A ROAD MAINTENANCE MANAGEMENT SYSTEM FOR NEW PROVIDENCE ISLAND

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ABSTRACT

MMM Group, in association with Caribbean Civil Group recently completed a Road Maintenance Management System (RMMS) for the island of New Providence in the Bahamas. Some features which made it feasible to offer a greatly simplified approach to maintenance management included:

- the small size and accessibility of the network;
- the public expectation for high quality roads, together with an existing network which meets largely matches expectations (with the exception of some areas awaiting attention);
- the sub-base conditions are uniformly good, predominantly lime rock.

The Project defines a road by a name and the intersecting roads at the start/finish. Since road names are often repeated, each road is given a unique identifier code. All roads administered by the Ministry were catalogued and mapped using "Quantum GIS" (QGIS), an open source geographical information system (GIS). By using QGIS features and hand-held GPS, it was possible to eliminate the milestone/offset location referencing system. The Project Team used new and historical traffic counts to assign traffic volume estimates to all roads. A three step condition rating based on visual criteria and roughness measurements was also assigned. The highway network was classified on a functional basis into arterial, collector and local roads and separate programs were prepared for each classification. Implementation priorities were assigned on basis of condition weighted by traffic volumes. Given the existing condition of the individual roads, and estimating the cost to upgrade, it was possible to estimate budgets to maintain or improve the network average condition. A fully populated GIS can also serve as a robust and flexible basis for more comprehensive asset management systems. The only proprietary system involved is MS Office® and the entire operation is now in the hands of Ministry staff trained as part of the project. There are no identified obstacles to long term sustainability.

INTRODUCTION

In November, 2011, the MMM Group, in association with Caribbean Civil Group Ltd, commenced a project in Nassau to develop and implement a computerized road maintenance management system (RMMS) for approximately 1,300 km (800 miles) of road network on the island of New Providence (NP). The broader scope within the project included :

- development of a road classification system for NP;
- development of a comprehensive set of performance based specifications for routine maintenance and;
- a review of the Bahamas road construction industry.

The draft Final Report was submitted on 22 April, 2012 and following Client comments, the Final Report was submitted in mid-July.

WHY DOES MAINTENANCE NEED MANAGEMENT?

The effective "life" of a new bitumen road is about 14 years. Older roads have shorter remaining lives. Maintenance treatments must be timely and for cost effectiveness the appropriate treatments must be applied at the deteriorating locations. Maintenance deferred is money wasted; a $100 pothole repair can quickly become a $500 repair if treatment is delayed. Inadequate maintenance leads to failure of the operational function of a road and requires total reconstruction and very high costs to restore the road. Fig.1 illustrates the ultimate fate of zero maintenance to a road. The management challenge is to apply the right treatment, at the right location, at the right time, to achieve overall cost effectiveness for each maintenance dollar.

Fig.1 25 years of neglect. Note the remnant AC surface in the foreground

ROUTINE MAINTENANCE, PERIODIC MAINTENANCE

Road maintenance is typically categorized under two broad headings:

Routine maintenance is a series of basic maintenance activities (pothole repairs, crack sealing, debris clearance etc) which, when applied continuously and effectively, will prevent a road reverting to natural countryside. (~ "housekeeping")
Periodic maintenance restores the riding surface to the design status, by application of overlays or surface reconstruction, thus minimizing vehicle operating costs to road users. (~"renovations")

TYPICAL OPERATIONAL LIFE OF A BITUMEN ROAD

The typical operational life of a bitumen road is described in Table 1 following:

Table 1 Typical Operational Life of a Bitumen Road

Years after construction	Status with Timely Maintenance	Status with No Maintenance
1-5	Fully functional, little or no maintenance needed apart from vegetation/debris clearance etc.	Fully functional, little or no maintenance needed apart from vegetation/debris clearance etc.
3-8	Cracks, raveling, potholes and edgebreak appear, repaired by <u>routine</u> maintenance activities. Road remains serviceable.	Cracks, raveling, potholes and edgebreak appear . Damaged areas become more extensive, users must slow down.
5-20 plus years	Roughness progresses. A new overlay or reconstruction will restore the road to design smoothness.	The surface moves towards total loss. Roughness increases, speed/safety are compromised, road eventually becomes a track

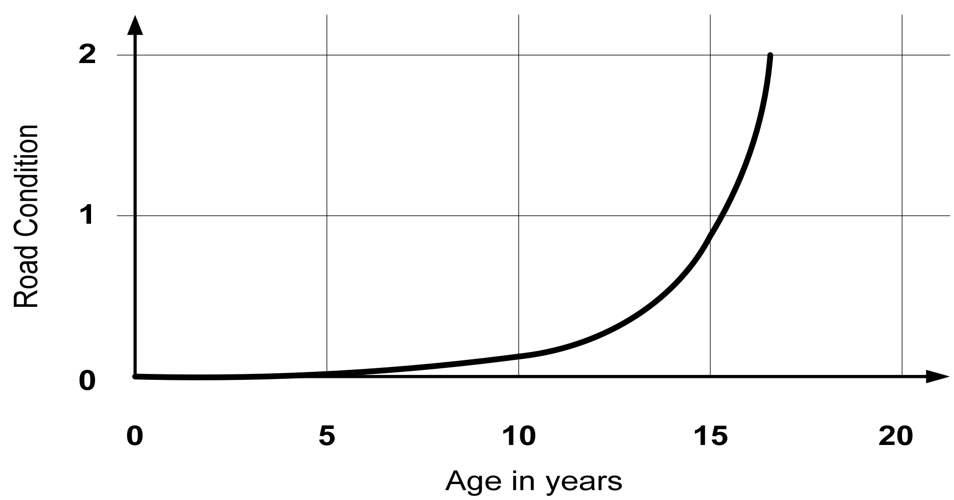

Fig. 2 Effective Life of a Bitumen Road Surface (0=good, 2=poor) (schematic)

Fig 2 illustrates the process graphically. Initially the deterioration is relatively slow, but in the final stages deterioration accelerates. Costs to remediate at the late stages of deterioration increase correspondingly, perhaps 2-3 times greater than the cost of timely treatment. Ideally a low cost treatment should be applied before deterioration is too advanced, as is illustrated in Fig. 3 following:

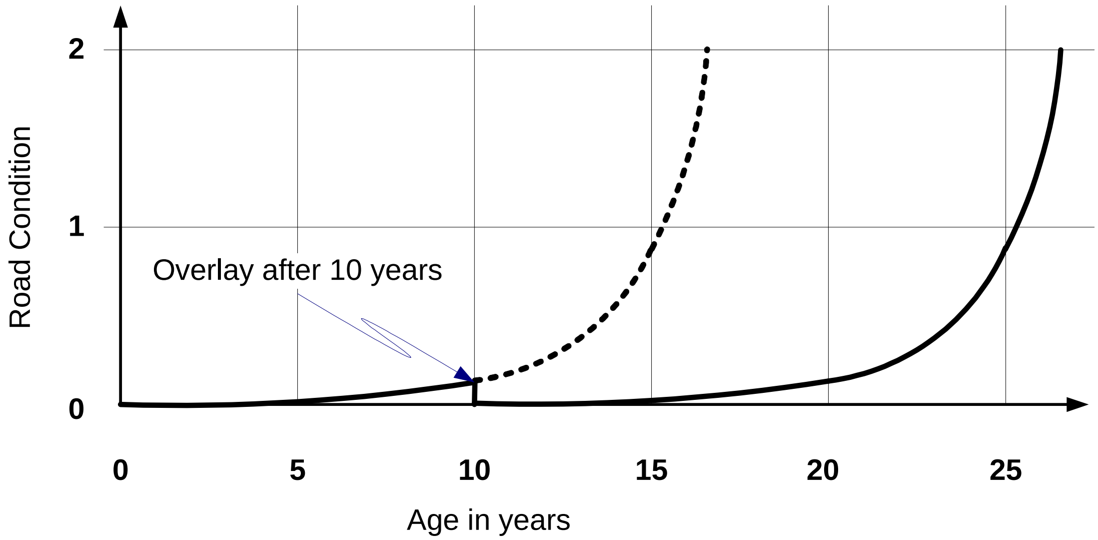

Fig. 3 Effective Life of a Bitumen Road Extended with an Overlay (schematic)

WHY DOES A ROAD NEED TO BE SMOOTH?

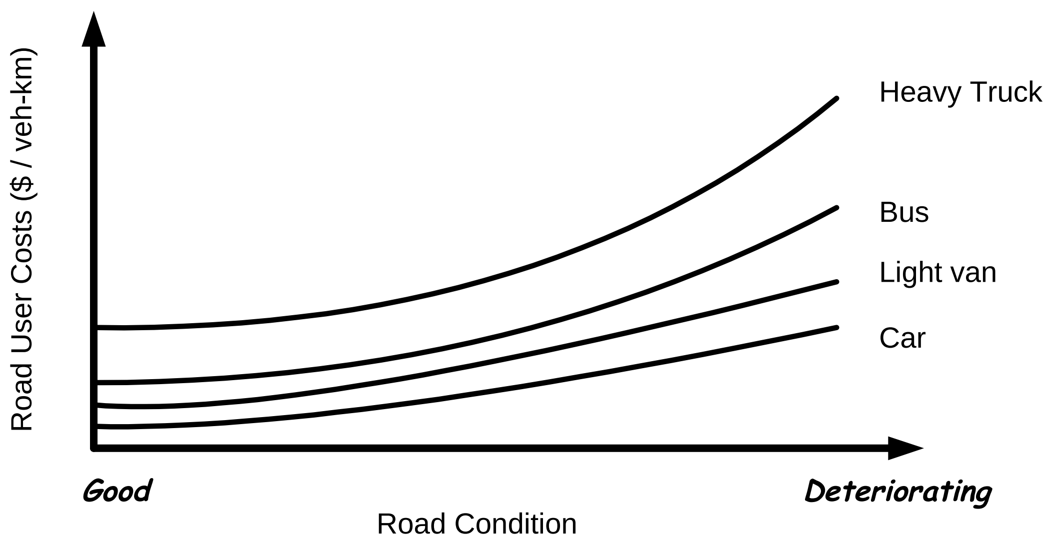

Fig. 4 Effect of Deteriorating Roads on Road User Costs (RUC) (schematic)

Road user costs (RUC) are the sum of vehicle operating costs, user time costs, costs arising from damage to cargoes and accident costs. Fig. 4 illustrates how RUC increase when the condition (roughness) of a road deteriorates. Agency costs make up only a small proportion of aggregated RUC, as Fig. 5 illustrates. Aggregated RUC can make up a significant percentage of the national GDP. Escalating RUC make for an inefficient use of national resources. Marginal increases in maintenance expenditure can result in significant reductions in aggregate RUC with corresponding benefit-cost ratios of 7 to 25 or more. In other words an additional expenditure of

$1m (cost) on maintenance can produce a benefit of $7million to $25million in reduced RUC, on a less than optimally maintained road network. In effect any activity in which road transport is a significant component becomes more profitable or competitive (compared to other national economies).

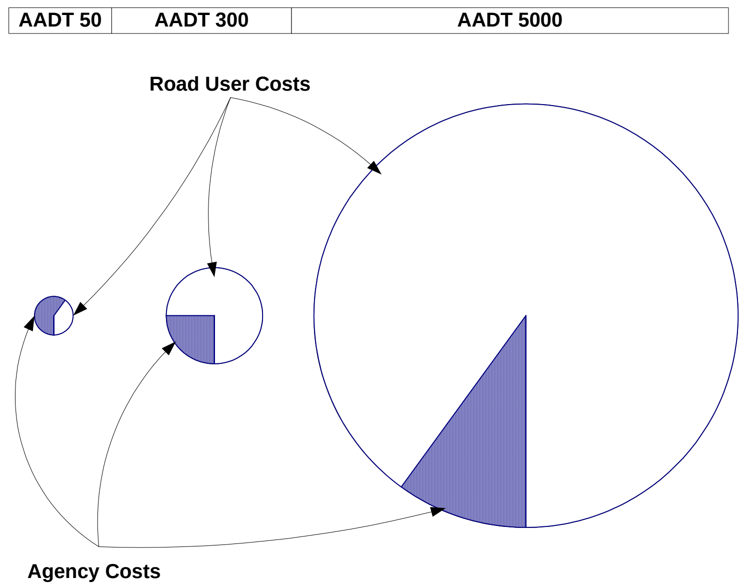

Fig. 5 Agency Costs as a Proportion of Total RUC (schematic)

THE ELEMENTS OF A ROAD ASSET MANAGEMENT SYSTEM

The key elements of a road asset management system, stripped to the absolute minimum, are illustrated in Fig 6 following:

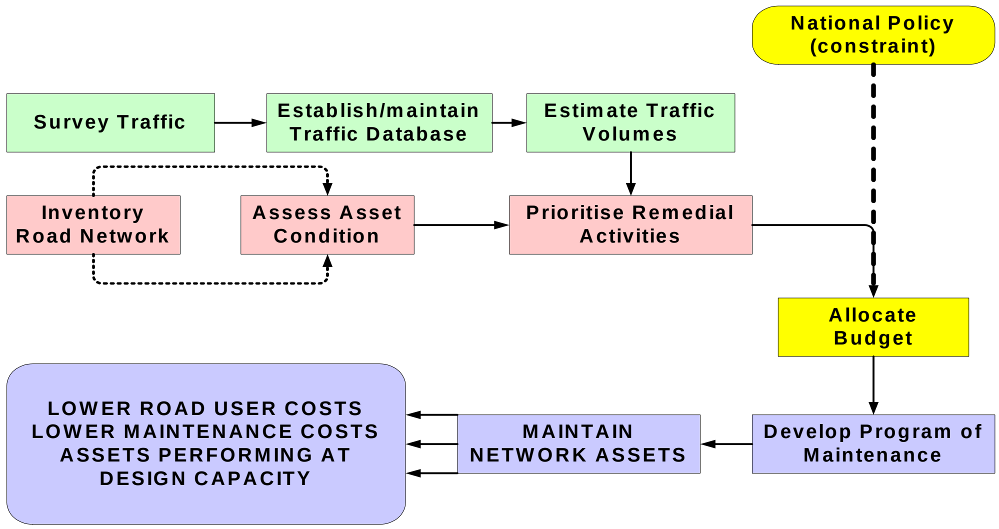

Fig. 6 The Asset Management Process

The main functional components for the New Providence road network are:

The Road Network Inventory consisting of a list of road names, a "from-to" descriptor (start intersecting road to finish intersecting road) and the length and the constituency in which the road lies. Over 4,000 roads totaling about 1,300km in length were located, mapped and named as part of this project.

A Traffic Database To enable traffic volumes to be assigned to network roads; a network level assessment of current traffic volumes in the network was undertaken. The RMMS is a network level tool (as opposed to project level). The annualized average daily traffic (AADT) values need only be a good estimate and the traffic volumes do not have to be counted on every road. The primary criteria for traffic volume evaluation is that the results be consistent across the road network. Traffic volumes were counted at stations throughout the network and traffic volumes were assigned to all roads.

A Measure of the Current Condition of the Roads This particular approach to RMMS is based on visual assessment of condition. The initial establishment of the system has been supported by roughness observations using a bump integrator to determine IRI values.

A Methodology to Prioritize Candidate Roads and to Estimate Budgets The World Bank and other major international financial institutions have promoted the use of economic models such as HDM-4 (Highway Development and Management Model–4) to justify investment in maintenance. Such models are complex and data hungry, and can be effectively operated only by specialists (who are in short supply). By using HDM-4, it is technically possible to select an economically optimum program of maintenance priorities. HDM-4 and its predecessor, HDM-3 have been applied to road improvement projects since 1966. The basic concept, that a well administered maintenance program massively benefits the national economy, is now widely accepted amongst highway administrations. However in a semi urban network, as prevails in New Providence, the final selection of maintenance projects must typically pass through a "filter" in which the "optimum" selection or works must be weighed against resource constraints, traffic management issues, overall Ministry programming requirements, national policy issues, community concerns, social issues in general and local politics. In practice a complex, economically optimum program of works in which priorities must be compromised by practical issues is much less sustainable than a workable, transparent approach producing sub-optimal results. The resulting programs and recommendations from this project can be understood and applied consistently. In the New Providence RMMS, priority for periodic maintenance treatments is established by ranking on the basis of a traffic weighted measure of road surface condition, as determined from observation. Priorities are assigned separately for each road classification (arterial/collector/local).

A Program Approach is necessary to ensure that maintenance is implemented consistently in future years. The output of the RMMS system is a program of "conceptual" level designs, (location/treatment/concept level cost estimates) which must go through the normal detail design/contract documentation process before being added into the current budget. All of the data associated with the RMMS and the development of implementation programs was stored in a geographical information system (GIS). Data input and output was via GIS features and/or by spreadsheets. The GIS is open source and freely available. The only proprietary software used was MS Office®. There are no other proprietary systems or programs involved and the entire operation is now in the hands of MOPWUD staff trained as part of the project. There are no identified obstacles to long term sustainability.

DETERMINING MAINTENANCE BUDGETS

By varying the budget amount we can increase or reduce the number of budgeted maintenance projects. Since we assume that the maintenance works restore the road condition to 0 rating, we can estimate the change in the network weighted average condition caused by the selected program of maintenance. It is not possible to directly predict the budget requirements for the NP network. A perturbation technique is used, in which the effects of applying varying budgets are assessed. By making assumptions about the rate of deterioration in the network, and the effect of annual program on the network average condition, it is possible to establish approximate, indicative budget levels. Table 2 following was prepared for the 1,300 km New Providence network, in three road classifications.

Table 2 Indicative Annual Periodic Maintenance Estimates ($million)

ARTERIAL, Est. Budgets	***$4.33 mill.***	***$5.28 mill.***	***$6.27 mill.***
	Weighted Average Condition		
Before maintenance implementation	0.3531	0.3531	0.3531
After maintenance implementation	0.3307	0.3219	0.3127
COLLECTOR, Est. Budgets	***$4.64 mill.***	***$5.31 mill.***	***$6.66 mill.***
	Weighted Average Condition		
Before maintenance implementation	0.4052	0.4052	0.4052
After maintenance implementation	0.3825	0.3762	0.3634
LOCAL, Est. Budgets	***$13.21 mill.***	***$14.99 mill.***	***$17.09 mill.***
	Weighted Average Condition		
Before maintenance implementation	0.4183	0.4183	0.4183
After maintenance implementation	0.3623	0.3548	0.3436
Tot. Periodic Maintenance Budget	***$22.18 mill.***	***$25.57 mill.***	***$30.02 mill.***

Notes on Table 2:

i. Assumed deterioration rate is 7% (14 year economic life)

ii Total budget assigned 20%:20%:60% to arterial : collectors : local roads

iii Weighted average condition reducing from 0.3531 to 0.3219 means the condition is improving

ROUTINE MAINTENANCE

In addition to expenditure on periodic maintenance, between $1,200 – $3,100 per km annually, ($1.6 - $4.0 million annually for the network) will be required for routine maintenance. It was recommended that routine maintenance be predominantly implemented by contractors. The cost will ultimately be set by competitive bidding. Routine maintenance slows the rate of deterioration, it does not improve the road condition (i.e. reduce roughness). One of the challenges of implementing routine maintenance by contractors is effective, quality management. Spot checks on contractor's performance are good for monitoring quality (adherence to specifications) but cannot be used to determine cost effectiveness. Inspections also place demands on Ministry staff. The orderly submission of digital photographs may aid in quality monitoring, as outlined in the section on "Features of a GIS Approach", following. Cost effectiveness of routine maintenance is a separate but closely related issue. Competitive tendering and comparison of costs of deploying own-forces maintenance crews will give some measure of cost control. If more rigor is necessary, it is possible to analyze and compare input time/materials/ plant hours by recourse to the summary reporting sheets recommended as mandatory reporting for both contractors and own forces, as outlined in "Features of a GIS Approach", following. The Project deliverables included a complete set of performance-based specifications for undertaking routine maintenance in the form of a content-controlled document, for insertion in standard Ministry contract documents. Recommendations are to let area-based routine maintenance contracts on the basis of fixed monthly payments, three year term and automatic extension for another three years for contractors whose performance is deemed to be in the top 50%. It is likely that these recommendations will be phased on a time scale appropriate to other planned changes and reforms to maintenance management.

FEATURES OF A GIS APPROACH

A GIS is an extremely powerful tool with many potential applications. By applying the GIS we were able to completely eliminate the cumbersome milepost/offset method of location referencing, together with the more complex, proprietary road databases which use such an approach. While the current application is centered on the RMMS, the potential applications are effectively unlimited. For example management of the inventory/maintenance of sidewalks, pedestrian crossings, parks/playing fields, marine protection works and signage are just a few of potential applications.

In particular there are opportunities for enhanced quality management of the routine maintenance processes, for example:

Digital Photographs of Activities and Outcomes As one of the mandatory submittals for monthly payment claims, contractors could provide date-coded photographs (monthly/quarterly etc as appropriate) together with GPS coordinates and or street names. These photograph/locations can be input and stored in the GIS and can be reviewed by activities delivered. By reviewing a series of dated photographs at a single location, (point and click), Ministry supervisors can be assured that work is being performed according to the service quality criteria. If sufficient GIS skills can be developed, the contractors themselves can prepare the GIS shapes files of their photographs, thus relieving Ministry supervisors of a time consuming, routine task and leaving more time to visit selected sites showing indications of quality lapses.

Monitoring of Input Resources: Another mandatory condition of payment for contractors could be standardized, summary resource consumption sheets (monthly/ quarterly etc as appropriate). The sheets will include location (road code/name, perhaps GPS coordinates), enabling quantities consumed to be readily mapped to the GIS model. By periodically reviewing where resources are being consumed, and comparing consumption between contractors, (point and click to open tables of quantities) the Ministry supervisor will be able to efficiently and effectively identify any contractor who is not performing to service quality criteria.

INSTITUTIONAL REFORMS / ORGANIZATIONAL STRENGTHENING

In a mature network, not subject to significant expansion, the ratio of maintenance to new construction spending is normally of the order of 80:20. When 80% of available funding goes to maintenance it is important to have an advocate at senior level in the road administration agency, where critical decisions on funding are made. A functionally oriented management organization is proposed in Fig. 6 following. The key feature illustrated by Fig 6 is that although function management is inter-connected and inter-related, the objectives are essentially independent. Achieving development objectives, (implementing construction projects on budget, on time and according to specifications) is quite independent of achieving maintenance objectives (road assets performing at design, or near design levels) based on timely and appropriate expenditure to a near-optimal program. Similarly planning objectives, (having more plans, supported by current data and information, ready for implementation than can be financed in any one budget period) should not be directly affected by the achievement or otherwise of development and maintenance objectives. In succinct terms, the Asset Development group builds, the Planning group prepares appropriate planning (including data and information collection) and the Asset Maintenance maintains.

CONCLUSIONS

A low cost, GIS based, sustainable RMMS has been deployed on New Providence Island and is beginning operation by local staff. The system involves no custom programming and no ongoing licensing/support fees, other than those involved with MS Office®. The operation of the RMMS is entirely transparent to Ministry staff, and in effect represents the systemization of good maintenance management approaches developed over many years of experience. Independently of the RMMS, the geographical information system offers many additional opportunities for asset management initiatives.

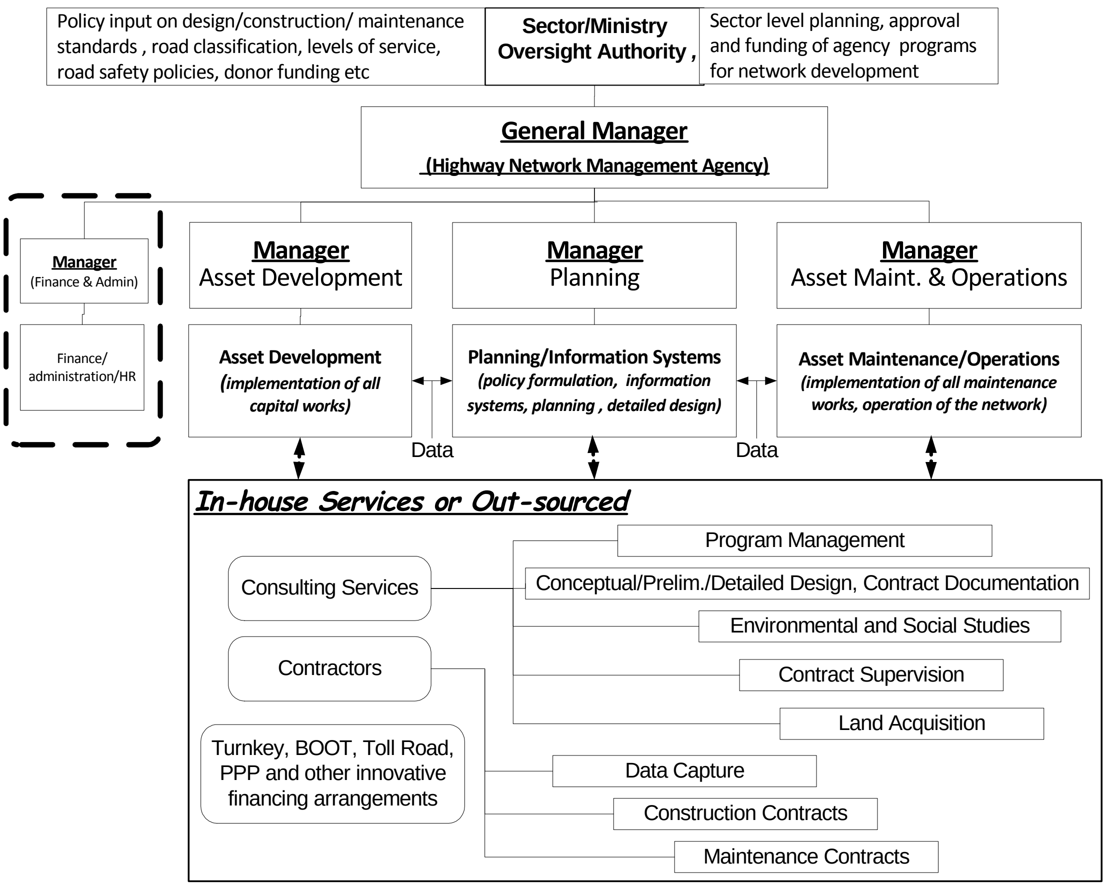

Fig. 6 A Functional Organization for Road Asset Management

ACKNOWLEDGMENTS

The authors wish to acknowledge the permission of the Ministry of Public Works and Urban Development, Government of the Bahamas to publish this paper. However the authors wish to make it clear that the contents are a summary of opinions, recommendations and conclusions offered to the MOPWUD, and in no way should be interpreted as policy or commitments by the MOPWUD. The material is presented with the permission of MMM Group and the Caribbean Civil Group but this paper does not represent an official position or commitment on the part of these companies. Opinions, errors and omissions are entirely the responsibility of the authors.