

# CUBA: HIGHWAY AND ROAD SYSTEMS PRIORITY IMPROVEMENTS

Jacob Greenstein and Carlos Penin<sup>1</sup>

Cuba, the largest Caribbean island, has approximately 186,554 km of roads; 53% of these roads are paved and provide reliable accessibility to nearly all the cities, towns, airports, harbors, and agricultural areas.<sup>1,2</sup> The Cuban road density is approximately 2.6 km per 1,000 people or 272 km of roads per area of 1,000 Sq. Km. These road densities levels seem to be sufficient to serve most of the current vehicle fleet and traffic demand. However, considering Cuba's strategy for its economic development,<sup>3</sup> the current institutional set up of the Cuban ministry of transportation (MITRANS), and post transition accelerated traffic demand, the authors recommend modernizing the management of the road sector including improvement of priority roads that would sustain reduction of road transportation costs and support the Cuban foreign exchange earning strategy.<sup>3</sup>

The authors estimate that the proposed modernization of the Cuban road system would probably support other crucial social and economic savings when traffic demand will grow, including improving the highway safety services, implementing clean and cost effective urban and inter-urban rapid bus services that support reduction of CO<sub>2</sub> and other transportation related contaminants, improving the pedestrian, bicycle and other non-motorized traffic, and optimizing the life cycle costs of road investment and maintenance programs. The authors have concluded that the road authority of the new Cuba could meet

donors' conditionality during a short and peaceful transition and sector modernization periods of approximately six to nine months and could start the implementation of a 15-month and a \$24 million (M) accelerated road improvement and sector modernization programs. This conclusion goes in tandem with the latest announcement of the acting Cuban president, Mr. Raúl Castro, published in *The Washington Post* (July/26/07, "Cuba's call for economic détente") and indicating that Cuba is considering opening itself further to foreign investments of capital and technology and U.S. might play a role in a new Cuba.

## INTRODUCTION AND POSSIBLE DONOR SUPPORT

Cuba's strategy for its economic development is in the process of reformulation and the "grand design" that predominated since the ending of the special relationship with the former Soviet Union has essentially been terminated.<sup>3</sup> The basic features of the new Cuban economic strategy include the generation of foreign exchange earnings now emphasizing exports of nickel, medical and educational services, and, in time, perhaps oil. Modernization of the management of the Cuban road systems would contribute to the reduction of the overall road transportation costs, including vehicle operating costs and will support the Cuban foreign exchange earning strategy. Lessons learned from international donors such as the Inter-

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1. The opinions expressed in this paper are those of the authors and do not represent the views of the U.S. Government.

American Development Bank (IADB) and the World Bank (WB) show that modernization of roads management would probably support other crucial social and economic savings when traffic demand will grow, during and after the transition period, including improving road safety services, implementing clean and cost effective urban and inter-urban rapid bus services, improving pedestrian, bicycle and other non-motorized traffic, optimizing road improvement and maintenance services and keeping low CO<sub>2</sub> and other transportation-related contaminants.

Considering that during the current Cuban economic crises, 1989 to date, investment in the road sector was insufficient to maintain the road network in safe traveling conditions,<sup>(1-4)</sup> the authors recommend to accelerate the modernization of the road sector to reduce transportation costs and support the new Cuban “grand design” for economic development.<sup>3</sup> In tandem, to accelerate urgent road improvement and maintenance works the authors recommend using:

1. Online GPS-digital video logging of road conditions and non destructive techniques pavement evaluation to identify and design priority road improvement and maintenance works for motorized and non motorized traffic services. The estimated cost and implementation time of the planning and design services is \$1.6 M, and 6 months.
2. The estimated cost and implementation time of the priority construction and maintenance works is approximately \$20 M and 9 months;
3. The estimated cost of the proposed road safety, urban transport and institutional modernization studies of the Cuban ministry of transportation-MITRANS is \$2.4 M and the implementation period is estimated at 6 to 9 months. Lessons learned from LAC and Asia indicate that these studies are needed in tandem with the accelerated road improvements and maintenance works to optimize the expenditures of MINTRANS, sustain the future effective and safer road services and attract institutional and financial support of international donors, including the WB and IADB.

### **THE CUBAN ROAD SECTOR: CHARACTERISTICS AND CONDITIONS**

The area of the Cuban island is approximately 44,206 square miles (110,860 sq. km.), about the size of Pennsylvania.<sup>5</sup> The Cuban population is approximately 11.4 million, close to the Pennsylvanian population of approximately 12.3 M. The total mileage of the Cuban road systems is over 18,750 miles (30,150 km) including 16,000 km of paved roads. Approximately 53% of the Cuban road networks are paved and the road density is 2.64 km of roads per 1,000 persons, or 272 km per unit area of 1,000 sq.m. (see Table 1). Nearly all Cuban cities, towns, airports, harbors, and agricultural areas are accessible by paved roads, and there are approximately 677 km of completed expressways (4 lanes or more) and 114 km of expressways in construction or near completion. In comparison, the length of the Pennsylvania road networks is approximately 116,016 miles (186,554 km), or 1567 km of roads per a unit area of 1,000 sq. km. (see Table 1).

The distance between the eastern and western extremities of the Cuban island is approximately 1,200 km, connected by the main Cuban highway between Pinar del Rio and Santiago de Cuba. The highest mountainous top is approximately 2,000 meters (6,000 ft.) above sea level, located in the southeast of the Island. Seventy percent and thirty percent of the Cuban population, respectively, live in urban and rural areas with a high literacy rate of 97%. Table 1 compares the road density and road surface-paving density ratio in ten countries.<sup>5,6</sup> Table 1 indicates that the Cuban road density is not surprisingly far behind the road density of the state of Pennsylvania, but similar to the road density rates of Guatemala, Peru, and Mexico of 1.17 to 3.51 km of roads per 1000 people. Nevertheless, in terms of paving ratio, Cuba is more advanced with 53.3% of paved roads that provide adequate accessibility to all the seaports, ports, major production centers, and nearly all Cuban cities, towns, airports, harbors, and agricultural areas. In comparison, Guatemala, Peru and Mexico have only 13.3% to 39.4% of paved roads that carry more traffic volumes than the Cuban roads, but do not serve many townships or other social and economic centers.

Lessons learned from international donors and Latin American countries indicate that road networks with high rates of paved roads and relatively low traffic volumes, similar to the Cuban road conditions, require first investment in road maintenance works and then in construction of new roads.<sup>6-11</sup> This conclusion is relevant for the Cuban road system that has suffered from insufficient road maintenance funding and accelerated deterioration for approximately 16 years.<sup>1,2,4</sup>

**Table 1. Road Density and Classification Characteristics—World Bank<sup>6</sup>**

Country	Road density		Length of paved roads as a % of the length of the existing roads
	Km of roads / 1,000 people	Km of roads/ area of 1,000 sq.km	
Cuba	2.6	272	53.3
Argentina	6.1	84	27.6
Brazil	10.0	197	11.4
Costa Rica	9.0	691	22.0
Guatemala	1.2	130	38.9
Jamaica	7.2	1727	70.1
Mexico	3.5	183	33.5
Peru	3.0	61	13.4
Pennsylvania <sup>5</sup>	15.1	1567	87.4

### DONORS' OBJECTIVES IN SUPPORTING ACCELERATED ROAD IMPROVEMENT AND MAINTENANCE PROGRAMS

Lessons learned from Latin America and the Caribbean (LAC), African, Asian and East European countries indicate that donors would finance accelerated infrastructure improvement works in transition countries to support the following goals:<sup>7-12</sup> (a) peaceful political transition; (b) sustainable economic growth; and (c) poverty reduction. In the road sector, these goals are translated into the following objectives:

1. Implementation of effective, productive and competitive employment of construction and maintenance services;
2. Acceleration of road improvement and maintenance activities;
3. Road safety improvements for motorized and non-motorized traffic demands;
4. Modernization of the road sector and provision of institutional and technical capacity building to road agencies, consultants, contractors; and

5. Incorporation of local communities into the road maintenance services (road ownership).<sup>7</sup>

Donors would tie their interest to support accelerated road improvement projects to the provision of the following socio/economic, technical and institutional tests, including:

- Definition of the problems that the project will solve, such as reduction of transport costs and fewer accidents, and the sectoral context of the project implementation and operation, including a commitment of Government to provide adequate funding for maintenance and road safety services.
- Determination of the root causes of the problems, including insufficient investment and maintenance funds, ineffective institutional capacity, and insufficient community and road users' participation in the project planning and implementation stages.
- Identification of the stakeholders who would benefit from (road users), or be harmed by the project (affected communities), and provision of adequate and affordable mitigation procedures.
- Determination of the project dimensions, socio/economic ranking and priorities, demonstrating that the proposed project is a clear priority in relation to other road needs and Government is committed to provide enough political support.
- Provision of a project level detailed financial and socio/economic viabilities, demonstrating that the project is viable (high financial and socio/economic values of net present value and economic returns) and affordable with reliable financing for the construction works and for the future maintenance activities.
- Verification of the project's internal and external consistencies, demonstrating that the project is consistent with the multi-annual macro-economic framework of the ministry of finance and considered a priority within the overall inventory of the country's projects, not only the road sector.
- Incorporation of lessons learned from international best practices of road and bridge modern planning and design tools to optimize the life cy-

cle costs of construction, maintenance and operation expenditures.

The authors estimate that the road authority of new Cuba could meet donors' conditionality during a short and peaceful transition period of approximately three months and could start the implementation of a 15-month and a \$ 24.0 M accelerated road improvement program using the engineering tools and related lessons learned described in the following sections.

### ENGINEERING TOOLS FOR IMPLEMENTING ACCELERATED ROAD IMPROVEMENT AND MAINTENANCE WORKS—LESSONS LEARNED FROM DEVELOPING AND DEVELOPED COUNTRIES

**Accelerated road and bridge improvement works**  
**Engineering considerations:** International donors have historically associated road improvements works, including pavement rehabilitation works, with major project level investment programs.<sup>7-11</sup> Road network-level routine maintenance works have been considered as recurrent expenditures. Pavement improvement works are major investments that play an important financial role and are evaluated using the highway design and management tool (HDM-4<sup>13</sup>), developed by the WB and the University of Birmingham (UK), among others. The HDM-4 is designed to achieve desired pavement serviceability levels for minimum life cycle costs. The HDM-4 achieves this by analyzing the road and its pavement condition assessments; social, environmental and road safety characteristics; construction, maintenance and road user's costs needed to predict the performance of several alternatives of road improvement works from thin pavement strengthening using road asphalt surface dressing to long range pavement rehabilitation, road widening and improvement works.<sup>9-13</sup>

The HDM-4 has been extensively and effectively used in LAC, Australia, Georgia and other countries in Asia and Africa to reduce overall road transportation costs including vehicle operating costs, travel time, and improved road safety. There are usually three levels of road investment works, defined by the HDM-4 that international donors have supported

world wide, including periodic maintenance, rehabilitation and improvement works. The selected projects normally undergo detailed engineering and design, usually by the private sector. Project construction and supervision is also generally performed by the private sector.<sup>7-12</sup>

- **Periodic maintenance** is defined as investments that extend the life expectancy of a roadway and have a life expectancy of from three to seven years. It includes the improvement of ride quality and possibly pavement strengthening with at least a double surface treatment and usually a thin overlay of 3 to 6 cm of asphalt concrete (AC). It may also improve the drainage conditions and safety.
- **Rehabilitation** has a life expectancy of seven to ten years. This is because materials, traffic, and environmental considerations in developing countries generally do not allow a life of more than ten years. It includes thick overlays with preparatory road surface repairs and improvements and, if feasible, restructuring of the original characteristics of the road. These investments require more detailed engineering so a level of service as near as possible to a new surface can be achieved. These will include restoration of all safety aspects and may include localized geometry changes when necessary, as long as it does not cause any environmental impacts.
- **Improvements** include pavement widening for safety or congestion reasons, realignment to achieve safety goals, and pavement strengthening. These generally achieve a life expectancy of 10 to 15 years. The expected life is usually closer to 10 years (the lower level) due to materials, environmental, construction quality and other constraints.

In comparison, in the United States other pavement management systems<sup>12, 14 to 18</sup> have been used to primarily covered capital improvement programs for reconstruction and rehabilitation projects. Safety improvements and widening are addressed when necessary on major rehabilitation and reconstruction projects. Minor rehabilitation and major periodic maintenance are handled by some of the more so-

phisticated systems. These general categories of treatment have different meanings and may include different specific treatments depending on the state DOT and the project location. The following are general definitions of these treatment categories.<sup>12, 16, 18</sup>

- **Preventive maintenance** includes larger maintenance treatments such as Chip seals, thin overlays, machine patching, and other more substantial treatments that extend the life of the pavement and drainage elements for a period of 5 to 10 years and bridges from 10 to 25 years. These treatments may be programmed by pavement management systems.
- **Rehabilitation** involves major treatments such as a thick overlays and milling with overlay. Such treatments are intended to restore lost structural strength and add significant new life of 10 to 20 years, and bridges from 10 to 50 years.
- **Reconstruction** includes major works in which the entire structure of the road is reworked in order to ensure a new pavement and drainage service life of 15 to 20 years and bridges 20 to 100 years. Reconstruction also includes roadway improvements to improve safety or alleviate congestion including realignment and widening.

**Modern planning and engineering tools:** Lessons learned from Peru and other LAC countries indicate that modern engineering tools are very useful to accelerate functional and structural evaluation of road and bridges. The online-GPS-GIS-multimedia road and bridge inventory and condition assessments system was very useful to accelerate the evaluation of the functional and structural characteristics and conditions of the 900-km Peruvian road corridor from Lima (Pacific Rim) to Pucallpa, located in the Amazonas region, the engineering evaluation and design of this road was financed by USAID. International donors recommend that online multi-media road functional and structural evaluation devices include (see Figure 1): (1) a video camera system, usually with 3 to 4 cameras, and voice recording hardware and software equipment; (2) a Bump Integrator to measure the road surface roughness, in units of m/km (see Figures 1 and 2), and a road condition information system that determines

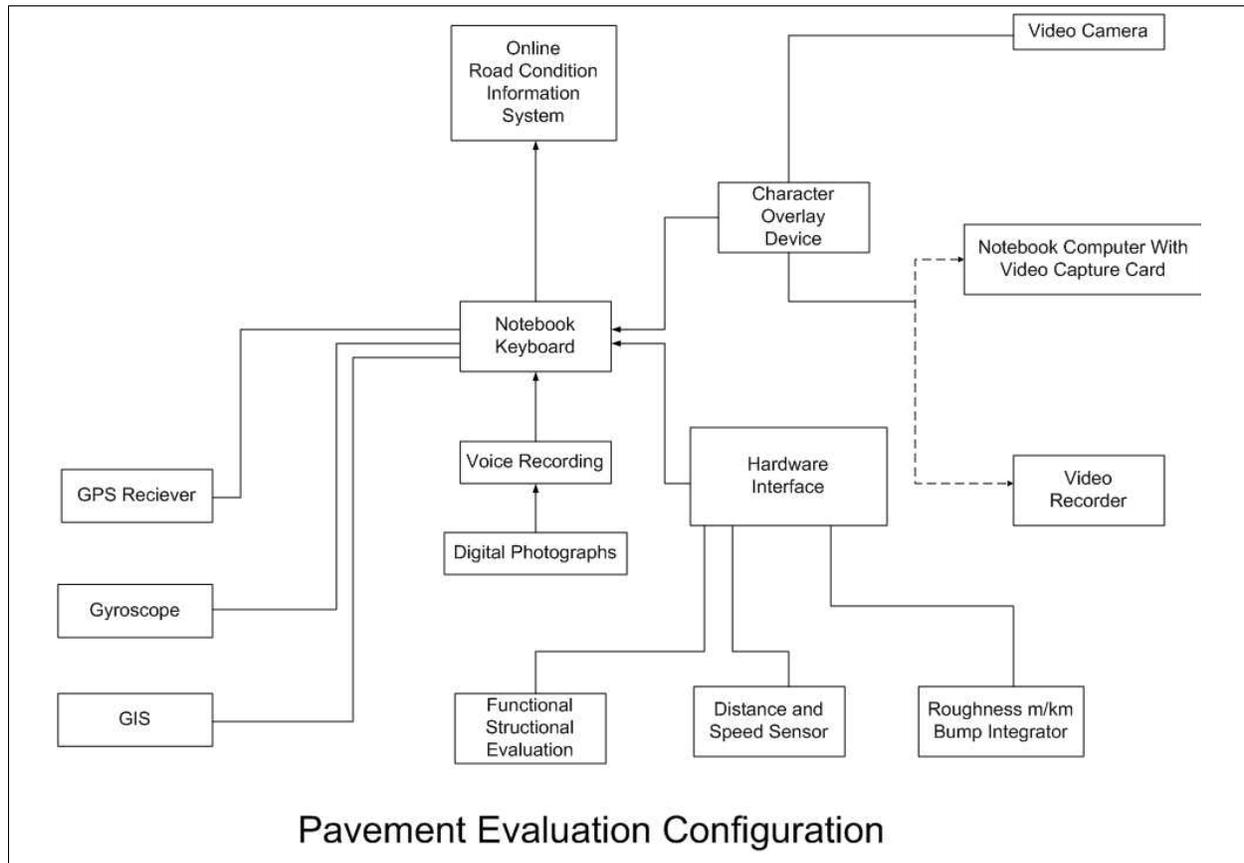
and records other road surface defects; (3) Gyroscope, GPS and GIS integrated systems; (4) notebook computer with video capture cards and distance-speed sensors systems; and (5) a laser-guided surveying equipment that measures other road's geometric characteristics and surface defects, including rutting and roughness.

The recommendations of *The Little Book of Roughness*<sup>19</sup> (see Figure 2), are universally used by all donors. This book indicate that paved roads in good to fair conditions should have IRI values of less than 3.0 m/km, and old roads with IRI of over 4.0 m/km with surface imperfections including minor but frequent depressions/defects need urgent periodic maintenance works to avert costly reconstruction works. The normal and safe traveling speed is greatly affected by road surface roughness, as an example the traveling speed is reduced approximately from 100 km/h to 60 km/h when the roughness is increase from 4 m/km to 10 m/km. Roughness values of over 4.0 m/km affect vehicle operation costs and road sections with high roughness values could be considered by donors for improvement if the HDM-4<sup>13</sup> program indicates that they are priorities.

The equipment devices of the online-multimedia road and bridge inventory and condition assessments are mounted to a vehicle that travels at a normal speed and gathers and records the road characteristics and conditions. Occasionally it is necessary to stop and survey structure defects of bridges, culverts and other drainage facilities that are hidden from the road surface and special video recording under the bridge or inside the culvert are needed. The productivity of one team, usually one driver and one technician is approximately 200 to 400 km per day.

The most practical and quick procedures to evaluate the pavement structural capacity is to use the falling weight Deflectometer (FWD) or the Benkelman Beam (BB).<sup>9, 10, 20–24</sup> The FWD and BB are non destructive testing (NDT) devices that measure the elastic surface deflections under the vehicle axle load, see in Figure 3 the principles of the FWD. The FWD measured the surface deflection basin of the 4-layer pavement system, including the asphalt layer- $h_1$ , the base course and subbase layers  $h_2$  and  $h_3$  and the

**Figure 1. Online Multi-media Road Surface, Structure and Pavement Evaluation Configuration**



pavement subgrade foundation. The thickness of each pavement layer,  $h_1$ ,  $h_2$  and  $h_3$  are determined using the Ground Penetrating Radar (GPR) device. Once the pavement layer-thicknesses and the road surface deflection basin are known, the pavement structural capacity, in terms of the layer elastic modulus,  $E_1$ ,  $E_2$ ,  $E_3$ , and  $E_4$ , is back calculated using linear or non linear universally recognized engineering tools.<sup>20 to 25</sup> The NDT test results are used to identify structural deficiencies of the pavement systems and to feed the HDM-4 to determine the most cost effective investment program.<sup>13</sup>

#### Selected road improvement program

The authors recommend using the HDM-4 program to select and design of approximately 100 km of priority paved roads that need urgent improvement works.<sup>1,2</sup> The HDM-4 will evaluate the: (1) the functional and structural deficiencies of the Cuban pavement and road systems; (2) projected traffic volumes

and axle load characteristics; and (3) financial, social and environmental constraints,<sup>1,2,26,27</sup> to determine the most feasible and affordable road improvement works.

The authors estimate the planning and design fee, for the 100 km priority roads, at \$1 M, and its accelerated implementation costs at \$18 M (see Table 2). The duration periods of the design and construction activities are estimated at 6 and 9 months.

#### Routine maintenance programs

Lessons learned show that the principles of routine maintenance programs of modern road administration include:<sup>9 to 12</sup>

- Quantitative evaluation of the road and bridge characteristics and conditions, using the modern video logging inventory described in the previous section, in order to determine the extend

Figure 2. The IRI Spectrum (meters/kilometer)

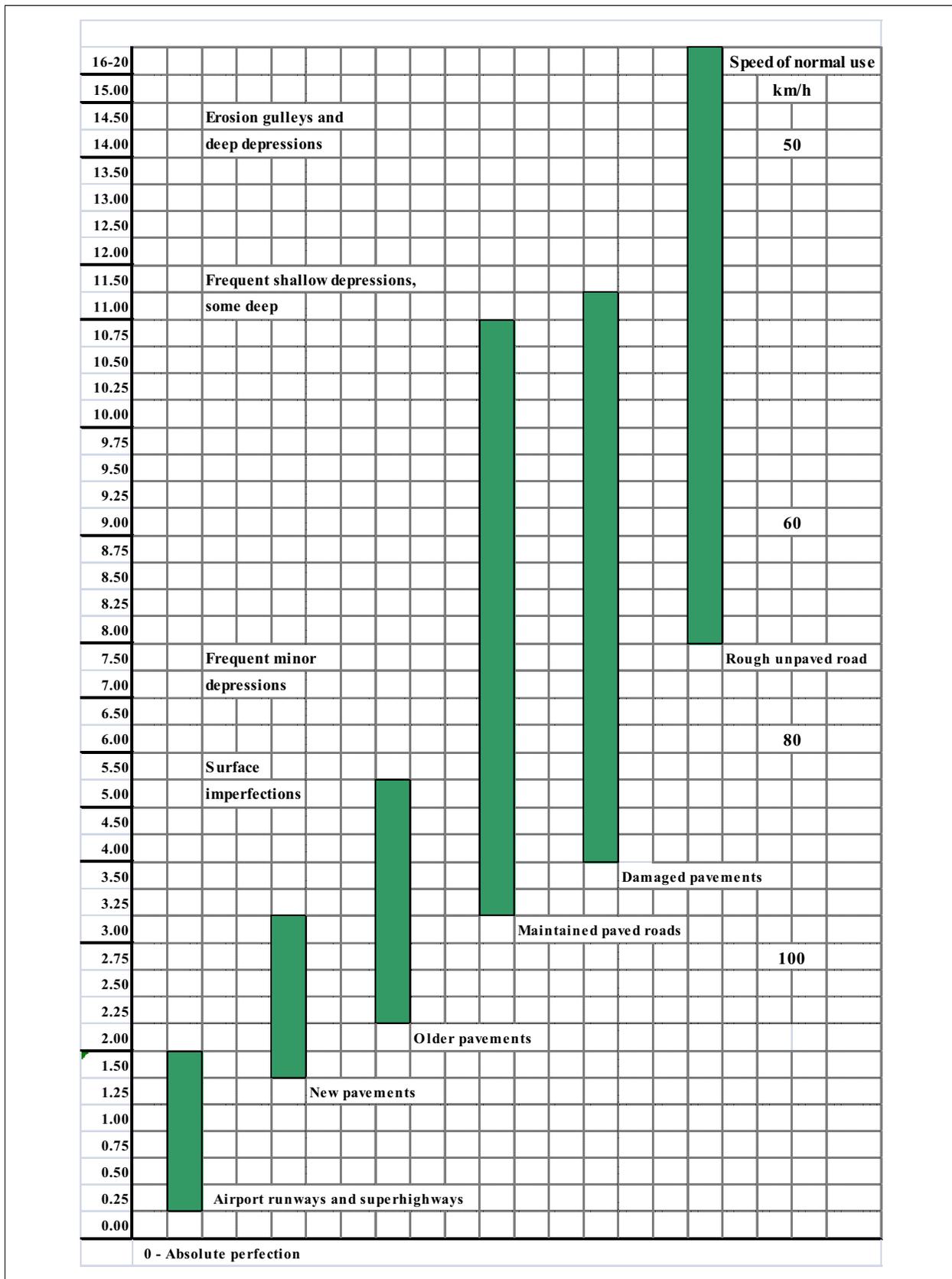


Figure 3. Example of Falling Weight Deflectometer Principles

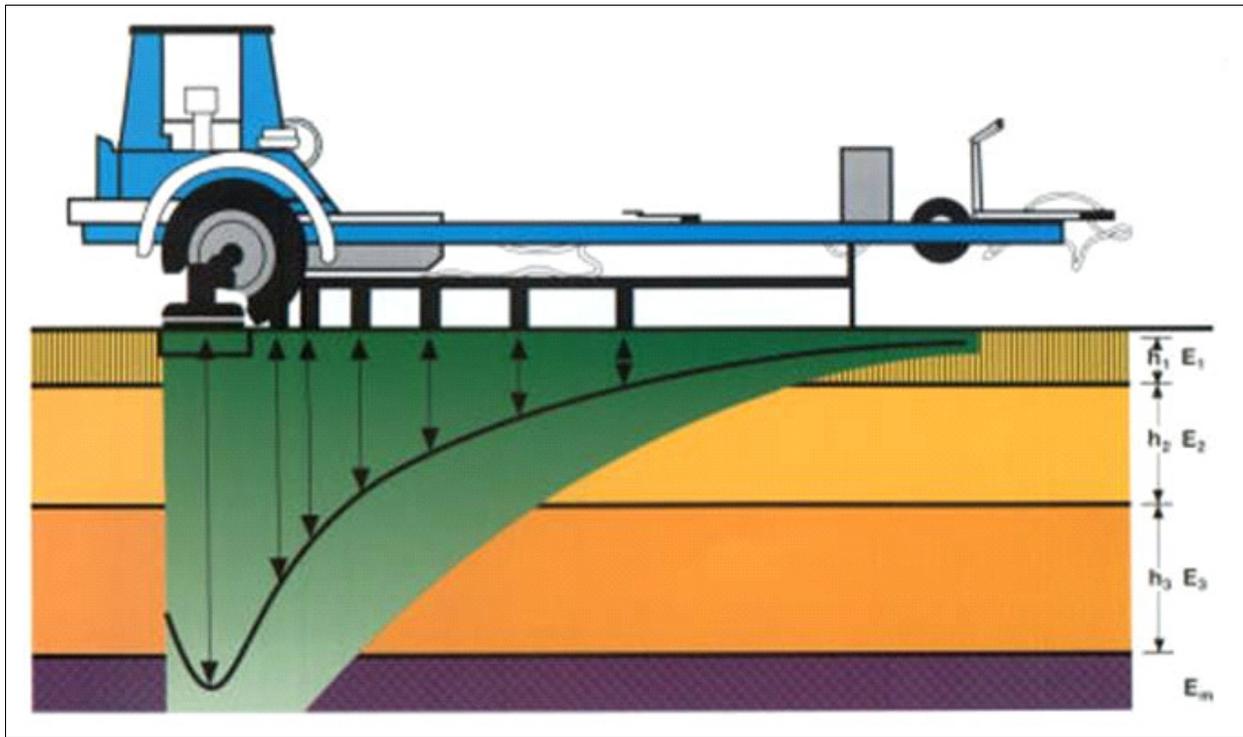


Table 2. Proposed accelerated road improvement, maintenance and institutional modernization projects

Activity Description	Year		Cost estimate \$
	1	2	
Transition begins	■		
1. Select 100 km of priority roads- using the HDM-4, prepare final designs and bidding documents	■		1,000,000
2. Select 500 km of priority roads and prepare maintenance program , using the RMMS program	■		600,000
3. Carry out a road safety improvement study and implement urgent traffic signs and demarcation works.	■		1,000,000
4. Carry out a urban transport study	■		900,000
5. Carry out an institutional modernization study	■		500,000
6. Carry out accelerated road improvement works (100 km)		■	18,000,000
7. carry out accelerated road maintenance works (500 km)		■	2,000,000
<b>Total cost estimate: proposed accelerated road program</b>			<b>24,000,000</b>

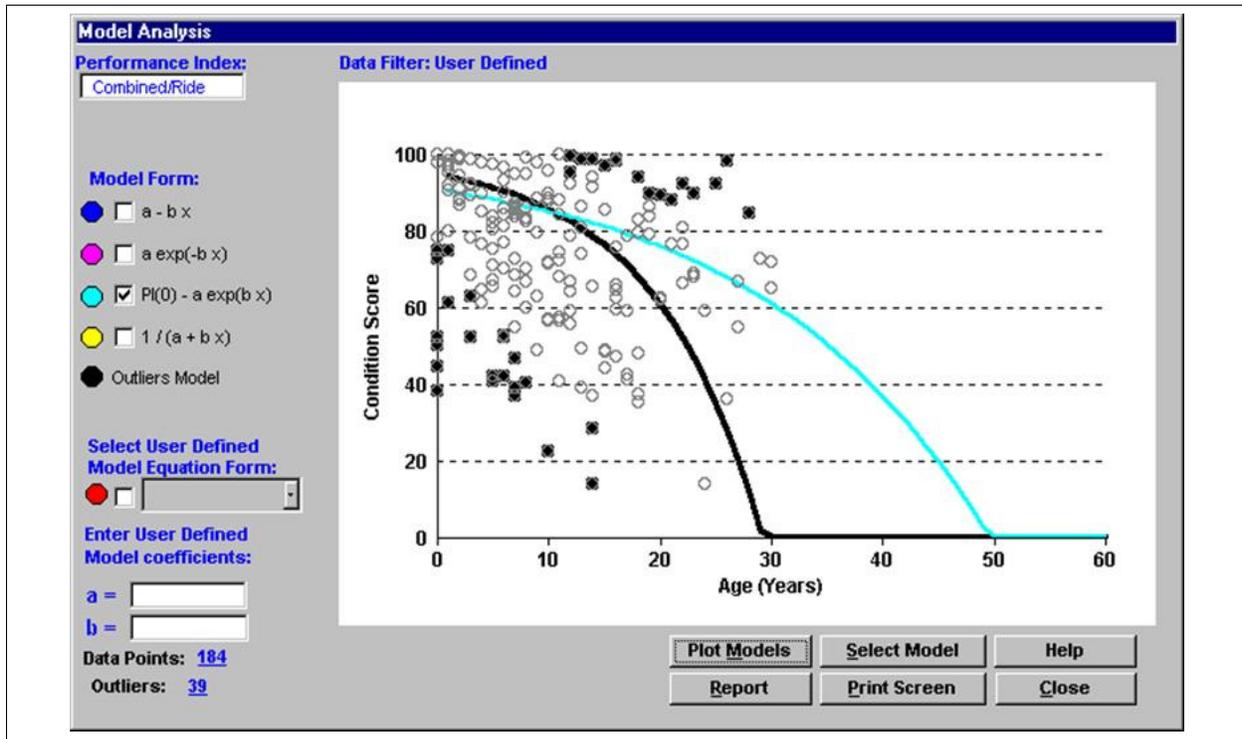
and the severity of the existing distresses that need urgent remediation works.

- Annual planning (network level) and weekly/monthly programming (project level) of maintenance work activities under budget, social and environmental constraints;
- Procedures of quality control (QC) and quality assurance (QA) including a system for reporting of the magnitude and quality of maintenance activities actually carried out; and
- A system for monitoring and evaluating road maintenance activities.

**Network Level Routine Maintenance Planning**

**Model:** Prediction models of pavement performance are used to estimate pavement deterioration and distress development.<sup>10 to 13, 18</sup> Figure 4 presents typical prediction of pavement deterioration curves from Jamaica.<sup>12</sup> The deterioration curves indicate the projected pavement conditions in terms of conditions scores from zero to 100, following the scale of the Pavement Condition Index (PCI).<sup>18</sup> Pavement conditions score of over 80 indicate good road surface conditions with roughness values (IRI) of less than 2m/km to 3m/km and conditions score of less that

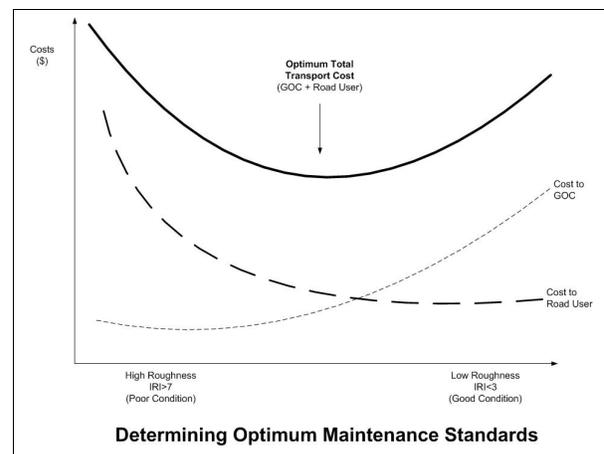
Figure 4. Typical Pavement Deterioration Curves (Jamaica)



40 indicates very bad road surface conditions with IRI of values of approximately over 5.5 m/km. Engineering decisions trees are used to select investment programs in terms of all periodic maintenance as well as major work (rehabilitation and reconstruction) required, and determine the scope of routine maintenance works.<sup>11 to 13</sup> These can be summed to develop overall needs and estimate the ‘desirable’ level of funding for pavement maintenance (and improvement). This is supplemented by minimization of life-cycle costs to ensure that maintenance and invested funds are properly accrued for any given network level of service in terms of surface conditions and highway safety conditions. An example of minimization of road investment and maintenance life cycle costs is given in Figure 5. This figure describes the optimal case of total transport cost including: (a) the capital and recurrent expenditures of Government (GOC) and (b) the road user’s costs. Good road conditions with IRI of less than 3 m/km are associated with low user’s costs and high GOC costs and vice versa. This can establish the baseline from which the minimum acceptable funding and finally the affordable level of funding may be estimated. A general

network level life-cycle cost analysis is used to estimate the minimum acceptable funding such that a structurally sound road will transition to a structurally damaged road if the routine maintenance actions are not accomplished. Likewise, all critical safety related maintenance is included.

Figure 5. Design of Optimum Transport Costs: Road Agency of GOC vs. Road User’s



**Desirable Funding (Optimum Level of Service):**

The desirable level of funding generally addresses all maintenance needs and minimizes life-cycle and road's user costs, as shown in Figure 5. It includes routine maintenance activities such as surface treatment, thin overlays, shoulder repair, patching, and crack sealing. Desirable funding levels always program these maintenance activities in a timely manner to maintain low distress severity levels and low user's costs. Also, application of the desirable maintenance service levels will defer needs for pavement strengthening, rehabilitation, or reconstruction. Under desirable funding, the level of service is maintained at a high level (e.g., roughness IRI value less than 4 for all roads and less than 3 for major roads).

**Affordable Funding (Reasonable Level of Service):**

An affordable level of funding is usually less than the desirable level but should be as high as possible within available budgets. Investment activities should at least ensure a five year life expectancy under routine maintenance management with no pavement strengthening. This will provide as much maintenance as a limited budget will allow. The entire network can be maintained somewhat above the minimum level of service with or a decision is made to maintain a reduced portion of the network at the optimum service levels obtained under desirable funding.

**Minimum Acceptable Funding (Minimum Level of Service):**

The minimum acceptable level of funding defines the maximum size of network dimensions where the surface distress severity varies between a medium to high degree, while the total distressed area is below a set maximum allowable level. The rate of deterioration is still being controlled to some extent, but road surface roughness is often above 4 m/km and rehabilitation and periodic maintenance works are needed. Distresses do not exceed the allowable maximums and high severity does not exceed 50%. The maintainable network starts to be reduced when funding drops below this amount. The level of service in terms of roughness will usually be IRI greater than 4.0 m/km and less than 6.0 m/km or less than 7.5 m/km in poor and post conflict countries.<sup>8</sup> Under the minimum funding scenario, although the distresses are still being controlled to

some degree, rehabilitation or reconstruction will definitely be needed in a relatively near term (e.g., 1 to 5 years). In other words, low level routine maintenance funds are shifted to a high level of expenditures of rehabilitation and reconstruction work (investment program) that could provide life expectancy of 7–15 years with affordable and desirable road maintenance funding.

**Model of Routine Maintenance Programming**

**—Project Level:**<sup>10 to 12</sup> The project level programming model determines priorities of actual maintenance project work in terms of actual quantity, schedule, and activity by project location. This analysis provides the monthly and weekly work program to address the specific pavement distresses and maintainable elements for any given level of service and quality assurance procedures.

The project level program includes quality assurance and quality control (QA/QC) procedures to evaluate, accept or reject maintenance works. A cost formula is used to acknowledge actual quality of pavement conditions vis-à-vis QA criteria in terms of measured extent and severity of representative pavement distresses; roughness, potholes, rutting, shoulder drop-off, drainage conditions, and cracking. Higher levels observed in the field trigger higher needs, in terms of cost to repair. This can also be used to flag poor quality work.

Affordability and regional or local cultures determine the allowable distress extent and severity, scope and preciseness of the road conditions database, and degree of reliability. Higher reliability leads to more certainty of donors' funding allocations and reduction of unjustified pavement expenditures. Reliable road conditions database and rational analysis of the maintenance needs are essential tool to produce transparent, feasible and practical road maintenance management recommendations attract the support of international donors.<sup>9,10,12</sup>

**Model for Monitoring Quality Assurance/Quality Control (QA/QC):** Maintenance quality is important in order to maximize the potential benefits of maintenance management and funding. The QA/QC model defines pavement condition before and

degree of the effectiveness of the implementation of the maintenance works. It determines road surface safety and drainage conditions and QA requirements for any given level of service and road classification (primary, secondary and tertiary). This model monitors actual work accomplished and new pavement conditions for contractor compensation or rejection when the new surface conditions do not meet QA criteria. To determine the actual contractor's compensation, the QA/QC model monitors the road conditions before and after maintenance work and compares it with quality assurance (level of service) criteria in terms of distress type, severity, and extent (e.g., no more than 0.2% of potholes is allowable for primary and secondary roads and less than 60% and 40% of the potholes will have high or medium severity respectively, all year round).<sup>10,12,25</sup>

**Model for Maintenance Effectiveness:** The effectiveness of maintenance depends on several factors including the budget, productivity of the maintenance activities, materials, procedures, prior conditions, elements maintained, and the environment. The maintenance effectiveness model defines the benefit of maintenance in terms of improved performance and the diminishing returns of these benefits as the original condition of maintainable elements drops below some maintenance threshold criteria. At these levels, if funds are available programming for rehabilitation or reconstruction by the HDM-4 becomes the most cost effective option.<sup>10,12,13</sup> The RMMS is used to determine the dimension of the reduced maintainable network, identified roads that local communities and users would have to maintain in accessible conditions. Therefore, the authors recommend using the HDM-4 and the RMMS programs to optimize the selection, planning and design of priority road investment and maintenance works, Table 2.

**Model for Reporting:** The reporting module provides standard graphical reports indicating what actually was accomplished including costs, quantities, and productivity. Reporting goes to all levels and includes budget, level of standards, network planning, project planning, level of service, quality assurance, lessons learned etc. The reports cover multiple levels of man-

agement including the administrative level, engineering level, and maintenance superintendent level.

**Selected Road Maintenance Program:** Lessons learned from accelerated maintenance projects in LAC and Africa<sup>8 to 12</sup> indicate that international donors could support a fast track road improvement and maintenance works, if: (1) detailed designs of road maintenance programs are developed, using the HDM-4 and the RMMS programs; (2) Government modernizes the road sector, and the procurement procedures are effective and transparent; (3) the road agency implements modern design tools and transparent QC/QA procedures. The authors estimate that a new Cuba road authority could meet donors' conditionality during a short transition period of 3 months and use the RMMS and HDM programs for approximately 6 months to design an accelerated 500-km road maintenance program. The design and the implementation of the maintenance works are estimated at \$600,000 and \$2.0 million.

## INSTITUTIONAL CONSIDERATIONS AND POSSIBLE MODERNIZATION OF MITRANS

**Institutional responsibilities and possible assistance and training needs:** The Cuban Ministry of Transportation (MITRANS) is responsible for directing, executing, and controlling the application of government policy in matters involving land, maritime, transportation or connected services, and civil maritime navigation.<sup>1, 2</sup> In the road sector, MITRANS is responsible for the planning, development activities, environmental protection, issuance of transport service licenses, security of all transport modes, road maintenance and safety services. The authors estimate that if requested by a transition government of Cuba, international donors including the U.S. Department of Transportation (DOT) and specifically the Federal Highway Administration (FHWA) could provide immediate assistance to support the capacity building of critical technical and institutional activities of MITRANS, including: (a) implement priority and urgent road improvement and maintenance works using the HDM-4 and RMMS programs; (b) implement innovative engineering technologies, including online multi-media video log-

ging of road evaluation services, non-destructive testing of pavements; (c) design and implement transparent and modern services of quality control and quality assurance procedures of road construction and maintenance works; (d) improve road safety services; (e) improve engineering preparedness of MITTRANS to minimize damages to roads and seawalls from future hurricanes storms;<sup>9, 28 to 30</sup> (f) promote private sector participation in road investment projects or in possible new concession projects and leverage donor's financial and technical support; (g); promote innovative procurement procedures such as performance-based-lump-sum road construction, maintenance and supervision services to encourage cost effectiveness and reduce cost overruns and implementation delays; (h) implement risk sharing procedures for public-private sectors partnerships of road investment and maintenance projects; (i) promote the use of community-based micro-enterprises for road maintenance works; (j) develop reference baselines for competitive construction and maintenance unit costs to attract international bidders, support the development of infrastructure market economy, break local monopolies and promote transparency; and (k) promote engineering initiatives to protect the environment and support energy efficiency for road construction and maintenance projects.

**Institutional considerations of construction and maintenance quality procedures:** Donors and LAC countries give high priority to quality, social and environmental conservation, ethics and transparency of road construction and maintenance works.<sup>7 to 12, 17, 26, 27</sup> Donors define quality as the responsibility to deliver safe, on time and effective road services to the taxpayer and user and associate this responsibility with quality assurance (QA) programs. Quality assurance refers to all the institutional activities necessary to verify, audit, evaluate and implement road quality services. It may also refer to the quality of data collected for use in the HDM-4 and RMMS road maintenance management systems. To obtain a reasonable degree of QA, cost effective and affordable design standards and specifications acceptable to the users and affected communities should be developed for the project specific characteristics and condi-

tions. QA procedures are adjusted to the inherent variability of construction conditions and local soils and material characteristics, sampling and testing guides, and maintenance standards.

Quality control (QC) procedures ensure that proper materials and procedures are used and placed in a definite context so that the end product will have the desired level of performance in terms of service and life. Quality control activities are specific steps taken during construction and maintenance to control the quality of materials and workmanship. Donors have requested that the QA and the QC procedures will be included in the bidding documents prior to their financial approval.<sup>7 to 12</sup>

Donors and road agencies give priority to implement construction and maintenance works, using contractors rather than using the agency's own forces. Therefore, MITTRANS would probably need to accelerate its institutional modernization and using international contractors to attract significant donors' support. However, to accelerate the improvement of the Cuban road services during a short transition period, donors may accept to finance urgent and high impact works perform by: (1) contractors, or (2) MITTRANS in-house forces, but using performance-based lump-sum road construction and maintenance contracts.<sup>7,9,10</sup> Therefore, MITTRANS must establish the necessary procedures to ensure that these contracts will be let on the basis of least costs and acceptable quality of services, following donors' approved specifications and QC/QA procedures. The authors have considered the following specifications, pay equations and value engineering procedures that could support transparency and quality of the proposed accelerated implantation of the road improvement and maintenance works:

*Recipe specifications:* Also referred to as method specifications, describe what is wanted and how it is to be obtained. For an asphalt pavement, the engineer would specify fatigue characteristics, stability, workability, air voids, durability, surface smoothness; plasticity, gradation and other requirements of the quality of materials; the general types of equipment to be used; and hauling, placing, rolling and degree of compaction. Presently, recipe specifications are used

in the cost plus fixed fee road construction and maintenance contracts and are primarily developed by experience.

Disadvantages of recipe specifications include: (1) natural product variability is not adequately accounted for; (2) little or no recourse is available if the specifications were followed but the results were unsatisfactory; (3) material sampling often does not yield a statistically significant or reliable result; (4) little opportunity or incentives for innovation is allowed on the part of either contractor or engineer; and most important (5) most of the project implementation risks lie with the public sector road agency.

Advantages of recipe specifications include: (1) the inspectors and contractors involved with construction are familiar with the specifications; (2) they are relatively easy to understand; and (3) clear guidelines are provided for those who are inexperienced in planning, supervising, and inspecting construction activities.

*Performance-based specifications (PBS):* Also referred to as end-result specifications, describe what the product is and what are its performance characteristics, QC/QA criteria and implementation procedures. PBS describe how the completed product must perform. In the case of road pavement construction works, the PBS would describe the allowable maximum severity levels of the road surface defects (such as potholes, cracking, breakup, rutting and roughness) during the project operation warranty periods and its lifetime, before a next cycle of pavement rehabilitation, usually 7 to 12 years and 3 to 5 years for well maintained paved and gravel roads. PBS give the contractor considerable freedom in choosing how to satisfy the requirements. With PBS, the primary responsibility for quality control is placed on the contractor. The engineer/supervisor monitors the contractor's quality control, and accepts, rejects or adjusts the work and the contractor invoice according to contractual pay equations and value engineering procedures included in the bidding documents of the project.<sup>9, 10, 31, 32</sup> PBS are statistically oriented and are based on random sampling techniques, with acceptance on a lot by lot basis (a lot being a given quantity of material, i.e.,

1,000 tons of implemented granular base course or asphalt concrete paving materials).

Disadvantages of performance specifications include: (1) full implementation requires good engineering knowledge of statistical procedures and engineering expertise associated with continuous training, on the job or in special training courses; (2) continuous research and performance monitoring of material characteristics variability and changes of projected traffic loading that may affect the road pavement performance and may modify maintenance needs, such as pavement resurfacing versus grading of gravel roads; (3) the additional responsibilities placed on the contractor could result in higher bid prices, however the authors experience indicates that in competitive procurement conditions this possible higher cost is insignificant; and (4) the lack of specific "how to" specifications require experienced and competent inspectors and contractors.

Advantages of performance specifications include: (1) a realistic picture of the true quality of a product or material provided to the engineer; (2) the incentives and relative freedom allowed contractors encourages innovation which should eventually result in lower prices; (3) an expected decrease in inspection requirements and expenses; and (4) less claims, less costs overrun, and less delays in project implementation.<sup>7, 9, 10, 32</sup>

*Cost effectiveness considerations of road investment and maintenance projects:* Donors and road agencies in LAC emphasize that their road projects must be transparent, cost effective and affordable. To achieve these goals in developing countries, especially in post conflict or poor countries, it is necessary to establish a baseline of productive construction and maintenance unit costs.<sup>8, 9, 10, 32, 33</sup> The goal is to carry out a unit price analysis for each construction and maintenance cost item.<sup>9, 10, 33</sup> For each unit cost it is necessary to consider:

- a. unit prices of ongoing and recent of construction and maintenance contracts;
- b. actual characteristics, conditions and dimensions of the project including geotechnical, geological,

- drainage, seismic, social/ environmental, quality and location of potential construction materials;
- c. project specifications and QA/QC procedures;
- d. productivity of materials produced by equipment, skilled and unskilled labor;
- e. hourly or daily unit costs of skilled and unskilled labor and equipment; and
- f. Overhead expenditures and profit, considering risk sharing procedures of the project implementation, maintenance and operation activities.

Donors and the author's experience indicate that having a reference unit cost analysis is useful to improve transparency, to attract national and international bidders and therefore reduce costs.<sup>9,10, 33</sup> The authors recommend incorporating reference unit cost analysis to the bidding documents of the proposed accelerated road improvement and maintenance works, using either recipe or performance-based specifications of construction or maintenance works.

*Pay Equation and Value Engineering principle:* Donors and road agencies in LAC recognize that adequate properties and uniformity of materials and construction procedures are important quality characteristics needed to reduce construction, maintenance and vehicle operating (VOC) costs. Therefore, these agencies have used construction specifications that award adjusted payment appropriate for the level of quality received.<sup>7 to 12,17,31,32</sup> This has led to the use of the term percent defective (PD), representing the portion of the construction or maintenance lot falling outside specification limits, as the statistical measure of quality.

Using asphalt pavement as an example, there are several measures of quality that are used for works acceptance, such as engineering properties of aggregates and bitumen, air voids, asphalt thickness, stability, elastic modules, smoothness or surface roughness.<sup>8,9,33</sup> Because it is possible to measure the engineering properties of aggregates and bitumen such as gradation, absorption, specific gravity, penetration and ductility before they are mixed together and placed on the road, it has been the practice of highway agencies to either accept or reject these materials based on laboratory test results as they are de-

livered to the job site. On the other hand, since the asphalt thickness, in-situ stability or density, and surface smoothness or roughness cannot be measured until after the asphalt concrete (AC) has been placed and compacted, tests for these characteristics are typically completed a week or so after the completion of the asphalt layer. In this case, the acceptance decision may take the form of a pay adjustment, depending upon the level of quality that has been achieved. One possible pay-equation that comprises, thickness, stability and roughness for individual acceptance lots is the following:<sup>10,31,32</sup>

$$PF=106-1.314*(TPD+DPD)-0.2045*(RPD) \wedge 2 \quad (1)$$

Where: PF= pay factor (percent); TPD= Thickness percent defective; DPD= Density percent defective; and RPD= Roughness percent defective.

The use of percent defective provides a clear pay equation. It can easily be seen that equation (1) pays a maximum of 106 percent or a bonus of 6 percent when all quality measures are at zero percent defective and that this value decreases as the percent defective of any of the individual quality measures increases.<sup>10</sup>

The use of the pay factor as a QA procedure requires the definition of the acceptable (AQL) and rejectable (RQL) quality level at which the road agency accepts or reserves the option to require removal and replacement or corrective action. As a general rule, RQL values must be clearly defined and set at sufficiently low levels of quality that such drastic action is truly warranted. Since asphalt pavement failure does not pose a major safety hazard (such as the catastrophic failure of a bridge or tunnel member) and can easily be repaired as compared with concrete pavement, the RQL limits for thickness and density can be set at a relatively high level of percent defective. On the other hand, surface roughness experience has indicated that a percent defective length of 15 that does not meet the smoothness criteria of a 10 foot straight edge along the wheel paths provides a rough and costly ride that usually requires immediate corrective action. Thus RQL limits for roughness are set at low level of percent defective. RQL-PD limits and pay factors in Table 3 are proposed.<sup>10,12,31,32</sup>

**Table 3. RQL-PD limits and pay factors**

Asphalt Pavement Quality Measure	RQL PD	RQL Pay Factor Percent
Thickness	35	60
Density	35	60
Roughness	15	60

The proposed RQL of PD=15 for pavement smoothness is usually required to achieve surface roughness of less than 2.5 m/km for a new construction of asphalt pavement. The proposed RQL for thickness and density is defined as the average values that are more than 12 mm and 2.5 percent less than the design values of thickness and density, respectively.

Equation (1) awards a maximum pay factor of 106 percent for pavement that is of clearly outstanding quality (zero percent defective for all three measures). In this case the highway agency and the road users receive more than comparable value in terms of the extended service life of pavement of this quality.<sup>9,10</sup> For pavement of varying levels of percent defective in the three quality measures, equation (1) assigns pay factors that range from the maximum of 106 percent down to a minimum of 60 percent. This minimum occurs when one of the three measures approaches its respective RQL or when a combination of the three measures results in the minimum pay factor of 60 percent. If the RQL value is reached on any one of the quality measures, the highway agency has the option to require removal and replacement of the defective pavement section or any other corrective action. If, for practical reasons, these options are not exercised, a minimum pay-factor of PF=60 is assigned. Another feature in equation (1) is the use of the second power of roughness percent defective. As a result, this term tends to exert greater influence so that relatively high levels of riding quality and lower VOC expenditures must be achieved in order for the contractor to benefit appreciably from the bonus provision.

A distinctive feature of this acceptance procedure is that, provided none of the quality measures reaches its RQL value, it permits surpluses and deficiencies in thickness and density to offset one another. As an example, if a contractor cannot produce roughness percent defective (RPD) and density percent defec-

tive (DPD) of less than 12 percent he will have to deliver a thickness percent defective of less than 1 percent in order to meet the acceptable quality level (AQL) and the minimum pay factor of 60 percent.

**Financial sustainability considerations:** Donors have concluded that most of the roads all over the world are owned and operated by different levels of governments.<sup>5,6,7,15,34,35</sup> Most of these roads, except the toll roads, are not capable of being operated on a strictly commercial basis.<sup>35</sup> Even the toll roads require a minimum amount of traffic in order to be commercially viable, and often governments secure minimum traffic volumes in road concession programs. As a result even in industrialized countries, toll roads account only for about 5% to 10% of the primary road network, which itself represents only about 10% to 20% of the overall road network, or toll roads account for less than 0.5% of the total road networks. Toll roads in the United States, for example, represent 0.08% of the paved roads. By and large the aim of all road administrations all over the world is to carry out the construction and maintenance of road works in a cost effective manner and try to recover from the road users as much revenue as possible to match the expenditure on roads. Motor vehicle tax and fuel tax are the two traditional sources of revenue. To the extent that the revenue from them is not adequate to meet the road expenditure, allocations are made from other general tax revenues of the country. Often a part of the revenues from the two sources are used for other purposes and only the remainder is allocated for the roads. To avoid this, many governments used to credit the fuel tax and vehicle tax to a separate Road Fund Account which would finance road maintenance expenses only. However, the more recent public finance practices of many governments do not seem to prefer this option on basis of greater flexibility of use of tax revenues. Therefore, the authors recommend incorporating the road financial sustainability issue into the institutional modernization study of the Cuban road authorities of MITRANS (see item 5 of Table 2).

**Institutional decentralization considerations:** Lessons learned from LAC indicate that institutional decentralization of responsibilities is a useful tool in

the administration of road systems.<sup>7,11,34</sup> Road agencies depend on quality and quantity of information technology, and it is important to keep pace with technological developments. Decentralization does not mean that everything is delegated. Activities that are best performed at the central level need not be delegated to the district level.

The principal advantages of a decentralized highway agency are: (a) better response to users and local community needs; (b) road investment and maintenance goals are adjusted to the local conditions of every district; (c) rational commitment of fund allocations; (d) effective and transparent distribution of allocated funds; (e) effective accountability and consistency procedures in monitoring and auditing the project. The authors recommend incorporating the institutional decentralization issue into the institutional modernization study of MITRANS.

**Possible donors' support for MITRANS institutional modernization:** Lessons learned from LAC<sup>5</sup> to<sup>9</sup> indicate that donors support institutional modernization of road agencies, including:

- a. decentralization of responsibilities and fund allocations of road agencies;
- b. improving quality and response to users and local community needs;
- c. optimizing and adjusting road investment and maintenance expenditures to the local conditions of every district, county or municipality;
- d. rationalizing the commitment of fund allocations;
- e. effective and transparent distribution of allocated funds;
- f. use of new engineering techniques for road investment and maintenance projects;
- g. use modern financial systems for evaluating various available funding scenarios.

The authors estimate that \$500,000 and 9 months are needed to develop an institutional modernization and capacity building for MITRANS, see Table 2.

## ROAD SAFETY IMPROVEMENT CONSIDERATIONS

Donors and LAC road agencies request that road investment and maintenance programs include quantitative road safety improvement sub-programs, accompanied with a socio/economic evaluation of the road safety improvement works.<sup>10, 36</sup> This conditionality goes in tandem with the mission statement of MITRANS to provide a safe transport system. Nevertheless, it seems that GOC has not implemented its mission statement, considering that 1,000 "Stop" signs, 2,000 "Yield" signs and 9,000 "One Way" signs are urgently needed in Havana. Also, international travel guides indicate that "there are very few road signs and directional aids and even rarer are protective crossbars or warning lights at railroad crossings". Considering the limited information on actual road safety conditions, and the lessons learned from donors and LAC countries, the authors recommend to integrate a road safety activity into the proposed road improvement and maintenance program (see Table 2), including:

1. Establish an inter-institutional working group including the ministries of transport, finance, education, health; police; road users; insurance companies; affected communities and their school systems.
2. Develop a road accident database, including: police reports; accident costs (fatalities, injuries, damages); severity, frequency, location and cause of accidents; traffic volumes; road network and demographic characteristics; vehicle registration; emergency medical services; traffic court decisions.
3. Train and monitor the police force in road safety, and in using the database and digital forms for evaluating and reporting of road accidents.
4. Develop a public transport policy, including road safety planning and modern regulatory services.
5. Improve the driver licensing and vehicle safety codes code and strengthen the regulatory capacities.
6. Develop a road safety education curriculum for introduction into the schools' systems at the primary, secondary and tertiary levels.

7. Carry out a quantitative engineering and a socio/economic evaluation of critical road sections with the most frequent and the most severe accidents.
8. Design road improvement works with quantitative calculations of accident reductions (AR) factors. As an example, following the recommendations of the Departments of Transportation of Florida and Louisiana that were adjusted by the IADB and the Guyanese road agency:<sup>10, 36</sup>

$$AR=R1+(1-R1)*R2+(1-R1)*(1-R2)*R3+(1-R1)*(1-R2)*(1-R3)*R4+....$$

Where: R1=0.4—for road signing; R2=0.7—for marking; R3=0.3 for reflecting spikes; R4=0.2 for road lighting; R5=0.15 for sidewalk services; R6=0.22 for effective law enforcement; R7=0.34 for removal of bridge/culvert obstacles; R8=0.42 for proper traffic lights-signalization.

The authors estimate that \$1 M and 9 months are needed to carry out an accelerate road safety improvement study and implement urgent traffic signs and demarcation works, not included in the accelerated road improvement and maintenance works.

### URBAN TRANSPORTATION PLANNING CONSIDERATIONS

Donors, national transport agencies and municipalities of medium and large cities give priority to the provision of safe and effective motorized and non motorized urban traffic services.<sup>37to39</sup> Lessons learned of the WB, IADB, DFID, and from LAC and Asian cities, including Lima, Bogota, Pereira, Quito, Guayaquil, indicate that proper planning and administration of public transportation services is necessary to avert increase of pollution, accidents and overall congestions. The authors have concluded that relevant donors' lessons learned applicable to major cities of the new Cuba, include: (a) design and implementation of rapid bus services (RBP), using an integrated strategy of urban transport planning, land use, road safety and air quality conservation; (b) design and implementation of a modern regulatory services of RBP; (c) Incorporation of low income users into the RBP system in terms of accessibility and affordability; (d) implementation of solid financing mechanisms of the RBP services to ensure long term sustainabili-

ty, including progressive private sector participation in the operations and investment costs.

The authors recommend to use the following planning and implementation principles:<sup>37to30</sup>

- a. get top-down approval procedures of high level decision makers early in the process;
- b. give priority to regulatory issues and try to create a special purpose agency (such as PROPRANPORTE in Lima Peru<sup>39</sup>) to plan, oversee and control the RBP system development and implementation;
- c. be creative in funding the project development, using new taxes, loans and non traditional financial sources including privatizations and special purpose bonds;
- d. involve existing operators to mitigate conflicts, but use open competitive bidding process with strong private sector-public sector collaboration and risk sharing procedures to reduce user costs;
- e. seek strong public support and go for gradual implementation, adapting the project on the basis of a pilot project;
- f. maximize the use of the existing ROW to avert land acquisition and non voluntary human resettlement;
- g. use modern pavement engineering, such as NDT, video logging and PMS procedures, to avoid rapid deterioration of the pavement systems;
- h. consider realistic maintenance and operation expenditures in the business plan in order to optimize the life cycle cost of the investment, maintenance and operation expenditures;
- i. dedicate funds for user and community education programs and emphasize general public and user benefits over special interests;
- j. focus on system integration during the planning and implantation and consider to renew the bus fleet using agile planning procedures to match the demand and remember that feeder-trunk operations might not be the one-size-fits-all;
- k. use strong road dividers to segregate traffic and improve the safety of pedestrian, bicycle and other non-motorized traffic services;

- l. give preference to median lanes and level access platforms with many doors to access the buses to increase speed and reliability;
- m. estimate future impacts on the reduction of CO<sub>2</sub> and other transportation related contaminants,
- n. use advanced transit management procedures and apply them to support service reliability and monitor the performance of the system;
- o. consider that the total capital costs vary from \$1.35 M/KM (Jakarta) to \$8.2 M/ KM (Bogotá) and if affordable consider fares similar to those of pre-existing services.

The authors estimate that the current low traffic demand in Havana and other major Cuban cities would increase significantly after the political transition and towards the establishment of a new Cuba. Considering that seventy percent of the Cuban population of 11.4 million already live in urban areas (2 million in Havana), and the current low level of income and automobile ownership, it is logical to assume that effective public transportation services would play an essential role in the socio economic development and competitiveness of the new Cuba. Therefore, the authors recommend carrying out a pilot integrated urban public transport study in two major cities to identify investment priorities in civil works, purchasing and operation of new buses. The authors estimate the cost of the RBP study at \$900,000 and its implementation period at 9 months (see Table 2).

### PRINCIPAL CONCLUSIONS

Modernization of the Cuban road sector would reduce the transportation costs and support the new Cuban economic strategy to generate foreign exchange. The road modernization would probably support other social and economic savings including improvement of highway safety, implementing clean and cost effective urban and inter-urban rapid bus services, expansion of the pedestrian, bicycle and other non-motorized traffic services, and keeping low CO<sub>2</sub> and other transportation related contaminants.

Since 1989, investments in the Cuban road sector have been insufficient to maintain the road network in safe traveling conditions for the projected post conflict traffic demand. The authors estimate that after the transition period, urban and inter-urban priority roads and bridges would need significant investment and maintenance works. To accelerate the implementation of these works and to attract international donors such as the IADB and the WB, the authors recommend to use innovative engineering techniques including agile transportation asset management programs with full infrastructure inventories capabilities (pavements, drainage facilities, signs, lighting, guardrails, walls, bridges, painting, etc) that fit the AASHTO transportation asset management Guide of 2002 including cameras, PC, GPS, DMI, Video-GIS software and hardware for road network functional and structural evaluation (see Figure 1).

The authors estimate that if the new Cuba would follow the latest declarations of Raúl Castro that Cuba is considering opening itself further to foreign investments, donors might consider to support the new Cuban road sector improvements of priority projects and could provide approximately \$24.0 M for an accelerated 15-months road investment, maintenance and institutional modernization program proposed in Table 2.

Lessons learn from accelerated road improvement and maintenance projects in LAC and Africa indicate that international donors could support a fast track road improvement and maintenance works, if the Cuban road agency would: (1) use the HDM-4 and the RMMS programs to develop road investment and maintenance programs; (2) modernize the road sector and demonstrate that the procurement procedures are effective and transparent; (3) implement modern design tools and QC/QA procedures to determine urgent needs of improvement and maintenance works and bridge works actually done.

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