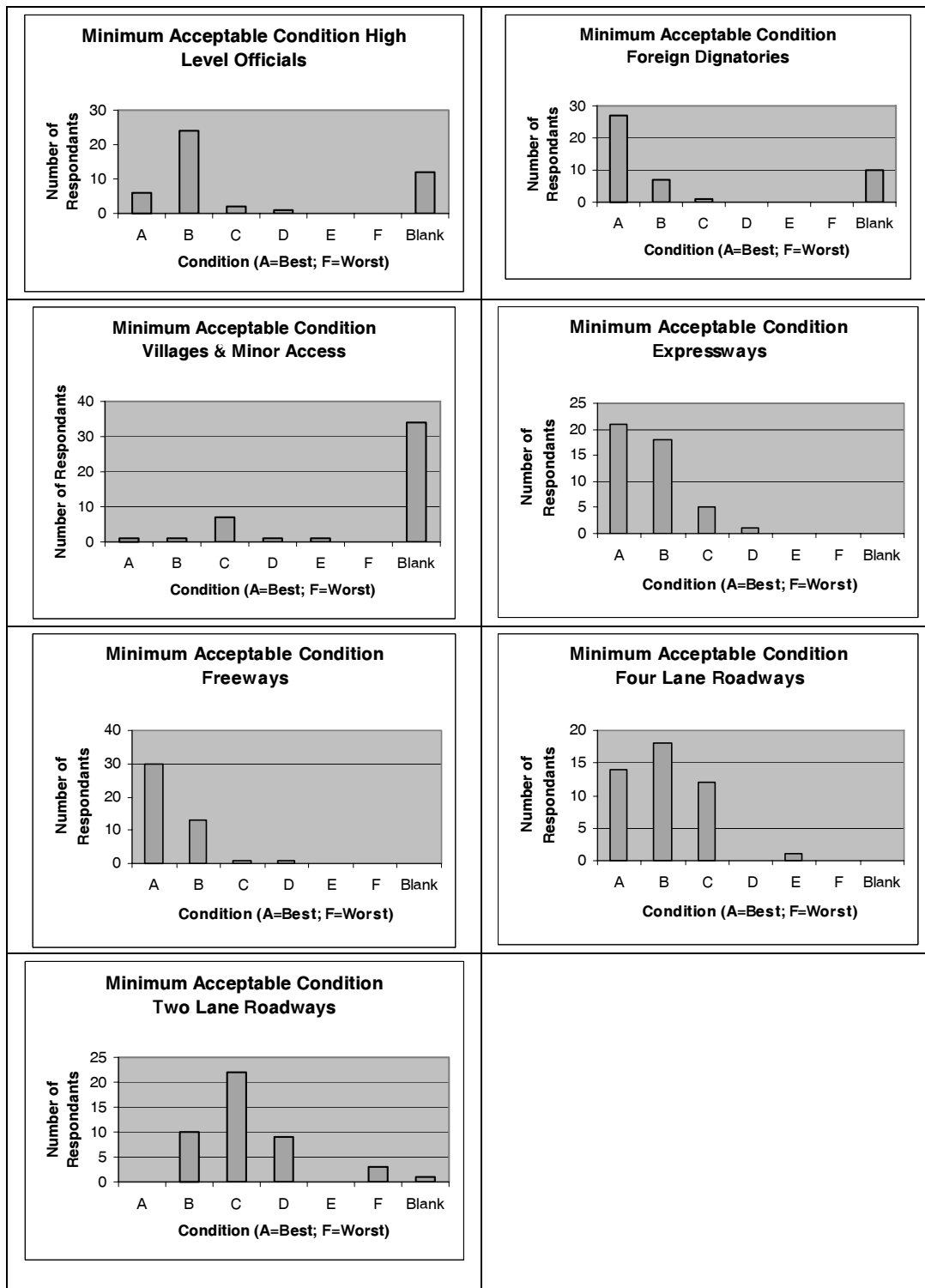
Minimum Acceptable Condition
Industrial Areas

Number of Respondants

Condition (A=Best; F=Worst)

Minimum Acceptable Condition
Agricultural Areas

Number of Respondants

Condition (A=Best; F=Worst)

Minimum Acceptable Condition
Emergency Centers

Number of Respondants

Condition (A=Best; F=Worst)

Minimum Acceptable Condition
Commuter

Number of Respondants

Condition (A=Best; F=Worst)

Minimum Acceptable Condition
Ports & Terminals

Number of Respondants

Condition (A=Best; F=Worst)

Minimum Acceptable Condition
Goods Transit

Number of Respondants

Condition (A=Best; F=Worst)

Minimum Acceptable Condition
Tourist

Number of Respondants

Condition (A=Best; F=Worst)

Minimum Acceptable Condition
Strategic-Military

Number of Respondants

Condition (A=Best; F=Worst)

Minimum Acceptable Condition High Level Officials

Minimum Acceptable Condition Foreign Dignatories

Minimum Acceptable Condition Villages & Minor Access

Minimum Acceptable Condition Expressways

Minimum Acceptable Condition Freeways

Minimum Acceptable Condition Four Lane Roadways

Minimum Acceptable Condition Two Lane Roadways

Figure 1. Plots of the Survey Results

Table 3. Results of the Investigation of the Surveys

TWO LANE HIGHWAY	FOUR LANE HIGHWAY	EXPRESSWAY	FREEWAY	MINOR ROADWAYS AND ACCESS TO REMOTE VILLAGES	FOREIGN DIGNITARY ROUTES	STRATEGIC-MILITARY ROUTES	TOURIST	TRANSIT OF GOODS	ACCESS TO PORTS AND TERMINALS	COMMUTER	TO EMERGENCY AID CENTERS	TO AGRICULTURAL LANDS	TO INDUSTRIAL REGIONS
C	B	B	A	D*	A	C	B	B	B	C	C	D	C

* Most respondents did not respond to this category, a category D is assigned by the authors.

Table 4. AASHTO IRI Values and Asphalt Concrete Pavement Condition (m/km)

NEW	CRITCAL	END
1.5*	4	6

*Can reach 2.5 if the original construction quality is low.

Table 5. Corp of Engineers Road User Pavement Condition and IRI Values

Good	Acceptable*	Bad	Very Bad
2.6	4.2	6	9

* This value is recommended by the World Bank.

Table 6. Unadjusted Alphabetical Designation for IRI limits- Iranian Highways

Rating Category	IRI (in/km)	IRI (m/km) (In/km Multiplied By .0254)
A	<70	<1.8
B	70-120	1.8-3.0
C	170-120	3.0-4.3
D	170-220	4.3-5.6
E	220-270	5.6-6.9
F	270<	>6.9

70

International Journal of Civil Engineering. Vol.4, No.1 March 2006

Condition Index (PCI) values for the same pavement sections using cross-referenced distress data. A transformed linear regression model was established that predicts PCI given IRI. They confirmed the acceptability of IRI as a predictor variable of PCI. Knowing that, with proper operational techniques, profilers can produce consistent IRI results, it is selected by the authors.

Montenegro and Mink researched the relationship between IRI and what the road user calls good and bad. They categorized roadway users perception into six categories of very good, good, appropriate, weak, bad, and very bad. Each category has a description that matched this research's surveyed categories very closely. The following table shows the result of their work. Assuming that the perception of the people in the country of their study is close to that of Iran, the categories are matched and an IRI is obtained for each alphabetic presentation in Table 1. The result of the opinion survey, as shown in Table 2, is investigated to determine the minimum levels acceptable for each category. Most categories show distinct preference patterns where one condition (alphabetic assignment) was selected by most respondents to be the minimum acceptable level. In the case of two close choices the lower choice is selected. Figure 1 shows the plots of the survey results.

The minimum acceptable conditions for each category are obtained by plotting the answers and examining the resultant graph. Where the distribution is such that two levels receive almost equal votes, then the lower boundary is selected.
The results are summarized in Table 3.

According to both AASHTO and the Corp of Engineers there is a relationship between the road user's perception of how good a pavement is and the roughness of the pavement (table 4 and Table 5). The IRI ranges obtained for each letter designated classification is converted from in/km to meters per kilometers and presented on Table 6. These ranges are plotted on a graph along with the ranges mentioned by AASHTO and The Corp of Engineers for critical and acceptable IRI values, as shown in Figures 2

Results

The results are adjusted considering the condition of pavement construction in Iran, response results, simplification, and the country's overall economy. The adjustments are shown as the white bar to the left of existing bars on the graph; see Figure 3. Category A, best pavement, acceptable limit is downgraded to 2.5 which is closer to Corp of Engineers and World Bank's recommendation. Categories B and C were combined and the limit set to 4.0. Category D lower limit is set at 7. Any number higher than 7 is designated F. These final adjusted recommended limits are shown in Table 7. This table shows the values in term of alphabetic designations. Next step is to convert back these designations to actual highway type and functional classification.

Table 7 shows the limits in terms of IRI. These limits are for each letter designation ranging from A to F.

These IRI categories and limits, which are close to well established international recommendation have been exclusively developed for Iran. They will provide an important tool both at the planning level and project level for the highway officials. The results can be used in order to make the
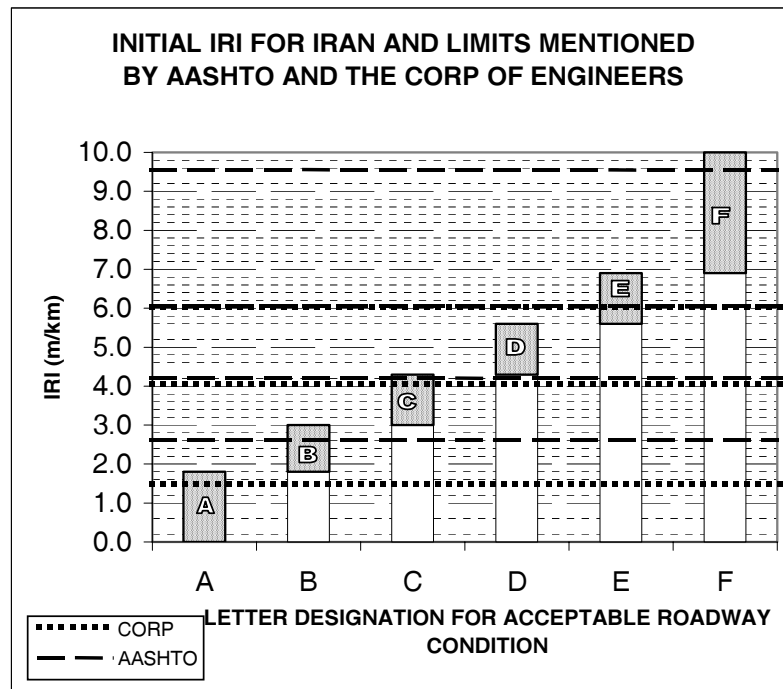
International Journal of Civil Engineering. Vol.4 No.1 March 2006

71

Figure 2. Plot of Acceptable IRI Ranges by Users, Shown Along With AASHTO, and The Corp of Engineers Acceptable and Critical Limits.
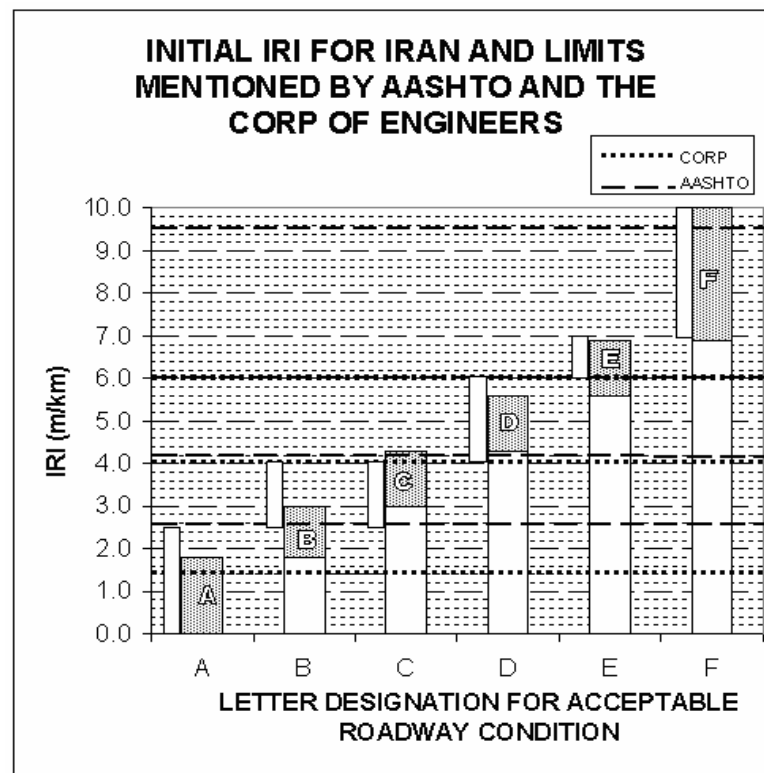

Figure 3. Ranges Proposed for Iran Added to Figure 2.

Table 7. Alphabetical designation for IRI Limits- Iranian Highways

Rating Category	IRI (m/km) (In/km Multiplied By .0254)
A	<2.5
B&C	2.5-4.0
D	4.0-6.0
E	6.0-7.0
F	>7.0

Table 8. Roadway Type and Recommended IRI.

Designation	Original Category	Adjusted Category	Recommended Adjusted IRI m/km
TWO LANE HIGHWAY	C	BC	2.5-4.0
FOUR LANE HIGHWAY	B	BC	2.5-4.0
EXPRESSWAY	B	BC	2.5-4.0
FREEWAY	A	A	<2.5
MINOR ROADWAYS AND ACCESS TO VILLAGES	D	D	4.0-6.0
FOREIGN DIGNITARY ROUTES	A	A	<2.5
STRATEGIC-MILITARY ROUTES	C	BC	2.5-4.0
TOURIST	B	BC	2.5-4.0
TRANSIT OF GOODS	B	BC	2.5-4.0
ACCESS TO PORTS AND TERMINALS	B	BC	2.5-4.0
COMMUTER	C	BC	2.5-4.0
TO EMERGENCY CENTERS	C	BC	2.5-4.0
TO AGRICULTURAL LANDS	D	D	4.0-6.0
TO INDUSTRIAL REGIONS	C	BC	2.5-4.0

optimal use of the limited institutional and financial resources available for roadway networks in Iran. The developed IRI limits has considered not only roadway class but types of traffic and land areas to be serviced. Planning around and design approaches based on these limits will allow to spend only what is needed for a roadway. It will minimize the life-cycle costs for investment and maintenance. This for example will means that roadways with low traffic loads will not be over designed. It also means that access roads that may be partially used by remote villagers during certain time of the year will have a much lower accepted pavement service level than other roads

Conclusion

It was possible to develop minimum acceptable roadway conditions by considering the Iranian top-ranking decision-makers' expert opinions. This is done by a relationship between their opinions with

numerical index. For the limits to be realistic and to increase the possibility of use, close categories are adjusted to merge into one. Table 8 shows the adjustments to the relationship between the roadway type, alphabetical categories and recommended IRI. These IRI values are to be used considering the guidelines under the recommended use, which is presented as the last section of this paper. These values are to be considered as rating scales.

Recommendations

Minimum acceptable pavement condition is just one tool for LCCA. This tool should be revised as the country's economical and social conditions change. The IRI limits should change to reflect the country's priorities in providing service and access to various geographical and economical sectors. Other tools in addition to the limits presented here are needed to complete the tool box set for managing Iran's highways. Research regarding highways in areas such as maintenance and repair costs, discount rate, actual service life versus design life, pavement economical appraisal methodologies is recommended.

It is also recommended that the results be used for the following applications.

New Pavement Specifications

When writing specifications for new pavements, the engineer should specify a minimum acceptable IRI expected from the contract work. The contractor must build the pavement within the specified IRI range. The project should only be accepted and final payment made only if the IRI limits are met. It is recommended that a category A IRI be specified for superhighways. An IRI within Category BC should be specified for other

new pavements. As the importance of the highway increases the specified IRI range should be smaller.

Existing Pavement Condition Surveys

Obtaining IRIs for existing pavements and comparing the data will give a picture of the condition of each and will a tool in decision making and choosing projects. This should be used in planning and budgeting for highways. If an IRI is close to the unacceptable limits for the type of highway, then the corresponding pavement should receive priority over the ones with lower IRI.

Functional Classification Vs. Usage

When deciding on an acceptable IRI for a particular roadway both function and type of use should be considered. For example if a two-lane roadway is going to serve a remote low populated area with little traffic then the Remote Villages Category D IRI should be selected. If the same two-lane is serving a populated high volume traffic area, then Two-Lane Highway Category BC should be selected.

References

[1]. Wolgang S. Homburger, Jerome W. Hall, Edward C. Sullivan and William R. Reilly. Fundamentals of Traffic Engineering, 15th Ed. University of California, Institute of Transportation Studies, Berkeley California 2000.

[2]. Traffic Engineering Handbook, Fifth Ed. Institute of Transportation Engineers. Washington, D.C., 1999.

[3]. Highway Capacity Manual. Special Report 209. Transportation Research Board. National Research Council,

Washington, D.C., 2000.

[4]. The Office of Highway Policy Information (OHPI), Measuring Pavement Roughness. http://www.fhwa.dot.gov/ohim/hpmsm anl/appe.htm, United States Department of Transportation, Federal Highway Administration, April 7, 2003.

[5]. SHRP-P-653, Accreditation For The Long-Term Pavement Performance Studies Pavement Distress Raters, Strategic Highway Research Program, National Research Council, Washington, DC 1993, National Academy of Sciences, Washington DC 20418.

[6]. The University of Michigan Transportation Research Institute (UMTRI). International Roughness Index (IRI), http://www.umtri.umich.edu/erd/rough ness/iri.html. January 17, 2005.

[7]. Sayers, Michael W., T. D. Gillespie, and W.D.O. Paterson, "Guidelines for Conducting and Calibrating Road Roughness Measurements," The World Bank Technical Paper Number 46, The World Bank, 1986.

[8]. Kyungwon Park, Kang-Won Wayne Lee, Natacha Thomas. Applicability of International Roughness Index as Predictor of Asphalt Pavement Condition. TRB 84th Annual Meeting. Washington D.C., January 2005.

[9]. Karamihas, S. M., T.D. Gillespie, R.W. Perera, and S. D. Kohn, "Guidelines for Longitudinal Pavement Profile Measurement", NCHRP Report 434, TRB, National Research Council, Washington, D.C., 1999.

[10]. C.J. Khisty and P.S. Sriraj. Transportation Project Selection Through Robustness Analysis for Developing Countries. 77th Annual Meeting, Transportation Research Board. Washington, D.C., January, 1998.

[11]. Guide for Design of Pavement Structures. AASHTO, Washington, D.C., 1986.

[12]. PAVER. U.S. Corps of Engineers Research Laboratory, Champaign, Ill.