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Best Practices for Managing Aging Transportation Infrastructure

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ABSTRACT

Transportation asset management (TAM) is an approach to more than optimize the use of transportation resources. It may also be used to critically provide a wider decision framework to manage transportation infrastructure risk. TAM attempts to: 1) optimally allocate what resources are available to needed transportation investments, *as well as*, 2) manage and reduce risk to the agency and society in general.

The first part of this paper is concerned with the adoption of TAM. It is unfortunate that with a crisis in transportation infrastructure management (i.e., in roadways, bridges, culverts, and slopes, etc.), there has been some resistance in adopting recognizing best practice management techniques, including TAM. TAM has in some instances been itself a high-risk exercise. Important lessons can be learnt from "*Generation 1*" TAM project efforts (including some significant project failures) and from "*Generation 2*" efforts that are now showing clear success.

One of the TAM struggle points is that at the transportation agency level in North America there has been a struggle in many agencies to clearly delineate between: 1) what is transportation "Maintenance Management" (MM) and what is TAM, and 2) more so, how to migrate from one to another in a risk-minimized fashion. Both of these activities fit within a wider transportation Infrastructure Management (IM) framework. The use of robust TAM methods in North America is still relatively new, yet now is the time to make deliberate and bold strides in this area.

In an age of limited resources, including available staff time, one of the fundamental issues is that the emphasis has been on TAM being a *new approach*. Field experience is that a more useful view is the use of a *migration* strategy from existing methods, techniques and tools to TAM to better manage both resources and risk.

The second part of this paper briefly introduces some of the "green" ideas and benefits that may accrue with TAM, and points to this as the next generation of TAM development. Specifically, contemporary TAM (and the software systems that support it) is a powerful enabler for implementing practical eco-friendly policies and techniques.

The paper draws on experience of undertaking TAM in a dozen DOT's in Canada and the US to date.

INTRODUCTION AND CONTEXT

This paper is a first in a three-part series on Transportation Asset Management (TAM). Based on North American field practice and experience to date, this paper addresses: 1) the appropriate *Definition* and 2) the *Benefits* of TAM. Despite much prior ground-setting work, these are still practical issues in many transportation agencies today. Without common ground and understanding on these points, it is not possible for example to best gain operational or green budget improvements through TAM.

ASCE's *2009 Report Card for America's Infrastructure* graded the nation's infrastructure a "D". This report confirmed that "the nation needs to invest approximately $2.2 trillion over the next five years to maintain the national infrastructure in good condition. Even with the current and planned investments from federal, state and local governments in the next five years, the "gap" between the overall need and actual spending will exceed $1 trillion in 2014" (2). With such important challenges that significantly impact the economy of the nation, it is important that the wider highway profession truly has unified vision, goals and clarity on core concepts and tools. The profession needs to be fully unified and aligned for field success.

A practical focus here is on highway infrastructure. The concepts reviewed, however, apply to most transportation infrastructure. Highway *infrastructure management* (IM) has been carried out since Roman times, paving the way for many of our current practices. The very term "highway" ties back to the elevated construction of Roman roads for drainage and to provide ground advantage for their relatively small armies given the wider geographic coverage of the Roman Empire. The Romans developed the use of linear referencing systems on their 55,000 mile road network.

TAM may be viewed in different ways. As the main differentiator, most authorities agree that TAM fundamentally brings economics (or, at very least, "business logic") as the core metric to infrastructure management decision-making. Asset Management (AM) can make a positive contribution to climate change policies by explicitly including environmental goods into the decision process (1). It can also help reduce agency operating budgets by making effective multi-year optimized budget decisions, as well as increasing efficiency

However, rather than reduce operating and environmental costs and risks, many first generation TAM projects were not successful. They in fact *introduced additional* costs and risks. Two key questions are: 1) why was there this common issue? and 2) how have second generation TAM projects improved?

A key field issue is that less successful first generation field experience with TAM has not been well written-up. There two main reasons for these failures:

1. *Mission and scope:* There was confusion in the field over exactly "what TAM is" and how it related to existing transportation agency business practice. In the US, until the late 1990s, the concept of IM was more common and better universally understood. The leading reference in the field at the time was so named (1). It is still this frame that at least some authorities prefer to work with.

2. *Implementation:* Many projects were either a) "*over-sized"* (i.e., sought to do too much at once or took on too much data detail), or, b) led by *inexperienced vendors* who did not have a successful record of successfully completing transportation agency-wide TAM projects.

Part A of this paper attempts to more fully address what turned out to be a basic but key question – the discernment of the relationship between "*transportation asset management"* (TAM) and "*transportation maintenance management*" (MM). **Part B** of this paper introduces a brief summary of the potential for the third generation of TAM that is the "green" TAM version and what may be realized in this area.

PART A: MISSION AND SCOPE OF ASSET MANAGEMENT

Attempt has been made to draw together a number of perspectives on TAM. These include in particular:

- US and Canadian transportation field agency experience (including through various workshop that have been presented in these agencies)
- The Transportation Research Board (TRB) Maintenance Management (MM) Committee and Conference
- Federal Highway (FHWA) Office of AM NCHRP publications
- AASHTO
- The International Infrastructure Manual (3)
- The AASHTO Transportation Asset Management Conference.

The lifecycle of an asset or facility from Planning to Reconstruction or Demolition (the "Highway Management Cycle") is shown in Figure 1.

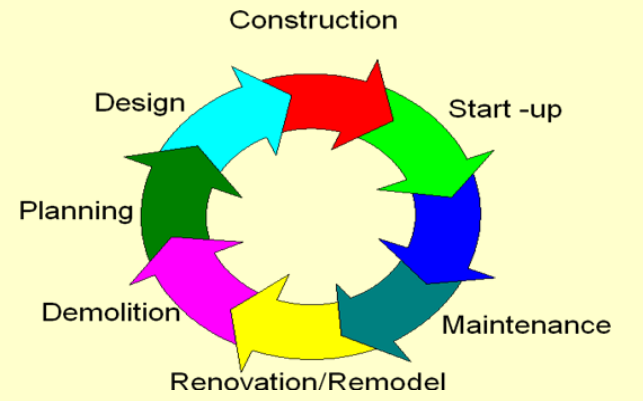


FIGURE 1: Life Cycle of an Asset or Facility

It is to be noted that "*Maintenance"* can involve both *Maintenance* and *Preservation*. Also, "Renovation/Remodel" can include Rehabilitation and Modernization.

There exists a corresponding cycle of highway (infrastructure) management. The basic cycle of highway management has been established for some time. It involves: 1) the setting of policies by senior decision–makers, 2) the setting of classifications and standards (traditionally done on an engineering standards basis), 3) field needs assessment, 4) a relation to available finance and resources, 5) the implementation of field maintenance and reconstruction, 6) performance and monitoring, and 7) a review of policies against the result of performance monitoring, as well as available resources and other external input.

Figure 2 represents the basic cycle of business that transportation agencies have been involved in for century or more. This cycle has perhaps been more formally recognized in other countries than the US, including in Canada.

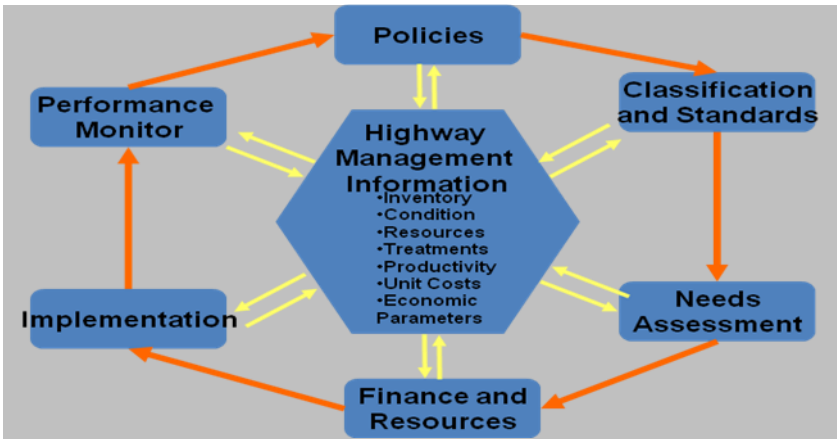


FIGURE 2: Highway Management Cycle: Asset and Maintenance Activities

The "*What IM does*" – the seven-step business process for IM -- is outlined below. This framework: a) describes what IM does, b) provides a good basis for comparison between MM and AM, and c) fairly closely relates to the standard "*highway management cycle*", outlined above. The seven business processes involved in the highway management cycle are:

1. **Asset Valuation:** Attributes a cost or a value to an asset
2. **Condition Assessment:** This activity typically allows an organization to understand the present condition against an established measure or the remaining life of its assets or components.
3. **Performance Measurement:** Policy objectives are translated into asset and system performance measures (PMs). These may be used for both day-to-day and strategic management.
4. **Alternative Analysis (AA):** It involves identifying available treatment options and carrying out evaluation of the effectiveness treatments or treatment packages.
5. **Trade-off Analysis (TOA):** It involves the better identification, evaluation, and investment decision-making across multiple assets. (In the US, this is sometimes called "scenario analysis" and leads to asset allocation). It enables the agency to be in a position to consider how to distribute assets between asset types).
6. **Program and Budget Review:** It allows different budget scenarios to be created by the user and budget limitations specified by year for the analysis period.
7. **Monitoring & Feedback:** This process monitors all prior stages and makes changes as a result. Feedback or changes are set as the result of monitoring the wider process.

Many of the steps above were not formally or explicitly completed or recognized historically, but they were nevertheless still key parts of the wider highway management process. They were often completed by local, "*engineering judgment and assessment".*

INTRODUCTION TO ASSET MANAGEMENT APPROACHES

Since 1999, when the USDOT FHWA Office of Asset Management was created, what are referred to as "AM" principles or approaches, for not just private sector but for the public sector, have been promulgated in the US (5). This initiative occurred some years earlier in other countries, such as New Zealand and Australia. It has been used regularly by the World Bank for the last 30 years, for example

supported by use of the Highway Development and Management System (HDM-4) (6). In the last 10 years there has been the publication of much useful conceptual literature in the field. However, with some agencies (not all), the exact relationship of MM and AM has not been fully clear. Clearly there are some differences in the field how concepts are understood and used. Clarifying and justifying the roles to transportation agencies has been a necessary and important task. Are the concepts synonymous? (Some in the field see them so). Are MM and AM different? Do they overlap? Are they a useful addition? Overall, how do they relate?

In the US, the use of *economics* as the "decision metric" is promulgated by the USDOT Office of Asset Management (6), as well as having gained established international adoption. However, both conceptually, and practically, this has only been partly accepted by state and local transportation agencies. This may be in part that the GASB Statement 34 ruling (a compilation of standards for financial reporting by state and local governments) provided a notable new requirement to report the *financial* status of transportation infrastructure assets. This occurred at the same time as the TAM initiative. There was thus some confusion what was *"financial"* and what was *"economic"* in TAM. While there was a common belief that economic and financial factors needed to be considered, few if any US DOTs have identified the need for a full-time economist on staff (the best case being a half–time economist). DOT engineers may have some nominal exposure to engineering economics, but relatively little practical training or experience in such.

Part of the effort and process to place AM *(not institutionally well-established)* next to MM (*long institutionally well-established*) has been witnessed through the efforts of the AASHTO Planning Subcommittee on Asset Management. As noted in recent committee minutes:

> *In order to fulfill its mission, the member departments need a common definition for asset management. What follows are the current definitions of asset management. It is motioned to combine these meanings into a single definition for use by the entire transportation community and to replace any previous descriptions.*
>
> *AASHTO's Asset Management Guide definition:*
>
> *Asset Management is: A strategic approach ... It focuses on … business processes for resource allocation ...*
>
> *FHWA, Office of Asset Management definition:*
>
> *Asset management is a systematic process… It combines engineering principles with sound business practices and economic theory…*
>
> *Highways Subcommittee on Maintenance Definition (July 2005):*
>
> *Asset management is a strategic and systematic process of maintaining, upgrading, and operating physical assets effectively throughout its life cycle ….*
>
> *Motion New Definition to Supersede Previous Descriptions*
>
> *Transportation Asset Management:*
> *Transportation Asset Management is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well defined objectives.* (8)

This latter joint definition clearly is a major step forward in amalgamating the other definitions. It attempts to be comprehensive. However, it still has some partial possible limitations in conveying core differences and sense. For example, at least compared to how AM has been conceived and developed around the rest of the world, it does mention "*business*". But it does not explicitly underlie the key role of *economics* as the prime decision rubric or tool for AM. This is one area where the US and the rest of the world are taking a slightly different approaches to AM. Additionally, the definition does not include *Preservation*, an accepted asset management strategy which extends the life of a transportation asset, differing from Maintenance, which keeps the asset in a serviceable condition.

MAINTENANCE MANAGEMENT: Definition

An overview is provided here in terms of data managed and the characteristics of the business process.

Maintenance Management Data:

The full set of data for MM is related to all the physical assets that the DOT owns and maintains. It may include pavement, street lighting, crossings, bridges, median strips, traffic controls, road surface, slopes, etc.

To support the publication *Guidelines for Maintenance Management Systems* (9), NHI developed a training course *Principles and Practices for Enhanced Maintenance Management Systems* (10). A survey on current MMS activities in US state DOTs was also undertaken. This included data on the MMS items collected, frequency, and whether the agency had an MQA (Maintenance Quality Assurance) and LOS (Level of Service) program.

MM data may be collected and analyzed down to the level of detail that is felt appropriate in a given agency. There is wide variation across states over what *level* of MM data detail is collected. A Sign Engineer for example may have an *operational* database of eighty items on signs (e.g., sign type, size, thickness, material, manufacturer, install date, location, condition, bolt types and sizes, inspection date, inspection results, etc.). Or, it may be more high-level, with perhaps just four items (e.g., class or unit type, location, install date, condition), if for example the database is set-up so that only *decision-related management* information is contained and the database is normalized so that key information is stored only once in look-up tables. A common field issue has been to gather more MM data than may be necessary for decision-making or parts ordering.

Maintenance Management Characteristics:

Key example activities for MM are in brief:

- Collect data on assets such as pavements, guardrails, etc.
- Create Work Orders, such as shown below
- Record "outputs" in terms of work accomplished
- Do staff resource planning
- Provide various Maintenance work reports
- Do wider region or time period reports.

A high-level summary of MM characteristics is provided below in Table 1.

TABLE 1. Summary of Maintenance Management Characteristics

CATEGORY	MAINTENANCE MANAGEMENT CHARACTERISTICS
Definition	• Tactical activity to create day-to-day work orders • Strategically, ensuring that the proper maintenance is applied at the proper time in the cycle of infrastructure • Program of activities to enable a transportation system to continue to perform at its intended level; comprises a range of services in preservation, cleaning, replacing worn or failed components, periodic or unscheduled repairs and upkeep, motorist services (incident response, hazardous materials response), snow and ice control, and servicing of traffic devices and aids; does not add to structural or operational capacity of an existing facility. (FHWA Office of AM definition)
What is Managed?	Materials, people, equipment, budgets, work orders
When?	Daily, weekly, monthly… yearly operation
What it Does?	Assign activities, track goods and materials, create work orders, etc. Capture work performed at project level generated by other AM systems, such as PMS, BMS, etc., to" close the loop"
Who Does it?	Key focus: typically, districts in a DOT, or local road agencies
How?	Budgets historically set by Chief Engineers decision …and/or, … the annual budget "food fight"

Maintenance Management Systems (MMS) carry out the MM process. Best practices for MMS are that work activities/treatments/projects that are generated from other AM systems (such as Pavement and Bridge) are also scheduled and captured as "completed" through the MMS (i.e., there is *process integration*). Thus, these activities then may be further tied back to a Pavement (PMS) or a Bridge Management System (BMS), where the performance of the asset (such as life extension) can be more fully analyzed. This is why it is important to distinguish between: a) "*Generation 1*" traditional or old "stand alone" MMS (which were largely cost accounting systems), and b) *"Generation 2",* with modern MMS, they are fully integrated with other AM, ERP, financial, GIS systems and other agency systems (10). With regard to "*What MM does*", using the seven-step classification given earlier, a summary of MM activities is made in Table 2.

TABLE 2. Summary of MM Activities

	PHASE	ACTIVITIES
1	**Asset Valuation**	Not typically expressly done
2	**Performance Goals & Measures**	Largely Engineering focused. Equipment, resources, efficiency. Some Safety, performance targets drive activities or tasks
3	**Condition & Performance Assessment**	Inspection based
4	**Alternative Analysis**	Undertaken on a qualitative basis; B/C used for Fed; May manually generate alternatives
5	**Trade-off Analysis**	Performed by an executive on a program basis from knowledge and experience
6	**Program & Budget Review**	Management annual budgets, thru to monthly monitoring programs, etc
7	**Monitoring & Feedback**	Appropriate data access levels across programs; continuous improvement,

		interfaced with other AM and financial systems

TRANSPORTATION ASSET MANAGEMENT: Definition

As with MM, this is provided here in terms of data managed, overall characteristics and a summary of the overall business process. In fuller terms, TAM may in short be regarded as:

- A change in *philosophy*
  - That is, to a more *comprehensive and long-term* view, which is proactive and deliberate
- A *process*
  - Investment choices, tradeoffs, decisions
  - Organizational roles and responsibilities
  - Improved horizontal and vertical communication
- A set of technical *tools*
  - Management systems
  - Integrated data
  - Specialized methods

The key tenet of AM is that generally, a series of Preservation treatments applied early in the deterioration curve of an asset over its service life can be accomplished more cost-effectively than Rehabilitation or Reconstruction strategies when the asset is badly deteriorated. More specifically, AM provides the proactive decision of what treatment is done to which asset at the determined appropriate time. Generally, this is sooner rather than later, but the point here is that proactive decisions are more efficient than reactive responses to managing assets.

Also, user costs such as vehicle damage or delay must be considered within a Life Cycle Cost Assessment (LCCA) model. Constrained budgets must be considered as well. Data needs to be captured and analyzed to determine when the optimal time is to undertake a particular treatment or strategy to get the most life extension based on LCCA.

Transportation Asset Management Data:

Two key characteristics of the data used by the TAM process are:

1. *Data Reduction:* TAM is likely to be undertaken at a reduced or simplified *data* level, than that typically used in the MM process. For example, in AM terms it is possible that all Signs will be analyzed in groups or perhaps even "as one mega sign" (i.e., at the network level). This may be justified because all the signs in the state, at least in replacement costs terms, *may* only be equivalent in cost to say one mile of highway. (*Note:* In a more detailed fuller TAM analysis, where Safety and other factors are more fully considered, the analysis might include Signs down to the individual level. It has turned out that for example spending $500 on one chevron sign at a 90-degree bend on a rural road is actually one of the very *most* cost effective AM decisions that can be made, where a wider set of economic and safety criteria are used).

2. *Enterprise Structure:* TAM will require, or at the very least benefit from, the creation use of an *agency data schema* (i.e., with formal transportation data model and data dictionary) as AM (when fully implemented) is essentially concerned with carrying out enterprise-wise analysis of projects across geographic and functional areas. This requires that data (even in a reduced form) must be

provided on a "semantically consistent basis" (e.g., a road's worth of data in District 1 means the same as the supposedly equivalent data from District 7). A high-level example is shown in Figure 3.

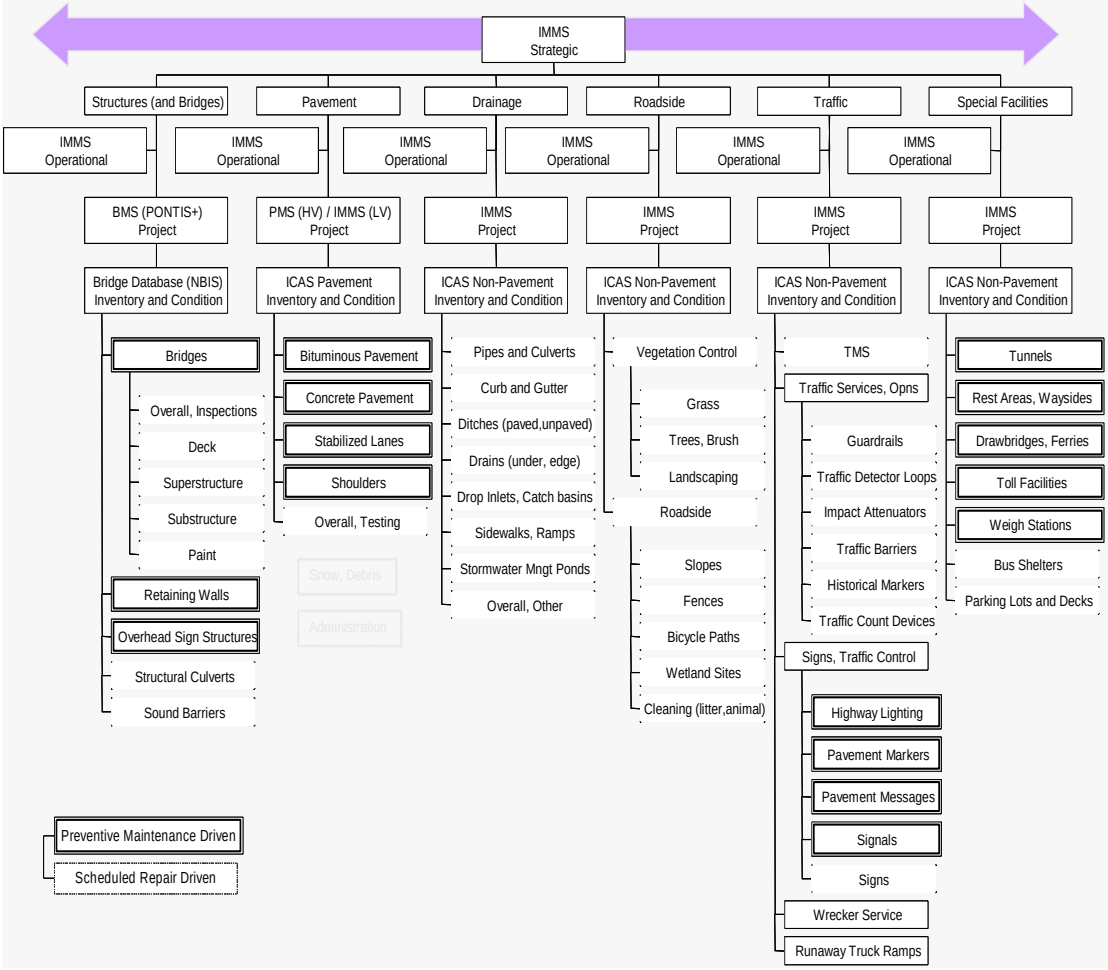
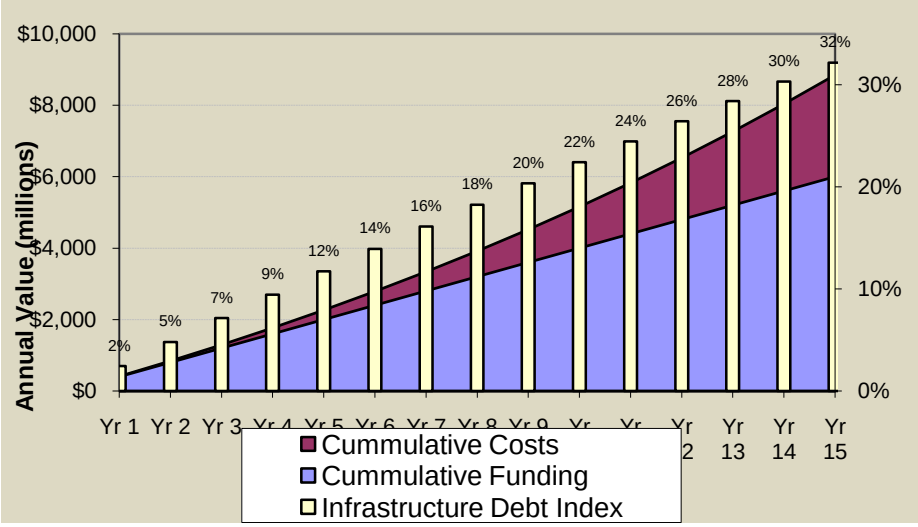


FIGURE 3. Transportation Data Schema

The key goal of the transportation decision-maker is to use available resources as best as possible to minimize the likely "*Infrastructure Debt Gap*", shown below in Figure 4.

FIGURE 4. Transportation Infrastructure Debt



An example of a typical key decision output for AM is shown below in Figure 5. A key end product is providing worked analysis to decision-makers on trade-offs between various project "packages".

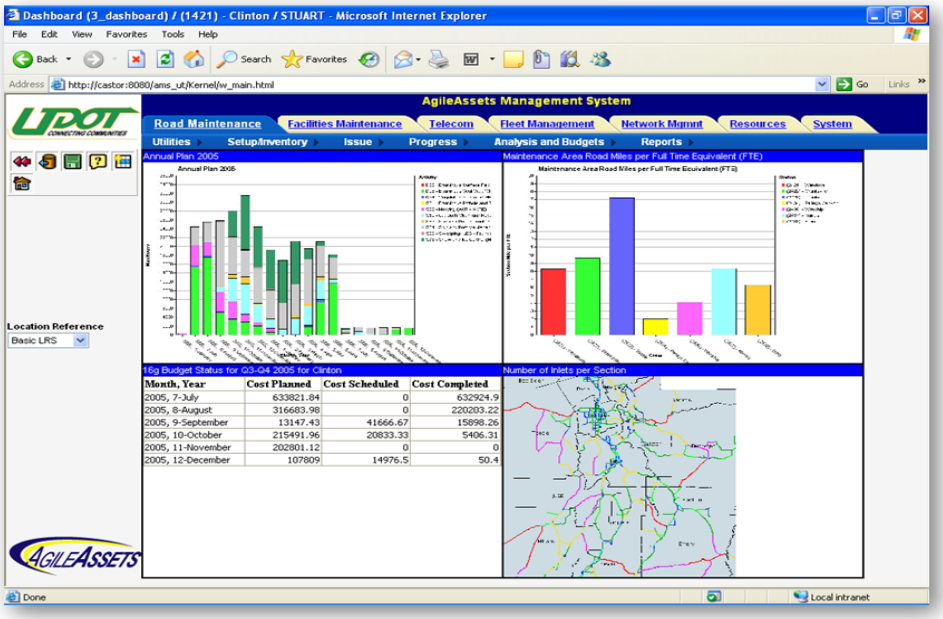


FIGURE 5. Asset Management Decision Framework

A summary of TAM is given below in Table 3.

TABLE 3. Asset Management Characteristics

CATEGORY	AM CHARACTERISTICS
Definition	Long-term, corporate decision-making, more pro-active than reactive Performance-based decision-making Long-term measurable performance indicators More relevant corporate measures
What managed?	Budgets at high-level; condition of assets
When?	Annual
What it does?	Economic optimization against stated organizational performance targets our outcomes
Who does it?	For senior management
How?	Economic tools

On the same basis as was earlier undertaken for MM, a summary of AM Activities is given across the seven infrastructure management phases (see Table 4).

TABLE 4. Asset Management Phases

	PHASE	ACTIVITIES
1	Asset Valuation	Deteriorated financial value or modified replacement cost
2	Performance Goals and Measures	Engineering (e.g., technical measures for asphalt) Safety VOC (vehicle operating costs) Environmental
3	Condition & Performance Assessment	Include economic measures
4	Alternative Analysis	Generate alternatives Math optimization
5	Trade-off Analysis	Use NPV/Cost or other economic measures
6	Program and Budget Review	Management of program focused on annual budgets, thru to monthly monitoring programs
7	Monitoring and Feedback	Annual and constant update. Data across all areas

Many potential benefits are ascribed to transportation AM. To date, these may be summarized to two main generic areas:

- **Optimal Economic Allocation of Resources:**
  - ***Improved Stewardship*** / custodianship of public assets; Financial Management; Economic assessment of various tradeoffs; Reduce short-and long-term costs; Tie resource allocations to savings from replacement, etc.
- **Information:**
  - ***Improved Transparency*** in Decision Making; Communication; Improve documentation of decisions; Improve information and access to information; Enhance knowledge of inventory and asset value; Improve information on return on investment and value of investments, etc.

MM and AM -- CONTRAST AND CONCLUSION

A summary comparison contrasting MM and AM is made below in Table 5. In short, in high–level business process terms, TAM:

- builds on data *from* MM activities
- may provide budgets *to* MM.

Two overall options for a high-level framework are shown below in Figure 6. Both may exist, but give different perspectives. In the first AM is seen as the *overall framework* which draws on MM, Pavement Management, Bridge, etc. AM however may only be viewed as "a delta" to MM (i.e., adding the management analysis tools, overall management structure, etc.). As much as 95%+ or more of the source data may lie in the MM and the bulk of day-to-day activities, transactions and processing will occur there.

TABLE 5. Maintenance Management and Asset Management Comparison

CRITERIA	MAINTENANCE MANAGEMENT	ASSET MANAGEMENT
Primary Goal	Infrastructure Performance	Economic performance of assets
Level of Data	Detailed Task-level	Higher-level Project-level
Principal Activities	Financially cost'ed, preservation, cleaning, replacing, etc.	Economically cost'ed Preservation Maintenance Replacement
Add (highway) Capacity	No	Yes
Principal Analysis Time Focus	1 (to 3) years	1 to 10 years (or more)
Staff Focus	Operational, District level	Senior management
Principal Output	Managed tasks	Optimal economic package of projects

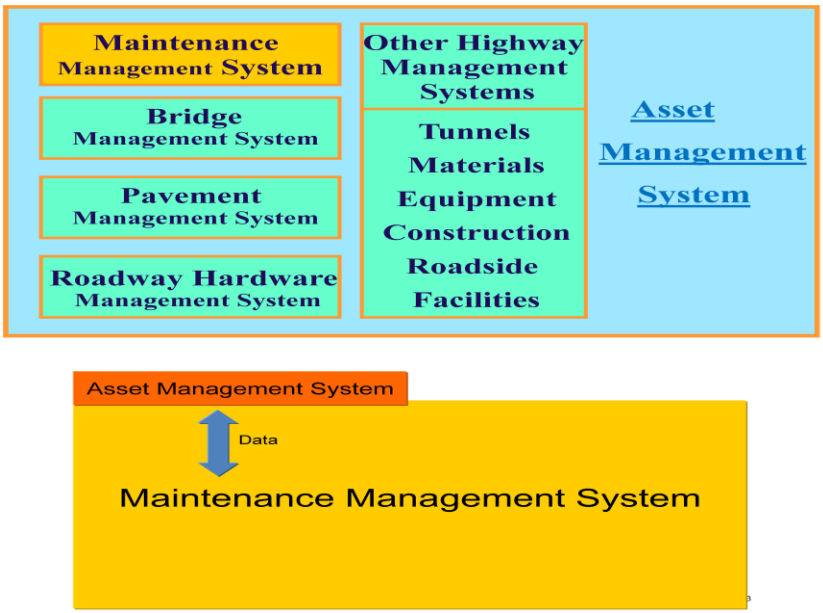


FIGURE 6. Asset Management Wider Framework

Figure 7 is another summary cut at the same concept. In short, AM activities occur at the thin top of the pyramid, drawing on the much larger, lower, operational tier.

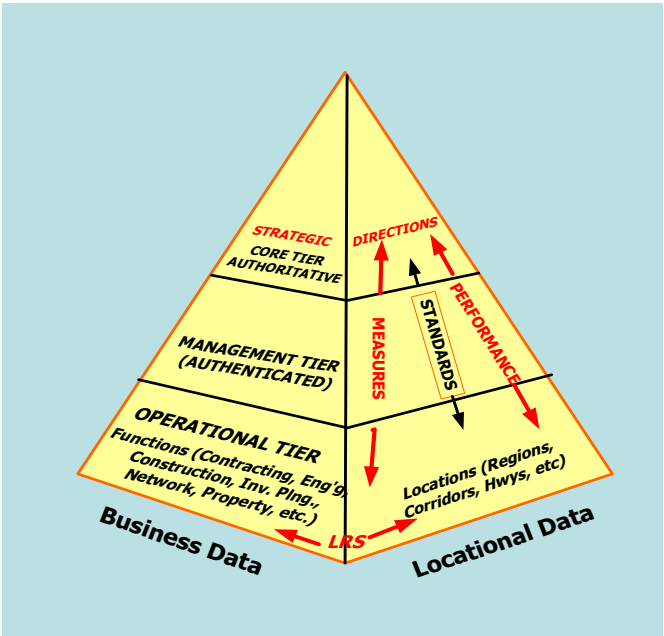


FIGURE 7. Asset Management Pyramid

In practical reality, there are trade-offs an agency may wish to make in setting up AM and MM analysis. There is a good case for: a) having a MM system in place, and b) some years of deterioration data developed and assembled, *before* fully building out the AM function. The converse argument – and what

has actually occurred in a number of agencies – is that the wider IM effort got so buried down in the detail of fine building the MM data function, that no AM was done. However, AM did not need data at such level of data granularity, anyway. Figure 8 summarizes this trade-off.

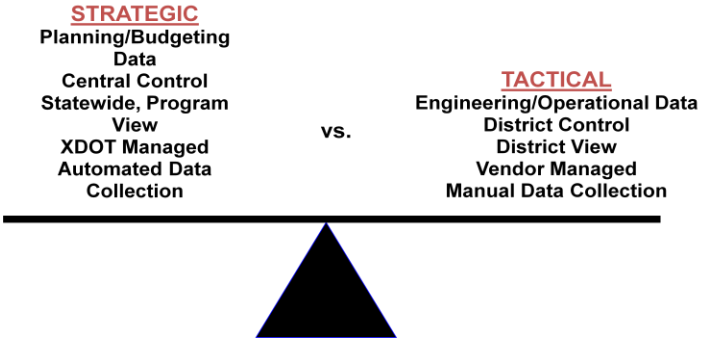


FIGURE 8. Asset and Maintenance Management Trade-off

Three of the alternative strategies for integrating MM and AM are summarized in Table 6. From experience to date, the approximate cost and time to implement applications to support these processes is indicated.

TABLE 6. Possible MM and AM Strategies

	"LEVEL"	AM FUNCTION-ALITY	MM FUNCTION-ALITY	DATA WORK	APPROX EXAMPLE COST	APPROX TIME
1	**AM HIGH-LEVEL DATA APPROACH**	Strategic	Use existing	Use existing	Low. Perhaps in DOT $0.5 to $2m	6 months to 1 year
2	**MIXED APPROACH**	Strategic and some operational/tactical	Separate MM	Some limited data collection and clean-up	Medium. Perhaps $1 to $3m	1 to 3 years
3	**MM FEEDS AM (most complex/complete)**	Strategic and much operational/tactical	Custom work, MM and AM integrated	Significant data clean-up, aggregation & other work	High $1.5 to $10m	2 to 5+ years

The current situation for at least many US DOTs is that there is primarily a heavy reliance on conventional MM approaches.

Part B: "Green TAM"

The discussion surrounding environmental impact has clearly moved from the margins to the core of transportation agencies, as well as the lifestyle of the taxpaying public. Initially viewed as a luxury for those who were prepared to pay hard-earned wages for a better world, today's "green" initiatives include very practical measures that allow agencies and tax payers alike to improve their role as environmental custodian and financial steward of their financial resources.

This societal recognition joined with practical engineering solutions provides energy and motivation for the transportation agency to lean forward in measured, deliberate and productive ways to adopt green-friendly policies, methodologies and technologies. Similar to family households that have moved from incandescent light bulbs to compact florescent light bulbs, provincial and state transportation agencies have an opportunity to extend their view and make better informed decisions regarding both economic and environmental impact: slightly higher investments today should be managed against longer-term payout periods.

We see that the current move in place from MM to TAM may (and should) give way to "*third generation"* – that of "green TAM". There are limited examples of this in place to date. However, aspects and key concepts of "green TAM" are emerging. The purpose here is to identify some key opportunities for improved policies that yield better environmental decisions while managing available budgets. Similar to trade-off analysis between pavement and bridge assets, TAM tools allow agencies to consider environmental impact and the positive investment return specific treatments provide.

Some of these examples include:

1. *Basic good:* Doing TAM itself is green if leads to the more efficient use of:
    a. Materials
    b. Energy, and
    c. Labor

    required to maintain highways and other transportation infrastructure. TAM should create a lowered footprint in supporting transportation infrastructure.

2. *Environmental economics:* Green TAM involves (allows) placing economic costs on both physical goods as well as environmental goods associated with wider transportation activities. For example, including quality of air or water as a discrete metric in decisions models allows decision-makers the ability to view their role more holistically. [The point here is that environmental factors *can* be included. The decision of *whether* they are is decision for the policy maker.]

3. *Standard setting:* While placing economic costs on environmental goods in North America is a less established practice as compared to standards from peer countries, this practice does provide some important guidance. Only in more recent times have economic values been minimally accepted in agency/field use for other "soft" costs, such as for example travel delay. It will likely require central governmental leadership, or at least some independent but well recognized national agency to create standards for such that will be more readily adopted. Such standards do exist for some economic measures (e.g., value of a highway life saved).

4. *Wider Agency Context:* Transportation agencies are large organizations with many people, offices, budgets and activities. Green TAM can best be realized and achieved by a wider strategy

of operating the agency in a green fashion, and cannot best be achieved in isolation --- as asset management (and operation) is really the core mission of the agency. For example, "operating more green" might involve less physical travel for meetings, more use of video conferencing, use of highway digital imagery to cut down site visits, better coordination of maintenance activities, further recycling of materials, operating buildings with less heating and cooling, use of energy efficient lighting, etc. Agencies will likely need to appoint a "green czar" to facilitate the shift of routine activities in modest ways to support green policies.

5. *Programmatic Pushes/Compliance.* TAM can help with particular green program "pushes," or compliance measures to that ensure a specific policy is measured and fully implemented. For example, currently TAM software is used for the State of Texas Comptroller of Public Accounts office to monitor the alternative/synthetic fuel use and to track compliance with mandated agency and state standards. TAM can keep track of parts and equipment so that they can be better utilized and recycled at appropriate life cycle points.

6. *Asset Tracking.* Detailed tracking of assets – for example, signs --- may in particular mean that less end up in landfills. Retirement strategies can be associated (refined, adjusted, etc) with asset classes through to individual assets. Reclamation of material from material in assets can be monitored and managed, thereby studying and improving techniques to improve ease of asset reclamation and recycling.

7. *Usage Tracking:* Similarly, the use of materials should be tracked and more efficient distribution and application processes be refined and adjusted. Operationally, this provides significant economic improvements in lowing required inventory on-hand, number of distribution points, etc. In fact, Pinellas County, Florida had an independent financial audit to study the impact of their asset management policies and system, and this audit revealed total savings of US$12MM in the first year. US$6MM was hard financial costs, and a second US$6MM was in shifting usage and other soft benefits.

Conclusions

In summary,

1. Traditional "*worst first*" MM strategies should transition to Preservation and Least Life-cycle Cost. An AM approach should focus on timely/strategic Maintenance and Preservation to extend the service life of the asset almost indefinitely.

2. Transportation IM challenges are significantly growing at present. Therefore, it is important that practitioners have a common wider frame of field reference. Concepts and practices that have developed elsewhere need adapting to national circumstances. Frameworks for doing AM and MM should continue to be evolved refined until they best fully fit exact North American practice, conditions and field needs.

3. An agency migration strategy should be in place from MM business practices, through to TAM business practices, through to "green TAM".

4. Contemporary TAM and the corresponding asset management systems are powerful enablers for executing agency-wide environmental (Green) policies, and receiving their corresponding financial benefits for the taxpayer.

The vision moving ahead is in Generation 2 for MM to be fully merged with AM. Then in Generation 3 environmental and wider societal costs are included in the TAM evaluation. This is summarized in Table 7, below.

TABLE 7. Current and Future Transportation Infrastructure Management Practices

Generation TAM	***"Generation 1"***	***"Generation 2"***	***"Generation 3"***
Period	**PAST AND MUCH CURRENT – MM**	**BEST PRACTICE CURRENT TAM**	**FUTURE "GREEN" TAM**
Modus operandi	Worst-First	Least-Lifecycle cost	Least-Lifecycle agency and with environmental cost
Principal Strategic Focus	Program Focus (Silos)	Network focus	Network in environmental context
Operational Focus	Event	Asset	Assets in environmental context
Management Focus	Short-term Budget Mgmt	Long-term Asset Mgmt	Long-term asset and evironmental mgmt
Decision cycle	Budget Cycle Planning (e.g., annual)	Real-time, Ongoing Planning	Real-time, Ongoing Planning
Inspections	Routine	Sampling	Sampling
Measurment Rubrics	Budget	Performance	Asset performance balanced with env impact
Valuation	Project Financial	Managerial	Societal
Process	Static	Continuous Improvement of Model and Process	Continuous Improvement of Model and Process with societal perspective

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