DETERMINING THE MINIMUM ACCEPTABLE ROADWAY CONDITION FOR IRAN'S HIGHWAYS FOR A HOMOGENOUS AND EQUITABLE ROADWAY SYSTEM

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ABSTRACT

To effectively evaluate, plan, design, construct, and repair the roadways a minimum acceptable condition must be defined. This will help evaluate the rationale of expending natural resources in relation to land development, access, mobility, and safety in order to prioritize and select roadway alternatives for particular purposes. No minimum acceptable condition has been defined for Iran. In this research the minimum acceptable conditions are developed based on an opinion survey of non-technical but high-level decision makers. Minimum roadway roughness values are developed in terms of the international roughness index (IRI). Higher sustainability of the infrastructure and lower use of non-renewable resources through reducing over-expenditure and under-maintenance is achievable. The results will help in producing homogeneity in decision making bringing about a more socially equitable system of roadways. In a questionnaire, the high level officials are asked to choose the minimum acceptable service levels. The responses show distinct preference patterns for most of the roadway types. Survey results are investigated using guidelines from AASHTO and the U.S. Army Corp of Engineers. Appropriate IRI limits and ranges are determined and adjusted for Iran. The results are also useful in developing specifications for pavement, accepting work from contractors, pavement management, and in roadway life cycle cost analysis. The results are subject to refinement over time. Once implemented and a uniform baseline established, an important refinement factor will be the user input and expectations.

1. INTRODUCTION

When making decisions, appropriate tools can help the decision makers to select the most desirable alternatives. This is also true for highways. Tools and information will help in making a better decision. Development of a basic tool for in highways is presented here. This is the minimum acceptable roadway condition. This, along with other pavement management tools, is needed to help keep 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 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 international roughness index (IRI). IRI is a widely known, acceptable, and a uniformly measurable index. It was originally developed by the United Nations. IRI is chosen because it is computed using a mechanical device enabling a more uniform data collection, it is recognized by the World Bank, and it can be related to pavement condition. The following sections contain the problem statement, methodology, results and recommendations.

2. PROBLEM STATEMENT

Roadway building and maintenance uses a considerable amount of natural resources. These resources are in form of materials used for construction and repair, as well as the fuel and motor oil required to operate equipment and machinery. A secondary cause of additional natural resources is extra fossil fuel consumption by roadway users due to inadequately built and maintained pavements. There is no management support tool for decision making regarding highways. An important management support tool needed for making decisions regarding the highways and pavement management is the minimum acceptable level of service 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 use 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.[1] By determining these levels, decision making across the country would more harmonious and equitable. . It will also help in evaluation of the success of design, maintenance and materials. 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 budging 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. Interview 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. Variation in surface conditions on a stretch of a roadway can result is speed differentiation. Design practices incorporate the concept of speed consistency.[2] Uniform minimum levels for same type of roadway, regardless of jurisdictional supervision, will help maintain a more desired uniform speed. Bad surface condition can reduce speed, which will lower the traffic level of service and cause delays.[3]

3. DETERMINING THE MINIMUM ACCEPTABLE LEVEL

3.1 Obtaining a baseline

To determine the minimum acceptable pavement service levels for Roadways a questionnaire is sent to the top level management officials who could influence and have a say in deciding what should be the minimum pavement service levels or Iran. These included people holding positions as Iran Minister of Roads and Transportation, deputies

to the Minister, and those people holding positions in Iran Management and Planning Organization who influence planning and budgeting of transportation systems. A questionnaire and a cover letter are mailed. They 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 the 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 go down as the importance goes down. The questionnaire is in form of a table with type of roadway, by both functional classification and area serviced listed horizontally, and the minimum acceptable service levels in form of alphabetic assignments listed as vertical column headings. A separate table explains what each alphabetic letter stands for. The Table 1 shows this latter table.

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

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 Corps of Engineers was 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.[4] The authors of this paper recommend 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 raters as far back as early nineties[5]. 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 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

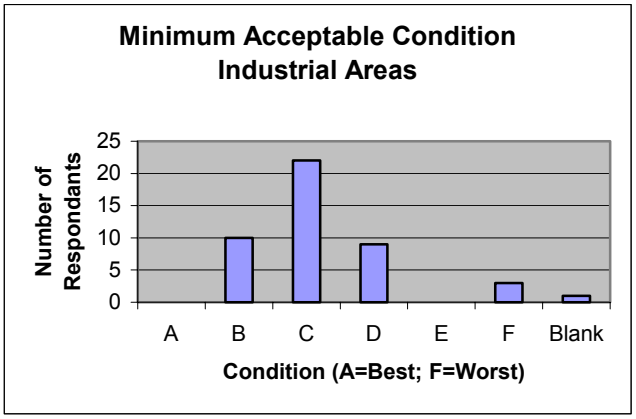
Roughness Index (IRI). The Federal Highway Administration (FHWA) in the United States has made it a requirement since 1990 for all the states to report road roughness on the IRI scale for inclusion in the Highway Performance Monitoring System (HPMS).[6] That is why IRI is recommended. IRI can be consistent since a mechanical means is used to collect the data. The mechanically collected and can be uniformly applied to rank projects. Extensive research has proven that the IRI can be related to the pavement condition.[7] One such work to was conducted to establish the relationship between 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 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[8]. Knowing that that with proper operational techniques profilers can produce consistent IRI results,[9] it is selected by the authors.

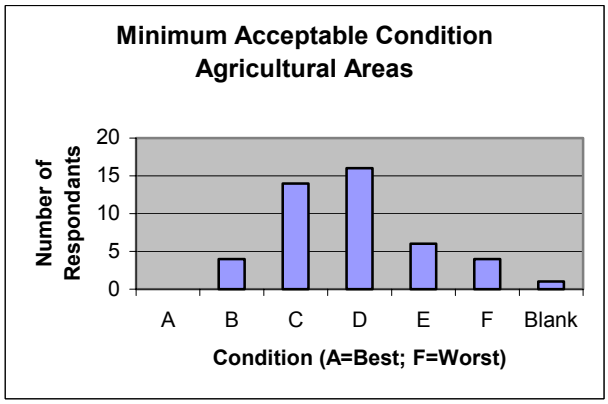
Montenegro and Mink researched the relationship between IRI and what the road user calls good and bad[10]. They categorized roadway users perception into six categories of very good, good, appropriate, weak, bad, and very bad. Each category has a description that matched this research's surveyed categories 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 case of two close choices the lower choice is selected. Figure 1 shows these plots of the survey results.

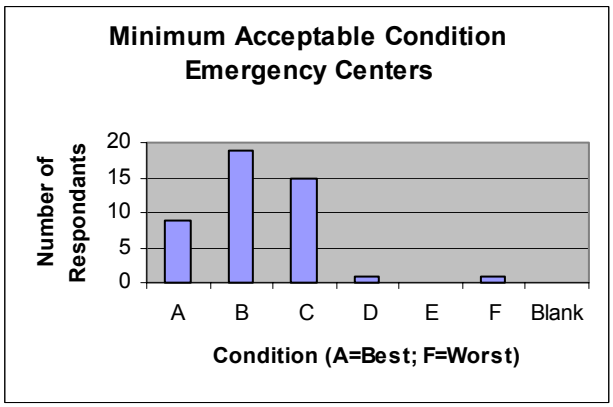
Table 2- Summary of the Result of the Opinion Survey

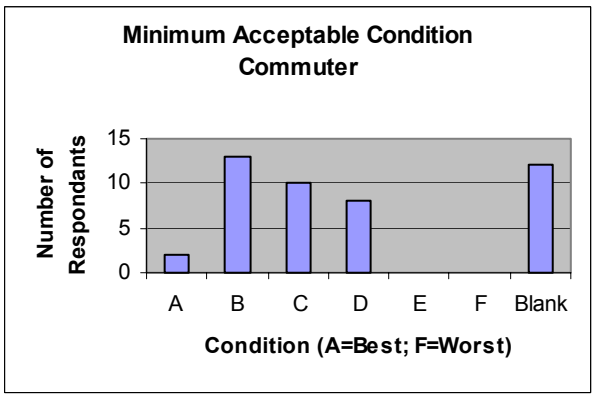
Pavement condition	Type of Route														
	Two Lane	Four Lane	Expressway	Freeway	Villages & Minor Access	Dignatories	High Level Officials	Strategic-Military	Tourist	Transit of Goods	Ports and Terminals	Commuter	Emergency Centers	Agricultural Areas	Industrial Areas
A	4	14	21	30	1	27	6	2	8	12	9	2	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

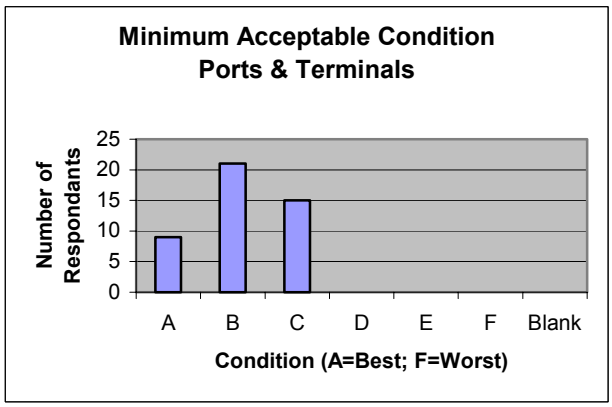
The minimum acceptable conditions for each category are obtained by plotting the answers and examining the resultant graph. Where the distribution is such that two levels receive almost equal votes, then the lower boundary is selected.

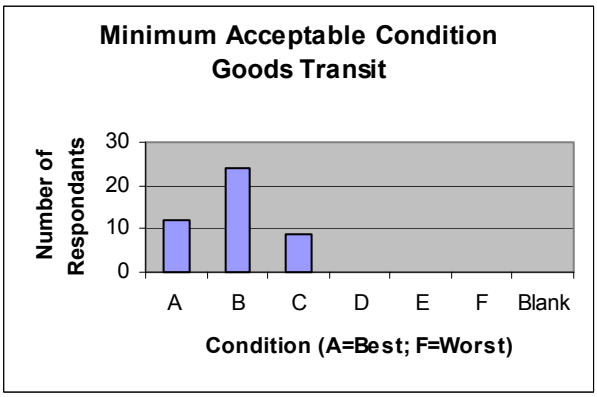


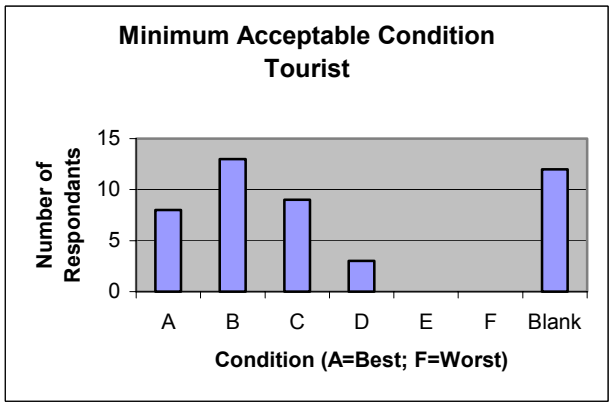


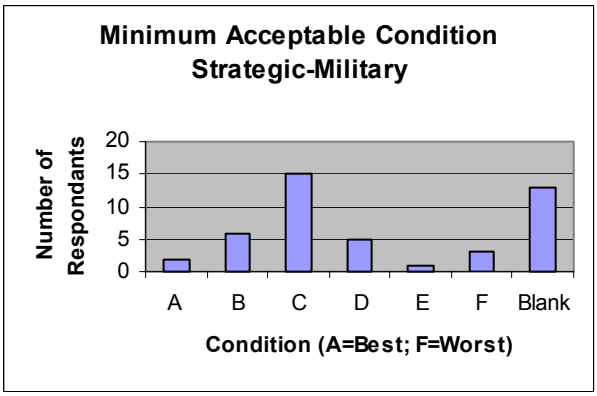












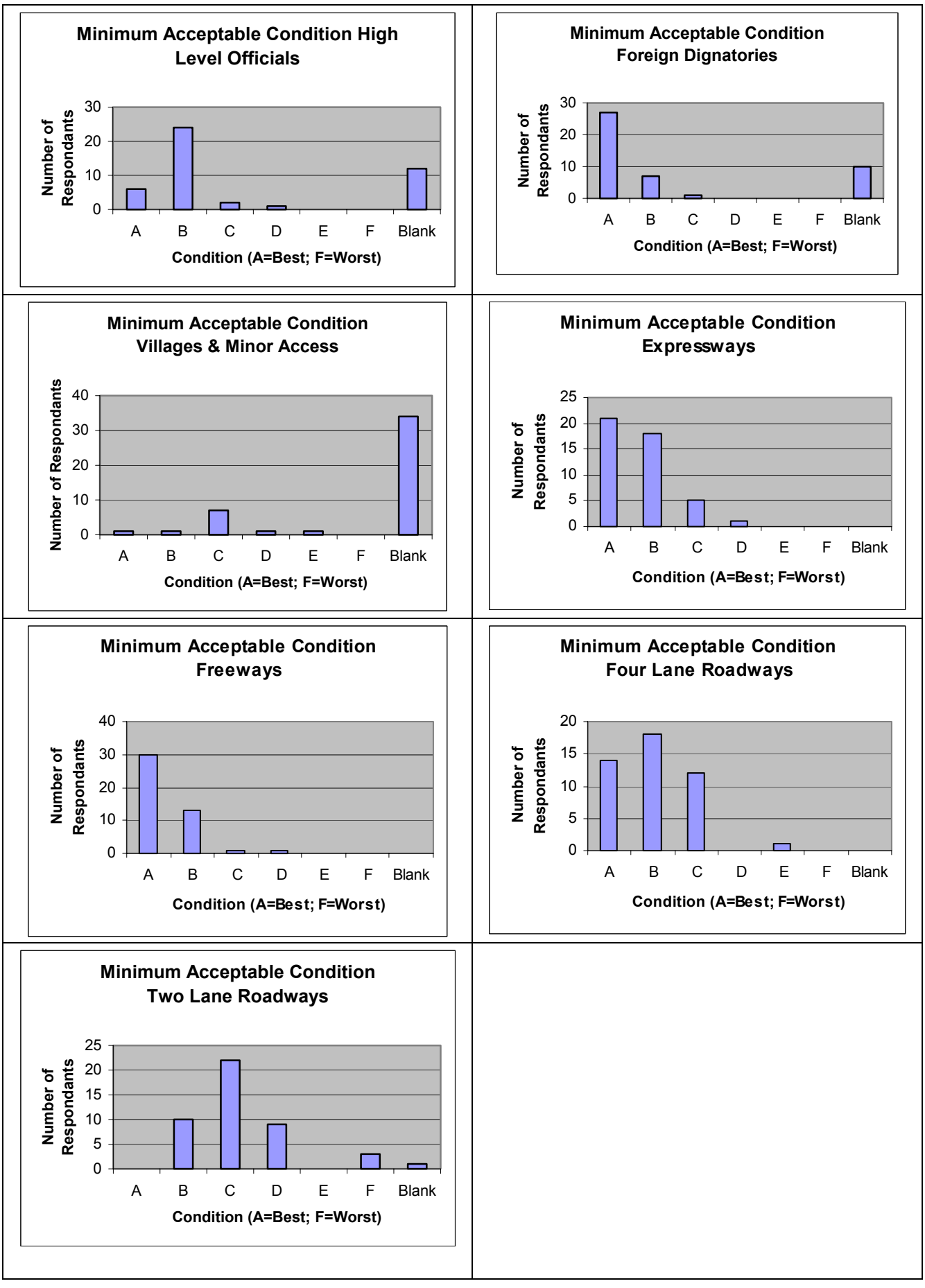


Figure 1- Plots of the Survey Results

The results are summarized in Table 3.

Table 3- Results of the Investigation of the Surveys

TOW LANE HIGHWAY	FO UR 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.

According to both AASHTO[11] and the Corp of Engineers[12] 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

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

New	Critical	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	120 – 70	3.0-1.8
C	170 – 120	4.3-3.0
D	220 – 170	5.6-4.3
E	270 – 220	6.9-5.6
F	270<	>6.9

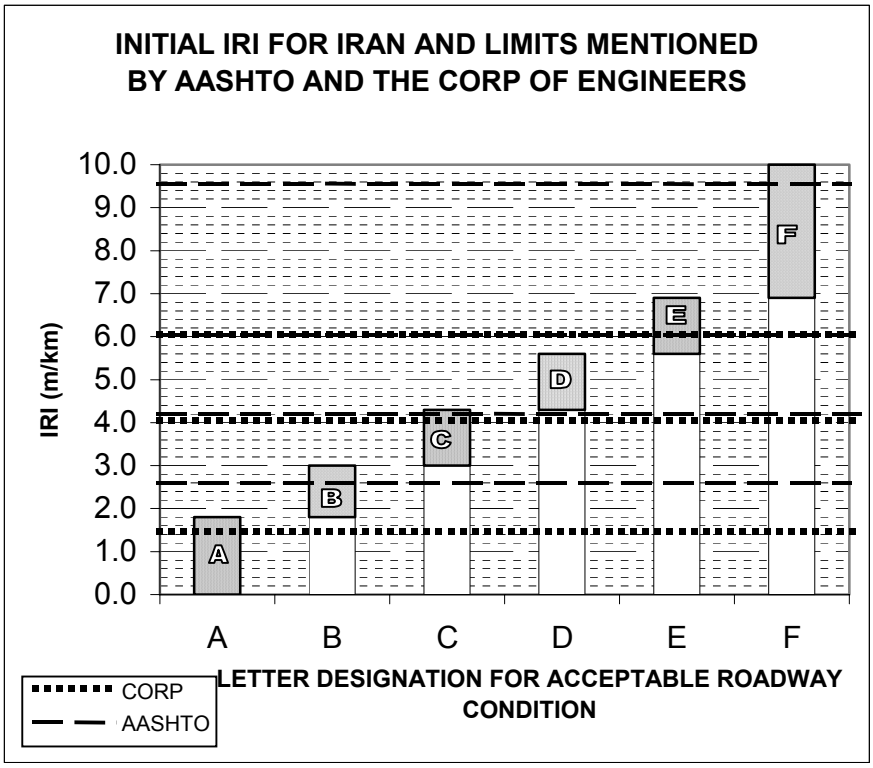


Figure 2

3.2 Expectations of Users and Residents

User expectation is an important factor that should be considered. The authors' observations indicate a vast range of what is acceptable to users. In large cities, where a large number of people own late model Iranian and French cars, demand for smooth pavements is very high. At the same time in remote villages a tractor pulled flat bed or even a motorized tiller pulled flat bed can be frequently observed as farmers' family transportation. These are often times driven on shoulders in order not to interrupt other traffic on the road. Knowledge of the quality of existing roadway surfaces is needed to evaluate the user's acceptability and how they feel about the existing conditions. Due to lack of consistent pavement quality data in Iran, this part could be done after a homogenous system is implemented. At that time survey of users and residents can be conducted and results can be compared to the existing conditions to quantify user expectations in ranking the projects.

3.3 Final Adjustments

Final adjustments are made to the values considering that 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 Band 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.

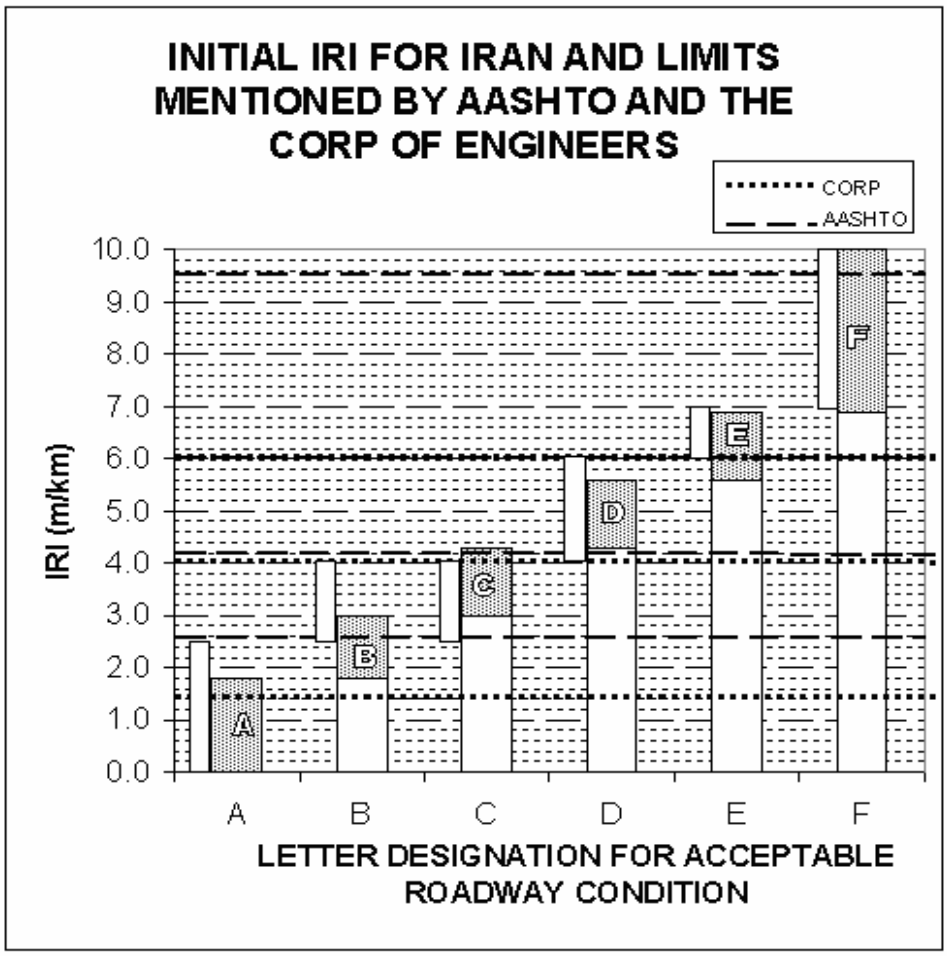


Figure 3

Table 7 shows the limits in Term

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 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.

Table 8- Roadway Type and Recommended IRI.

Designation	Original Category	Adjusted Category	Recommended Adjusted IRI m/km
TOW LANE HIGHWAY	C	BC	2.5-4.0
FO UR 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

4. RECOMMENDED USE OF THE RATING SCALES

4.1 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.

4.2 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.

4.3 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 same two-lane is serving a populated high volume traffic area, then Two-Lane Highway Category BC should be selected.

These IRI categories and limits, which are close to well, established international recommendation has been exclusively developed for Iran. They will provide an important tool both at planning level and project level for the highway officials.

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