Theoretical framework for transportation infrastructure asset management based on review of best practices

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ABSTRACT

The transportation agencies have historically focused on major building and expansion of roads, bridges, and other transportation infrastructure. However, the emphasis has drastically shifted from development of new infrastructure to intelligently maintaining the existing one. In recent years, budget tightening and increasing demands had also impacted the allocation of funds in transportation infrastructure. This situation has lead to emphasize the development of asset management systems. At its core, asset management is a business process that often changes the way of thinking in an organization and drives the decisions based on information. A strong asset management system provides a solid foundation that optimizes the performance and cost effectiveness of transportation facilities’ operations and maintenance. Keeping in mind, this paper provides an overview of transportation infrastructure asset management. It provides a review of the best practices adopted by different transportation infrastructure agencies internationally & United States. The review shows that the front runners in the asset management system internationally are Australia while Michigan takes the lead in US. Finally, based on the review of best practices, a theoretical framework for transportation infrastructure asset management has been proposed. The framework is focused on six important aspects of an asset management system i.e. asset management organization and concept, planning, contractual arrangement and mechanisms, monitoring and performance measurement, information systems and decision making.

Keywords Asset management, transportation infrastructure, best practices.
INTRODUCTION

Public infrastructure in the United States faces many challenges including aging, inadequate funding, short-term focus, limited infrastructure information, globalization, and the need to satisfy multiple stakeholder demands. The U.S. has fallen sharply in the World Economic Forum's ranking of national infrastructure systems. In the Forum's 2007-2008 report, U.S. infrastructure ranked 6th place in the world (Lange 2011). Now, according to an infrastructure report recently published by the American Society of Civil Engineers (ASCE) and the World Economic Forum’s Global Competitiveness Report 2010–2011, in terms of certain major infrastructure such as roads and railroads, U.S. infrastructure no longer ranks in the top ten nations (ASCE 2011).

The allocated infrastructure-related funding is spent on a mixture of system expansion and preservation projects. Since the 1970s there has been a drastic decline in funding that supports the infrastructure of the U.S. In 1960, the U.S. federal public spending on infrastructure was 5% of gross domestic product (GDP); by the mid-1990s, this figure was down to 2.5% (Snavely 2011). Today, the U.S. spends roughly 2% of GDP on infrastructure; about half what it did 50 years ago, according to a U.S. government report (Lange 2011).

The transportation agencies have historically focused on major building and expansion of roads, bridges, and other transportation infrastructure. However, the emphasis has drastically shifted from development of new infrastructure to intelligently maintaining the existing one. Asset management, as a term that came into vogue in the mid-to late-1960s, is often defined as the process of maximizing value to a property or portfolio of properties from acquisition to disposition within the objectives defined by the owner.

The Federal Highway Administration (FHWA) defines asset management as a “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 philosophy of approach for handling both short- and long-range planning”

This scenario requires transportation agencies to view the infrastructure management process as a business process and thus have an asset management framework. The framework should address changing dynamics in terms of performance challenges and financial constraints. The paper proposes a theoretical framework for transportation infrastructure asset management to suffice the need.

STUDY SCOPE, OBJECTIVES AND BENEFITS

The scope the study is focused over the organizational aspects and processes of the transportation infrastructure asset management agencies. Based on the literature review there are six important aspects required for defining asset management framework. These are (1) asset management concept and organization (2) planning (3) contractual management and mechanisms (4) monitoring and performance measurement (5) information management system and (6) decision making. The study provides review of best practices with regards to these aspects and proposing the theoretical framework. The framework proposed in the study is developed from macro level perspective.
The following text presents a review of best practices in transportation infrastructure asset management. The review of the best practices has been utilized in the next section to propose a theoretical framework for transportation asset management agencies.

**Asset management concept and organization**

At the national level, the Highways Agency of the Department for Transport is responsible for England’s major roads. Asset management is not a stated objective. This is because the agency views itself as a traffic service provider and hence, its philosophy is that asset management is built in within the system (Geiger et al. 2005). Such a concept disseminates the responsibilities to all the stakeholders, team members at a local level. The New Zealand Transport Agency (NZTA) was established in 2008 by combining Transit New Zealand and Land Transport New Zealand (Transit NZ 2011). It provides an integrated approach to transport planning, funding and delivery (Queiroz and Kerali 2010). The Ministry of Transport (MOT) in China is responsible for policy and regulation of all transport modes, except railways. At the local level, the implementation of the transport programs is the responsibility of the Provincial Transport Departments (PTD). In mega cities (Beijing, Chongqing, Shanghai and Tianjin) transport bureaus has the responsibility of managing the infrastructure (Queiroz and Kerali 2010). The Transportation Association of Canada (TAC 2003) is a national association of approximately 475 members. These include federal and provincial transportation departments, municipalities, private-sector firms, and academic institutions. Transport Canada’s role is to develop transportation policies to maintain a high level of safety, security, and sustainability in transportation systems (Vanier and Rahman 2004). At local level, the provincial departments are responsible for asset management process. In Australia, there is a group called Australian Asset Management Collaborative group (AAMCoG 2011). The main aim of AAMCoG is to collaborate nationally on asset management strategies between all asset management groups. The group is comprised mainly of seven members. The civil infrastructure related members are Australasian Procurement and Construction Council (APCC), Australian Green Infrastructure Council (AGIC), Australian Water Association (AWA), Cooperative Research Centre for Infrastructure and Engineering Asset Management (CIEAM). The APCC itself has various members specifically state level and regional departments related to infrastructure management.

In US different departments of transportation (DOT) have different organizational arrangement and concept for the asset management process. In Florida DOT asset management is considered as an entire process of planning, programming and system monitoring. It does not have a separate asset management unit. Michigan DOT, recognized as leading transportation agency in asset management, has a separate division “Asset Management” for the purpose. It has some official full time employees and some shared human resource. Minnesota DOT works on performance based methodology and thus considers asset management as an integrated part of the department as a result of this (Cambridge Systematics and Meyer D.M. 2007).
Asset management planning

In England, the transportation asset management plan development is largely dependent upon the efforts of local authorities. They have been encouraged to demonstrate how they use their assets in the form of local asset management plans. These plans are then utilized for macro level planning by the central government and regional government. In some cases, it has also been advised to keep in consideration other related infrastructures. In New Zealand, at the strategic level, statement of intent for three years defining the investment priorities and needs is prepared. A national state highway strategy defines the capital and preservation strategies that are used to meet adopted goals and performance targets. A network level statement (for each individual network) comprising of condition overview, performance measurements and issues and objectives, asset management practices and strategies, current contractual commitments for maintenance, safety impacts, performance targets, a 10-year works program based on modeling (including pavement deterioration), and a description of any new initiatives (Geiger et al. 2005). In China, MOT sets policies, standards and provides investment support toward the construction cost. Once the expressways are opened, they are managed by the provincial transportation departments (PTDs) through an operating company or other authorized entities. The private sector provides finance on a limited scale through different types of concession schemes PTDs being in charge of the detailed planning, engineering design and building of the selected roads (Queiroz and Kerali 2010). The Transportation Association of Canada has published a primer on highway asset management identifying its benefits, listing the components of an asset management system, discussing critical success factors, and itemizing a seven-step implementation plan. In Australia, APCC (2001) guide stresses that strategies for the management of individual assets and portfolios should be based on defined service delivery objectives. The local planning agency’s own principles for whole of-life management of the assets should then be reflected into these objectives. It also defines the key issues to be considered in developing a strategic asset management plan. These include; utilization, capacity, functionality, condition, cost, value, service dependency and procurement strategy (public or private sector involvement). The local transportation infrastructure management authorities’ also include other factors in line with their specific needs. For example; Brisbane’s transportation plan also emphasizes renewed investment in public transportation and the use of demand management strategies to reduce transport demand (Geiger et al. 2005).

In US, there are different planning approaches. Florida DOT has to prepare a 20-year Florida Transportation Plan (FTP) other than a more detailed program and resource planning for specific operating policies under statutory requirements. Similarly, Michigan DOT develops a State Long-Range Plan (SLRP) for providing investment framework for transportation system. Furthermore, it develops a five year plan and three year state transportation improvement program (STIP). On the other hand, Minnesota develops a Highway system operations plan (HSOP) which focuses on maintenance and operations need (Cambridge Systematics and Meyer D.M. 2007).

Contractual management and mechanisms

One of the key aspects of the transportation asset management system in England is encouragement of Public Private Partnership (PPP). The road network is
divided into 14 operational areas with each area managed by a managing agent (MA), a private consultant usually operating under a 5-year contract. MA can be of two forms. First form has a consultant that oversees work of the separate maintenance contractor. In second form, area is managed by a single firm made up by combining consultant and maintenance contractor. Furthermore, a local government act of 1999 (LGA 1999) and Compulsory Competitive Tendering (CCT) policy has paved the way for best value based selection. Many of the guidelines and processes now include the best value aspect for the asset management and maintenance. These guidelines define and stress over, the key principles of asset management such as life cycle focus, strategic planning, systematic monitoring, risk management, sustainability and lesson learning approach to provide best value in asset management (See IHP 2001). New Zealand has also developed successful innovative performance-based maintenance contracts. About two-thirds of these 5- to 10-year contracts are performance based (Geiger et al. 2005). It is interesting to know that even in the economy like China (which is still considered as a closed economy by many) tendered build-operate-transfer (BOT) concessions have recently been introduced. In this case, the concessionaire finances, builds and operates the toll road for a defined period, and takes on most categories of risk. For example, in 2005 Sichuan offered the first of its BOT projects, the 137-km Leshan-Yibin expressway, through open tender (ADB 2006). In Canada, provincial agencies outsource much of their activities, including maintenance functions. These contracts define the types of work activities that are to occur via contract activities and establish desired outcomes of such contracts, but does not specify how to produce these outcomes (Geiger et al. 2005). In Australia, AAMCoG (2011) suggests that since assets are now owned, governed and operated by an expanded set of decision-makers, there is a need for hybrid models for management of assets such as such as public-private partnerships, alliance and relational contracts.

In US, some of the agencies use private contractors for providing long-term maintenance services while others relied primarily on their own forces. Two types of contracts are used—work accomplished and performance-based (Cambridge Systematics and Meyer D.M. 2007).

**Monitoring and performance measurement**

In England, the major performance indicators, termed as best value performance indicators include but are not limited to, road condition, injuries, customer satisfaction with the services etc. The Highways Agency has performance indicators for structures that include the physical condition of the infrastructure asset, usage and service level reductions due to maintenance requirements, Road Safety, reliability of the infrastructure and customer satisfaction (Queiroz and Ker ali 2010). In New Zealand, at strategic level, performance indicators are a part of statement of intent. At technical level, an annual high-speed network condition survey is conducted that provides input into key performance measures (KPMs) and key performance indicators (KPIs) (Geiger et al. 2005). Three categories of infrastructure performance are used for all asset types to measure current and future performance. These performance measures relate to condition, use, and functional adequacy. In Canada, the condition measure is differentiated by road type. Use is measured as the percent of road kilometers at service Functional adequacy is determined as the
percentage of kilometers that meet width standards, horizontal alignment standards, and appropriate road surface type for traffic volume levels, and that have no weight restrictions (Geiger et al. 2005). In Australia, the AAMCoG (2011) guide stresses on the evidence-based assessment. An evidence-based assessment provides the tool to affirm and assure quality service delivery and to support internal and external reporting.

In US, DOT’s usually use scorecards as in Minnesota DOT, maintenance rating program (MRP) as in Florida and condition rating index such as pavement condition rating (PCR) as in Ohio DOT (Cambridge Systematics and Meyer D.M. 2007). The measurement mechanisms as far as condition assessment is concerned are very strong. However, there is a need for improvement in measuring subjective factors such as socio-economic benefits, sustainability etc.

**Information management system**

There are various information management tools and systems developed in England by the highway agency. These include Highways Agency Pavement Management System (HAPMS), United Kingdom Pavement Management System (UKPMS), Structures Management Information System (SMIS), HAGDMS, a geotechnical/slopes database; HATRIS, a traffic information system, HA-ES, an environmental management system; and NOMAD, a technology equipment database (Geiger et al. 2005). These systems receive data from a variety of sources and provide outputs to a public web site, a program investment development tool, and budget analysis. In New Zealand the Road Asset Maintenance Management (RAMM) system, begun in the 1980s, includes the primary road inventory, condition data, and treatment selections and interfaces with the pavement design system (Geiger et al. 2005). In Canada, provincial agencies have also developed customized asset management systems. For example, Government of Alberta developed transportation infrastructure management system (TIMS), a unique Web–based knowledge system designed to ensure that $50b worth of highway assets and annual capital investments of 1.5b are managed for optimum lifetime performance by measures of safety, economics, environmental sustainability and innovativeness (AT 2011). The information management strategy in Australia is based on the concept of total asset management. The APCC (2001) defines basic categories that should be included in the information system. These include Asset characteristics (description, age, location, property life etc), categorization, valuations (market value, depreciated amount), expenditure, condition, suitability and utilization. The local authorities follow the same concept.

In US, DOT’s have customized information management systems as per their need. However, comparatively, the better approach is that of Michigan DOT. It was the first state to develop a comprehensive information management system that works in integration (Cambridge Systematics and Meyer D.M. 2007). It based more on the enterprise system concept rather than stand-alone, single user system.

**Decision making**

In England, there are four key documents that guide the decision making include corporate strategic plan, business plan, balanced scorecards, and annual report (HA 2011). The highway agency has incorporated the asset management elements within each of these documents. Project prioritization for maintenance also includes
risk identification and management. Agencies in England use a scoring approach based on the risk matrix to fulfill this aspect of the decision making (Geiger et al. 2005). New Zealand has also established a performance-oriented asset management decision making structure. The decision-making process for determining priorities is based on whole-of-life costing (known in the United States as life cycle costing) procedures, which includes deterioration modeling to determine useful lives (Geiger et al. 2005). NAMS also publishes various manuals and guidelines such as “Optimized Decision Making Guidelines” that expands on topics in the international infrastructure management Manual. (NAMS 2011). One of the important distinctions between the Canadian and U.S. transportation systems is that highway projects in the provinces are funded almost entirely by the provincial government. Therefore, highway budgets compete with other infrastructure (e.g., schools and hospitals) as well as other budgetary priorities (Vanier and Rahman 2004). Therefore, the decision making process becomes more competitive but also complicated. It pushes the transportation decision makers to essentially consider other type of infrastructure and thus many social and economic factors (that may not have been calculated otherwise) have to be calculated. Scenario analysis is used to examine investment strategies. The decision making is Australian system is depended on total asset management concept (APCC 2001). For instance, the TAM framework, of Brisbane’s is an asset planning tool that can examine asset performance over variable time horizons, including annually, 10-plus years, and 30-plus years. Furthermore, Brisbane’s asset management program leads to a process of prioritization based on tradeoff analysis (Geiger et al. 2005).

Decision making with reference to fund allocation is the most critical stage of the asset management system in US. Policy wise, the best practice found was that in Ohio DOT, where a funds management committee decides the relative distribution of budget to the districts. For capacity projects, a nine-member council called the Transportation Review Advisory council (TRAC) sets policies and criteria for selection of the projects for funding. Minnesota DOT use the performance based selection system, to decide the fund allocation. In Michigan, there is a legislation that requires 90% of the funds to be spent over the asset preservation (Cambridge Systematics and Meyer D.M. 2007).

PROPOSED THEORETICAL FRAMEWORK FOR TRANSPORTATION INFRASTRUCTURE ASSET MANAGEMENT (TIAM)

Following text proposes theoretical framework for transportation infrastructure asset management (TIAM) based on the review of international and US best practices.

Asset management organization

It is proposed that there should be a separate section at the state level in the DOT’s dedicated to asset management system. There could be an advisory council that can run the asset management system. This will help states to plan their investments and maintain their assets more strategically. The council should act as an advisory body having members form all the districts, representative of the public interest groups and field experts as observers. The only dedicated employment could be that of “State Asset Manager” who should be responsible for the coordination of
the asset management issues internally in the State DOT and externally to all the other stakeholders. At the district level, an existing officer can be assigned with the additional responsibility of “District Asset management coordinator”. This type of arrangement will not require states to change the system from its roots; neither will it require big investments into the system development. The state should define its “Asset Management Statement” in line with the State Transportation Infrastructure Vision (STIV) which is described later in the text under the section of planning.

**Planning**

Asset management agencies or the DOT should focus on a two tier system for asset management planning.

1. **State Transportation Infrastructure Vision (STIV)**

   This plan should be developed through a detail study involving multiple stakeholders. These stakeholders should include local infrastructure organizations (as districts of DOTs), fund providers, public interest groups, economists, researchers and academicians and representatives of associated infrastructure management agencies (such as water, power etc.). This plan will strategically define long term goals and objectives of the infrastructure management in the jurisdiction of a particular asset management agency. This plan will help in defining and procuring funds at the state and legislative level. Since, it will be a long term vision; the plan will ensure the continuity of the asset management concept despite the change in administration and financial constraints. It will also ensure the sustainability of the infrastructure.

2. **District Performance Based Plan (DPBP)**

   The districts under the state department of transportation should define their own performance based plan. The objectives of this plan should be aligned to those defined in the STIV. It is suggested that state should link the procurement of funds to five major performance indicators. These include the level of service, condition, operational improvement, socio-economic improvement and sustainability improvement contribution of the entire infrastructure under a district.

**Contractual management and mechanisms**

Contractual arrangements should be made based on the project needs as done usually. However, there is a rising need to involve private sector into the infrastructure maintenance and rehabilitation specifically due to quality concern and financial constraints. Sates and districts should model themselves as regulatory authorities in case of maintenance and management projects. Public-Private partnership (PPP) should be encouraged specially for assets such as rest areas at highway exits for their maintenance, security and renovation. This practice is very much there in case of Florida DOT.

**Monitoring and performance measurement**

The monitoring and performance measurement system should be strongly integrated to the information management system. The monitoring and performance measurement system should have the following characteristics.

1. It should have an evidence-based assessment and monitoring. The evidences, obtained in whatever form, should be the part of information management system.

2. Performance indictors should include the physical condition of the infrastructure asset, usage and service level reductions due to maintenance
requirements, road Safety, and reliability of the infrastructure and customer satisfaction

3. Rating systems, checklists, scorecards etc. can be used in a customized fashion by different districts and department within the districts but still be able to be interpreted in a common referencing system.

4. It should not only be able to measure current performance but should also be able to predict future performance.

**Information Management system**

The information management system for the asset management should work on enterprise concept. Instead of having a single-user data base, in which all the information is first collected and then recorded by an assigned expert; the system should grant access to multiple professionals of different departments. Each department should be allowed to develop their own performance indicators to be used within the information system. There should although be common referencing, a uniform set of technical standards and definitions. Each department should manage the data related to its scope of work and then a committee of decision makers should use the information system as a decision support tool. The system should be capable of maintain past project records as well. On the basis of past project information, each department should list the major lessons learned within the information system. This will make sure, that even if the decision makers in the future are changed, new decision makers will be on the same page while making the decisions for the future infrastructure management investments.

**Decision Making**

The investment decision making should be conducted by a funds management committee. The committee may be comprised of the district officials and representative of the state official. The fund management committee should act as an advisory council to the main decision maker. The committee should use the district performance based plan, information management system and performance and monitoring reports (out of the information management system) for the decision making. The fund allocation should be done on the basis of performance of districts as much as possible. However, need basis should also be considered as special requirement. The decision makers have to make a shift from traditional thinking of making maintenance and rehabilitation decisions on just the need basis. They should adopt the treat the maintenance projects in the same manner as they do for development of a new infrastructure. This requires socio-economic considerations, usage, sustainability factors and condition all to be considered while allocating the money.

**CONCLUSION**

A comprehensive review of best practices internationally as well as in United States was presented. A theoretical framework focusing on the six key aspects of the asset management system has been proposed. This framework can be used as a starting point to define a more comprehensive and detailed framework.

**REFERENCES**


