ROAD ASSET MANAGEMENT SYSTEMS IN DEVELOPING COUNTRIES: CASE STUDY UZBEKISTAN

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Summary: *Transportation infrastructure assets are not only costly to build but also expensive to maintain in order to adequately meet public expectation. The key issue is to how to manage existing assets in way that it delivers maximum benefit to public taking into account limited financial resources. Road asset management system reviewed from perspective of four major components such as goals, budget, asset and performance. There are several issues at policy level of analysis such as set up long term goals, expansion of road network, traffic safety action plans, environmental impact analysis, economic development and other; at budget level to plan year and multi year financing plan, budget breakdown and cost estimation; at data management level inventory and condition data collection, database management, traffic data and other; at performance modelling level to predict future condition, network level analysis and other; at programme optimisation level to perform economic, environmental and risk analysis, multi-criteria analysis and other; implementation programme to carry out construction, maintenance and operation of assets and other. Proposed approach to network level of analysis simplifies road network evaluation and uses the analytic hierarchy process to rank regions in terms of asset, cost and traffic. The data needed for the analysis is available in road agencies or easy to collect.*

Key words: *Road asset management system, analytic hierarchy process, network level analysis, prioritization.*

INTRODUCTION

Transportation infrastructure assets are key factors of economic development, mobility and social equity. Road asset management system (RAMS) is relatively a new concept although developed countries have developed roadmap to implement it but their counterparts are facing obstacles due to lack of systematic approach. Road sector in many parts of the world is heavily subsidized by government budget. Asset management is routinely applied in private sector with main objective of getting highest profit whereas public sector is more concerned with supplying

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with goods and services according to public demand and with less concern about profit. Literature review on asset management revealed that interpretation of the concept has slightly different variations. Asset Management is systematic process of maintaining, upgrading, and operating physical assets cost-effectively. It combines engineering principles with sound business practices and economic theory, and it provides tools to facilitate a more organized, logical approach to decision-making. Thus, asset management provides a framework for handling both short and long range planning [1]. Asset Management is a systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organized and flexible approach to making the decisions necessary to achieve the public's expectations [2]. Asset management is "a comprehensive and structured approach to the delivery of the community benefits through management of road networks" [3]. The goal of infrastructure asset management is to meet a required level of service in the most cost-effective way through the creation, acquisition, maintenance, operation, rehabilitation, and disposal of assets for present and future customers. The key elements of infrastructure asset management are: taking a lifecycle approach; developing cost- effective management strategies for the long-term; providing a defined level of service and monitoring performance; managing risks associated with asset failures; sustainable use of physical resources; continuous improvement in asset management practices [4]. Managing highway assets is not new concept; highway agencies have been using pavement, bridge, and maintenance management systems for decades. What sets asset management apart today is the move to merge these single-asset management systems into an integrated whole. Asset management is a comprehensive process that allocates funds effectively and efficiently among competing pavement, structure, and other infrastructure needs [5].

ROAD ASSET MANAGEMENT SYSTEMS

Definition of asset management in above-mentioned paragraph conveys almost same meaning with slight difference depending on each road agency's goals and strategies. The key words in all definitions are efficient and effective use of funds to meet public demand. The definition could be described as asset management is harmonized combination of engineering principles and sound business practices which meets public expectations.

Figure 1 shows proposed two-way monitoring scheme for asset management system. A road agency provides services by applying engineering principles and sound business practices to meet public expectation. Road agencies monitor key performance indicators such as technical, economic and other to evaluate agency performance. Feedback from road users provides insight on the level of satisfaction for provided services.

Existing road asset management systems in developed countries are complex to implement in developing countries due to high costs related to automated road data collection and data management systems. The other side of coin is that lack of standards, guidelines and research in

field of road asset management system from the point of view emerging and low cost technologies such as mobile, GIS and internet which are developing very rapidly in this part of the world. Implementation of RAMS is process of change existing pavement management system in way that road agencies achieve better optimization through adequate evaluation maintenance and rehabilitation projects. Developed countries implementing more sophisticated tools and systems to predict performance of the assets and optimize budget more efficiently. There are certain issues related to implementation sophisticated systems such as lack of sophisticated analytic tools, database issues, identification of effective communication devices, jurisdictional challenges, and institutional challenges [7].

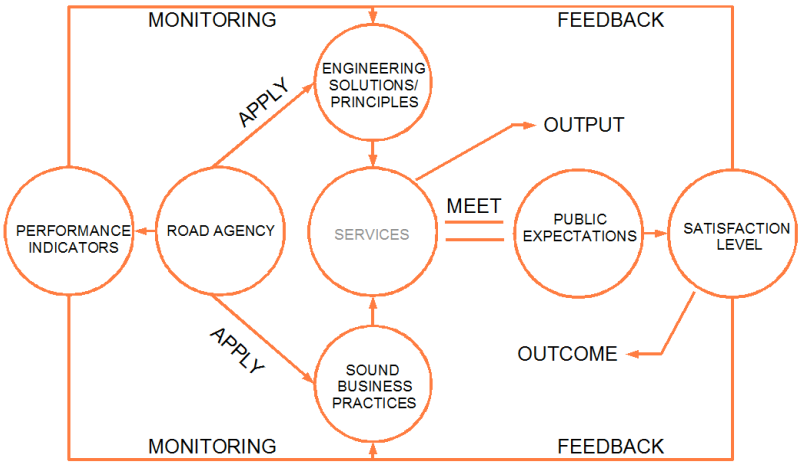

Figure 1. *Two-way monitoring scheme for Road Asset Management System [6]*

Life circle cost analysis of assets including roads is currently predominant approach in evaluation highway projects. Many countries have been utilizing systems for asset management. For example, the Highway Design and Maintenance Standard Model (HDM-4) developed by the World Bank and the World Road Association (PIARC) is used mainly in developing countries. Most of the developed countries use their own asset management systems such in Canada Transportation Infrastructure Management System (TIMS) [8]; in UK, Infrastructure Asset Management software; in New Zealand dTIMS software. These software solve broad range of problems including cost benefit analysis, traffic safety analysis, condition performance analysis, environmental assessments and other.

Road agencies daily face various types of challenges. They are at policy level to set up long term goals, expansion of road network, traffic safety action plans, environmental impact analysis, economic development and other; at budget level to plan year and multi year financing plan, budget breakdown and cost estimation; at data management level inventory and condition data collection, database management, traffic data and other; at performance modelling to predict future condition, network level analysis and other; at programme optimization level to perform economic, environmental and risk analysis, multi-criteria analysis and other; implementation programme to carry out construction, maintenance and operation of assets and

other.

Following measures in policy, planning and management level direct to the development of road sector in Uzbekistan [9]:

- To create executive task force for developing standards/norms, for supervising maintenance and operation works, for monitoring traffic safety and environmental assessments in order to harmonize with international practice of pavement management system
- Systematic approach for the development road standards and guidelines taking into account international standards.
- Upgrading equipments, machinery and mechanisms to meet demand for construction Uzbek National Highway System.
- Staff development and continuous training for road workers, engineers and managers.

Road agencies both in developed and developing countries face same obstacles in implementing road asset management systems but with different level of implementation. RAMS can be grouped in four major components. They are goals, budget, asset and performance. These components are interconnected with each other and together they form four pillars of asset management system (Fig.2). If one of the pillars fail or incorrectly set the whole system will not work in efficient way to achieve best possible solution.

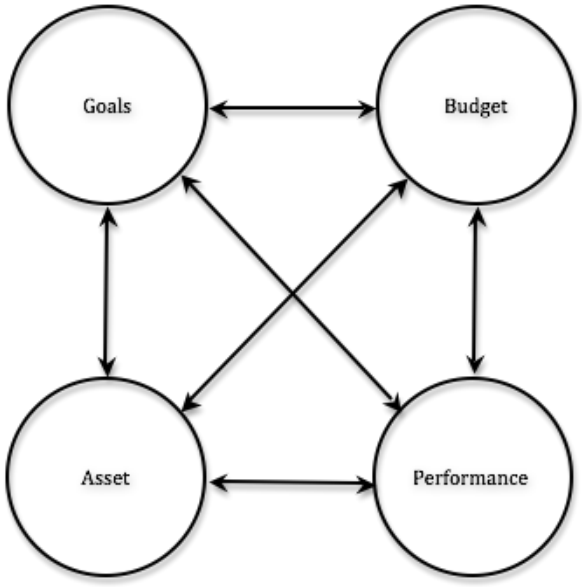

Figure 2. *Interaction between RAMS components*

Goals set to meet available budget. Based on allocated budget road agency perform maintenance and construction projects. Before performing maintenance or construction road agency assess asset condition. The other way is when budget depends on goals. On long term

planning and programming road works budget can be adjusted depending on goals for each year; in the same way the amount asset condition data can be adjusted depending on goals, budget and performance. Road asset management system is sophisticated approach to manage assets, it requires large amount of data, resources for data collection, storing and management, utilizes complicated performance prediction and assessment models, up to date hardware and software. In turn this requires highly qualified experts to make right decisions based on results obtained from the system. All these requirements are difficult to meet in developing countries therefore there is a need for simplified approach managing assets.

Review of implementation RAMS in [10] revealed that there are some similarities in implementation depending on a level of country development. In some of countries such as Laos, Pakistan, Philippines, Vietnam, Kyrgyzstan and Uzbekistan were made an attempt to implement RAMS through international development programs. The reason for that the process of implementation of RAMS requires large amount of financial and technical resources. International development programs serve as general reference and RAMS could be implemented partially. The importance of balance between four pillars of RAMS: goal, budget, asset and performance could not be overemphasized because it provides adequate solutions for efficient asset management.

ANALYTIC HIERARCHY PROCESS

The analytic hierarchy process (AHP) proposed by Saaty [11] is a very popular approach to multi-criteria decision-making that involves qualitative data. It has been applied during the last several decades in various decision-making problems. The method uses a reciprocal decision matrix obtained by pairwise comparisons so that the information is given in a linguistic form. The pairwise comparison method was introduced in 1860 [12]. Based on pairwise comparison, Saaty proposes the analytic hierarchy process as a method for multi-criteria decision-making. It provides a way of breaking down the general method into a hierarchy of sub-problems, which are easier to evaluate. It utilizes multiple criteria, and provides a simple process for weighting portions of the hierarchy that is difficult to enumerate directly. This method describe a general multi-factor decision problem in way that decision tree in each of the hierarchy levels include some types of criteria. The idea behind making decisions is to compare the relative importance of each criterion in adequate manner so that it can fit into general concepts. They are some of the concerns regarding application of AHP in making pair-wise comparisons between alternatives, the more alternatives the more problems occur regarding the consistency of the comparisons, and the assignments of the scores. An expert makes decision regarding the relative importance of each criterion and then specifies a preference, which is rated on a scale from 1 to 9, for each decision alternative. If there are n alternatives, then n*(n-1)/2 pair-wise comparisons are needed. Obviously, for practical application of AHP, the number of alternatives must be reasonable limited. The result of AHP is a prioritized ranking that indicates the overall preference of each alternative. The expert responsible for adequateness of assigned that they

reflect the importance of the issues. The consistency of the judgments of the expert can be measured with a consistency ratio (CR). The CR is calculated as follows:

$$CI = \frac{(\lambda_{\max} - n)}{n - 1} \quad (1)$$

$$CR = \frac{CI}{RI} \quad (2)$$

Where, CI- consistency index, λmax = the eigenvalue corresponding to the principal eigenvector n = the number of alternatives or criteria being compared RI = the random index, a dimensionless value that is a step function of n.

CR of 0.1 or less is considered acceptable. If a decision-maker's responses fail the consistency test, then the analyst must repeat iteration until consistent responses are obtained. Applications of AHP highlighted in various transportation projects evaluation [13-19]. A popularity of AHP method in solving multicriteria problems in infrastructure projects, clearly related to easy to use and the way it prioritize alternatives. The logic behind prioritization is based on expert's judgment. Besides in decision-making the method can use quantitative and qualitative data. Despite of advantages there are some disadvantages such as scaling alternatives from 1 to 9, weakness of priorities estimation methods, large number of comparisons when many alternatives exists [20, 21].

Before applying a method it is important to observe the issues, which affect the outcome of the research. Certain methods are good to apply at policymaking level but some are good at project level when detailed data available. An expert utilizes general data at policy level due to a nature of analysis.

SIMPLIFIED APPROACH FOR NETWORK LEVEL ANALYSIS USING ANALYTIC HIERARCHY PROCESS

According to the United States Federal Highway Administration [1], decision-making in Road Asset Management can be considered at two levels:

- Executive Level (policy/strategic/programming)
- Operational Level (project development)

The first level develops a long-term strategic plan and a short-term program of projects intended for funding. The second level provides evaluating and selecting projects in different parts of the network. The two levels of decision-making take place within political and technocratic processes. Generally, at the more detailed planning levels, more weight is given to technical decisions. Highway development and management software HDM-4 v2.0 utilizes multi-criteria analysis based on AHP when criteria cannot be assigned an economic cost [22].

Road network length is 183 783 km in Uzbekistan. Public roads are 42 530 km, internal

local roads are 71 324 km, city streets and roads are 69 229 km. Public roads are main arterial roads of the country [23]. In order to efficiently manage public roads and implement road asset management at network level of analysis, we propose AHP consisting following components (Fig.3).

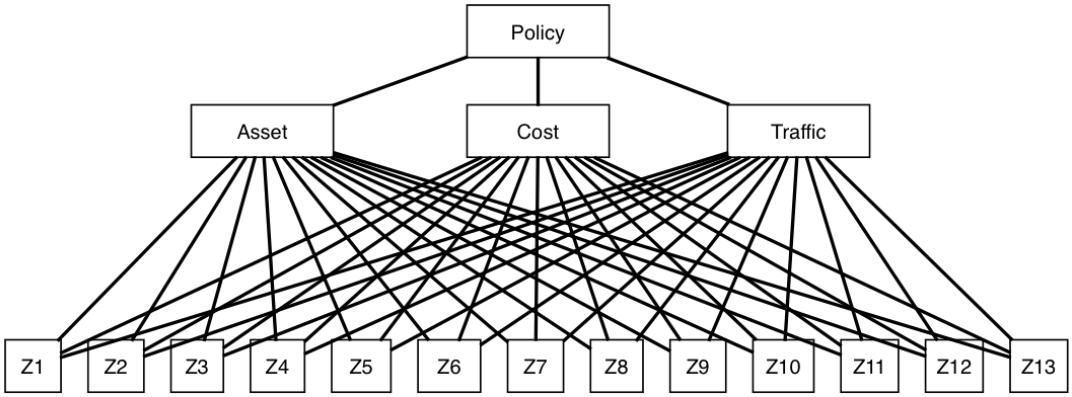

Figure 3. *Analytic hierarchy process for network level of analysis*

There are three decision criteria such as asset, cost and traffic. Road agency's focus is a policy on how and when to apply maintenance & rehabilitation projects depending on asset condition, road work costs and traffic. Some researchers [24,25] proved that to evaluate road condition, pavement roughness namely IRI is suitable to use. This approach could be useful and meaningful at network level of analysis. Detailed condition data needed at project level due to what type of repair measures need to be applied. In this research asset data is evaluated in terms of road network size. Cost data is a budget for the whole network. Budget can be allocated among regions taking into account population size in the region. Cost estimation of highway projects described in detail in [26]. Traffic volume was selected as traffic decision criterion. In evaluation road user costs traffic volume is the most important factor. There are 13 administrative regions in Uzbekistan. They are marked from Z1 to Z13 as alternative in Table 1.

First we assign importance for decisions then for each zone. Intensity of importance varies from 1 to 9; 1 – equal importance, 3- somewhat more important, 5 - much more important, 7- very much more important, 9- absolutely more important, 2,4,6,8 – intermediate values used when compromise is needed.

Road agency sets a policy to optimize resources efficiently depending on three decision factors such as asset, cost and traffic. Next step to assign importance factors to each decision factors. Based on heuristic method an asset is 3 times less important than a budget and 5 times less important as traffic. On other hand a budget is 3 times less important than a traffic. Importance factors for each zone are calculated for each parameter such as size of population, vehicles per km and road network size. For zones the procedure of calculation importance factors are based on percentage share for each parameter. After obtaining matrices for each parameter, eigenvalues were calculated. Prioritization of alternatives (zones) repeated until CR

value is less than 0.1, calculations showed that after second iteration CR value significantly less that 0.1. The results of AHP for a policy to optimize resources among regions based on decision factors such as asset, cost and traffic showed in Table 2.

Table 1. *Zones descriptions*

Zones	Regions	Population	Vehicles per km	Road Network, km
Z1	Andijon	2 672 300	45	2459
Z2	Buxoro	1 683 800	35	4002
Z3	Jizzax	1 166 700	25	2543
Z4	Qashqadaryo	2 722 900	38	3454
Z5	Navoiy	873 000	20	4196
Z6	Namangan	2 279 500	39	3355
Z7	Samarqand	3 270 800	32	4128
Z8	Surxondaryo	2 052 000	26	2719
Z9	Sirdaryo	727 200	22	1422
Z10	Toshkent	2 644 400	50	3833
Z11	Farg'ona	3 229 200	48	4175
Z12	Xorazm	1 601 100	46	2265
Z13	Qaraqalpaqstan Respublikasi	1 680 900	28	4175

Table 2. *Regions ranking based on AHP*

Zones	Regions	Ranking
Z5	Navoiy	0.034
Z8	Surxondaryo	0.037
Z7	Samarqand	0.040
Z2	Buxoro	0.045
Z4	Qashqadaryo	0.045
Z9	Sirdaryo	0.059
Z6	Namangan	0.063
Z13	Qaraqalpaqstan Respublikasi	0.077
Z1	Andijon	0.079
Z3	Jizzax	0.104
Z12	Xorazm	0.112

Z10	Toshkent	0.116
Z11	Farg'ona	0.129

The results indicated that most of the important regions are in the east Z11, Z10, Z1 and Z6 and in the west Z12, Z13. Significant share of international goods go through from east to west. Based on simple AHP approach it was proved that roads in these regions need priority to improve road condition (Fig 4).

Over the past 10 years Anijon – Tashkent – Nukus – Kungrat highway was went though planning, designing and presently reconstruction and rehabilitation road works carried out in Bukhara and Xorazm regions. Based on this analysis for each region, road agency could proceed to analysis at project level where more detailed data is needed.

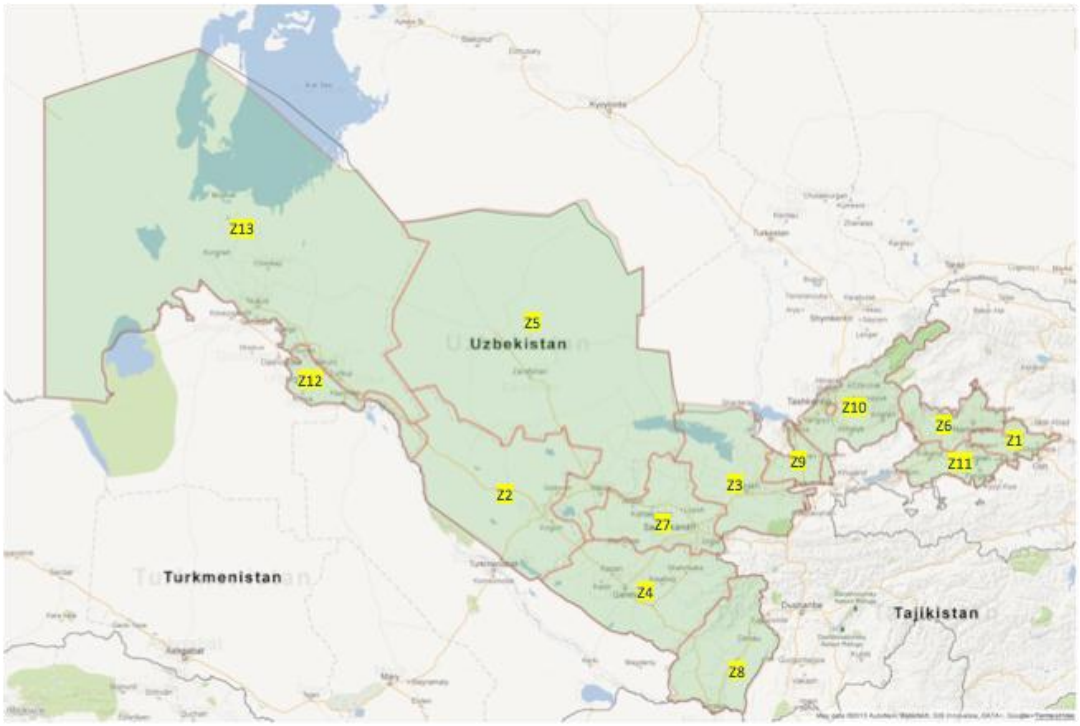

Fig 4. *Zoning for Network Level of Analysis*

CONCLUSIONS AND RECOMMENDATIONS

Transportation infrastructure assets are expensive to build and more expensive to maintain to meet public expectation. Road asset management serves as key tool to manage existing assets in way to better and efficiently operate and maintenance all the road assets. Road agencies both in developed and developing countries face similar barriers in implementing road asset management systems but with different level of implementation. RAMS can be grouped in four major components. They are goals, budget, asset and performance. These components are

interconnected with each other and together they form four pillars of asset management system. If one of the pillars fail or incorrectly set the whole system will not work in efficient way to achieve best possible solution. There are several issues at policy level of analysis such as set up long term goals, expansion of road network, traffic safety action plans, environmental impact analysis, economic development and other; at budget level to plan year and multi year financing plan, budget breakdown and cost estimation; at data management level inventory and condition data collection, database management, traffic data and other; at performance modeling level to predict future condition, network level analysis and other; at programme optimization level to perform economic, environmental and risk analysis, multi-criteria analysis and other; implementation programme to carry out construction, maintenance and operation of assets and other.

Present status quo of road asset management system is sophisticated approach to manage assets, it requires large amount of data, resources for data collection, storing and management, utilizes complicated performance prediction and assessment models, up to date hardware and software. In turn this requires highly qualified experts to make right decisions based on results obtained from the system. All these requirements are difficult to meet in developing countries therefore there is a need for simplified approach managing assets.

Proposed approach to network level of analysis simplifies road network evaluation. Data needed for the analysis is available in road agencies or easy to collect. There is also a drawback in this approach that it can only evaluate road network indirectly through parameters such as asset, cost and traffic. Further research will be focused on project level of analysis and the ways to simplify methods and tools.

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