MARICOPA ASSOCIATION of GOVERNMENTS

Roadway Operations and Maintenance Cost Study

DRAFT REPORT

April 2012

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Prepared for

MARICOPA ASSOCIATION of GOVERNMENTS

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Executive Summary

The purpose of this study was twofold; (1) to develop typical annual operating and maintenance (O&M) cost factors for application at a regional level, and (2) to survey and review current pavement management practices of Maricopa Association of Governments (MAG) member agencies and identify O&M challenges they face. Nearly all MAG member entities were interviewed during the data collection portion of the study. Data gathering efforts relied primarily on the information provided and direction given by those interviewed. The results of the interviews were used to generate:

- Annual O&M cost factors and summary matrix;
- Interactive O&M cost estimation model;
- MAG member agency pavement management summary; and
- Summary of key pavement management challenges faced by the MAG member agencies.

Many of the MAG member agencies experience similar O&M challenges. Many agencies struggle to find consistent funding and are challenged by rapidly growing networks, which have not been met with equally fast-growing budgets. Various pavement maintenance approaches are employed, but most agencies typically address the most high-traffic roadways first, and then turn their attention to less traveled roadways.

Smaller communities tend to perform pavement maintenance as funding permits, without a highly structured preventative maintenance program or routine. They typically have lower available budgets; however, they often have less dense/developed infrastructure to maintain. Many use all of their O&M funds for a large project to obtain economical pricing, and then defer non-routine maintenance until funding is available again.

Though there are variations in pavement rating methods, frequency, and software used, there are two primary pavement maintenance approaches used by agencies. One approach, used by the majority of agencies, is to maintain their networks by frequently applying minor surface treatments to postpone more significant maintenance activities. The other approach, used by fewer agencies, is to seldom use minor surface treatments and take a ”hands off” approach until the pavement is over ten years old, at which time they apply a more aggressive treatment.

Differing target levels of maintenance and average age of infrastructure cause significant variations in O&M costs. For example, extensive landscaping and aging pavement (network average age greater than 15 years) would require a much higher maintenance budget. On average, pavement maintenance for “mature” networks can cost approximately two to three times as much per lane mile as a “new” network.

An Interactive Cost Factor Model was developed using composite maintenance costs from the MAG region based on roadway functional classification and facility characteristics. The model provides menus for a variety of factors, such as street lighting and landscaping, that would allow the user to develop a composite roadway O&M cost. The costs and categories can be adjusted in the model to adapt it to changes in O&M costs. A matrix of typical O&M costs was developed for use in the O&M cost factor model, and is presented on the following page. Costs are representative of annual expenditure patterns during 2007 – 2011.

Operations and Maintenance Cost Reference Matrix[3]		
ITEM:	ANNUAL COST (PER LANE MILE):	ANNUAL COST (COMPLETE NETWORK) [4]:
FREEWAYS:		
Rural Freeways:		
ADOT Rural O&M Cost	**$5,409.01**	**-**
Urban Freeways:		
ADOT Urban O&M Cost	**$26,187.73**	**-**
ITEM:	ANNUAL COST (ARTERIAL ONLY):	ANNUAL COST (COMPLETE NETWORK) [4]:
ARTERIALS:		
Rural Arterials:		
MCDOT Rural O&M Cost	**$6,441.82**	**-**
Urban Arterials:		
Concrete[1]	**$908.44**	**$1,514.07**
General[1]	**$1,723.25**	**$2,393.40**
Landscaping[2]	**$10,283.67**	**$10,283.67**
Pavement[1]	**$4,455.28**	**$7,425.46**
Signals[2]	**$10,663.64**	**$10,663.64**
Signing[2]	**$1,056.68**	**$6,493.03**
Storm Drains[2]	**$1,860.69**	**$3,101.15**
Street Lights[2]	**$3,480.17**	**$20,875.07**
Striping[1]	**$1,323.79**	**$2,074.61**
Sweeping[2]	**$3,920.34**	**$8,753.44**

(1) - Cost of Maintenance Item per Lane Mile
(2) - Cost of Maintenance Item per Centerline Mile
(3) - Based on average available reported budget information (2007-2011)
(4) - Complete network includes the O&M costs associated with arterials plus collector and local roads

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1. Project Purpose

Operating and maintenance (O&M) costs are a significant element of the total cost of providing roadway services. Inadequate maintenance can lead to increased facility life cycle costs and result in the inefficient use of limited resources over the long run. Reasonable estimates of O&M costs are needed to ensure that the planning process is recognizing the full cost of providing roadway services and is allocating available resources appropriately.

The purpose of this study was twofold; (1) to develop typical annual O&M cost factors for application at a regional level, and (2) to survey and review current pavement management practices of Maricopa Association of Governments (MAG) member agencies and identify O&M challenges they face. Nearly all MAG member entities were interviewed during the data collection portion of the study. Data gathering efforts relied primarily on the information provided and direction given by those interviewed; the results of the interviews were used to generate:

- Annual O&M cost factors and summary matrix;
- Interactive O&M cost estimation model;
- MAG member agency pavement management summary; and
- Summary of key pavement management challenges faced by the MAG member agencies.

O&M Cost Factors
The purpose of developing average annual O&M cost factors is for MAG to apply the results in the transportation planning process to evaluate sub-regional and system-level alternatives, and to develop regional long range financial plans.

Pavement Management Survey
The purpose of conducting the pavement management survey was to provide an up-to-date summary of pavement management practices in the region, and to gain an understanding of the pavement management challenges typically facing the agencies in the MAG region.

2. Project Approach

The project commenced with data collection in May 2011, which included reviewing Capital Improvement Programs (CIP)s, O&M budgets for the agency roadway/street O&M departments, and scheduling interviews to collect additional data.

Interviews were conducted with nearly all MAG member agencies. The interviews included three major questions:

1. Please describe your pavement management approach.
2. What are the major challenges your agency is facing with pavement management/ maintenance?
3. What is your agency's total annual expenditure on roadway operations and maintenance?

In order to discuss these three major issues, eleven interviews were conducted via teleconference and three were conducted in-person. An additional twelve in-person interviews were conducted to address the three issue areas identified above, as well as to obtain more in-depth information relating to the agency's O&M budget. This typically included a review of the published O&M budget, as well as the CIP, if maintenance activities were included in that document.

In-person interviews were conducted with the following agencies:

- Arizona Department of Transportation
- Maricopa County
- City of Avondale*
- Town of Buckeye*
- City of Chandler
- City of El Mirage*
- Town of Gilbert
- City of Glendale
- City of Goodyear
- City of Mesa
- City of Peoria
- City of Phoenix
- City of Scottsdale
- City of Surprise
- City of Tempe

*Discussion based upon three questions listed previously

Teleconference interviews were conducted with the following agencies:

- Town of Apache Junction
- Town of Carefree
- Town of Cave Creek
- Town of Fountain Hills
- Town of Gila Bend
- City of Litchfield Park
- Town of Paradise Valley
- Town of Queen Creek
- City of Tolleson
- Town of Wickenburg
- Town of Youngtown

In general, the agencies interviewed do not organize or budget their O&M programs the same way. Each agency has different assets, with varying ages and levels of complexity. As the purpose of the study is to generate regional costs and not agency specific costs, all data has been presented without attribution. Municipalities were divided into two groups with similar characteristics. Group 1 includes nine of the agencies that were interviewed in person; Group 2 includes all other municipalities interviewed. The Group 1 cities and towns own and maintain 85% of the centerline miles in the MAG region and represent 91% of the population.

Assemble O&M Cost Factor Data

Once data collection was complete, the data was reviewed to assure an agency's entire roadway O&M budget was captured for the study, even those not necessarily part of the street maintenance department. For example, if discussion with an agency revealed that O&M activities such as resurfacing, including pavement mill and overlay was included in the CIP, it was added to the maintenance budget. If other roadway maintenance costs were part of another department's budget, such as roadway landscaping and storm drain maintenance, they were added to the agency's reported roadway/street O&M cost. In addition to capturing all costs associated with the maintenance activities themselves, agencies were asked for all staff costs associated with the roadway/street maintenance. Maintenance activity costs and frequency were obtained and processed into an annual cost factor to be included in the overall roadway O&M composite cost. After compilation, the data was sorted by category (as

reported by the agency) and arrayed to determine a typical cost per lane mile or centerline mile, as applicable, for each budget category item.

O&M Cost Factors

Roadway O&M cost factors in this Study include rehabilitation, preservation, and routine maintenance. Cost factors depend on roadway functional classification, and include the following:

- Concrete
- General
- Landscape
- Pavement Maintenance
- Signage
- Signals
- Storm Drain
- Street Lights
- Street Sweeping
- Striping

Maintenance costs specifically associated with dirt road maintenance were excluded from the cost factor estimation, as the intent is to develop O&M cost factors for paved roadways. Cost factors include contracted labor and projects, as well as the agency's staff and supplies/vehicles. By including both agency direct costs and contracted costs, the "complete" O&M cost was obtained, and adjusts for agencies that use outside contractors for their O&M needs or perform maintenance "in-house."

Some agencies combine related cost items (e.g. signals and street lights) into a single category for ease of fund management and cannot separate them. Others have special taxes and funds to cover specific maintenance items, such as street lights. Budget costs presented in the matrix and used in the model represent the complete cost associated with a maintenance activity, including these special district costs.

Many maintenance activities become more intensive as a network ages and thus require more funding and staff (such as pavement maintenance). Data collected from the member agencies included varying network ages and levels of complexity, and thus represents the MAG region as a whole.

Concrete – Many of the reporting agencies capture costs in this category. It typically represents sidewalks and ADA ramps, as well as miscellaneous concrete costs. The majority of this expenditure was typically used to update ADA ramps to current standards.

General – Several agencies use "General" as a "catch all" for minor miscellaneous costs. Some agencies did not have this particular category, but had several others with small budgets allocated to each individual function. In these instances, these items were combined into a General category for that agency, with the intent of capturing all roadway O&M expenditures in the model. These types of costs may include general operations, right-of-way (R/W), pest control, R/W coordination, and other miscellaneous categories.

Landscape – Reflects agency costs to maintain landscaping in medians and along the roadway R/W. This typically includes weed control, trimming, irrigation (water and systems), and other related costs. Many agencies include this cost with park landscape maintenance; if the costs could not be separated from another budget item, they were not used in the model. Agencies reported that they do not maintain landscaping in residential areas or along collector roads, as typically homes and businesses maintain these areas.

Pavement Maintenance – Reflects all of an agency's expenditures on pavement maintenance, including rating the network, materials, equipment, and contracted labor. The freeway cost can be adjusted to include rubberized asphalt maintenance, although this item is not currently funded. Pavement maintenance costs vary greatly between new and mature areas within the MAG region. As previously mentioned, there are frequent and infrequent maintenance approaches used in the MAG region. This cost represents a composite of both approaches and new and mature networks.

Signage – Includes costs typically associated with sign replacement, including routine replacement due to age/sun, vandalism, and theft.

Signals – Includes signal maintenance for the signals themselves, electricity, cabinets, and ITS. Signal maintenance was only applied to arterials.

Storm Drain – Item is intended to include storm drain pipes, basins, and pump stations associated with roadway R/W; however, some agencies included these costs in their landscaping costs. In these cases, data was back checked but not included in unit cost formulation.

Street Lights – Includes costs to maintain street lights on arterial, collectors, and local roads. If a special street light improvement fund was established within a community, it was included in this cost.

Street Sweeping – Includes street sweeping costs for arterial, collector, and local roadways. Sweeping frequency varied among agencies, but was averaged to a per centerline mile cost rather than a per occurrence cost, which adjusts for this variation. Agencies typically could not provide the total length of medians, so the arterial cost includes arterials with and without medians. Since both are included for all reporting agencies, the unit cost is indicative of a network wide average sweeping cost, which takes into account medians, but does not provide a separate cost.

Striping – Includes roadway striping, which typically involves arterial and collector roads. Agencies interviewed typically do not stripe local roads. Many agencies include signing and striping in one budget item; if the two could not be differentiated, the data was used as a check against the costs reported by other agencies.

These costs were then organized into a matrix used to populate the model.

Categorizing O&M Cost Factors

The costs were organized by roadway functional classification and the urban/rural designation. In the matrix, model, and this summary report, the urban designation was developed from data obtained from the in-depth O&M budget discussions. Typically, freeways and arterials are the primary roadway types under regional consideration. However, the model was developed with the ability to include costs for collector and local roads based upon data collected from the Group 1 budget discussions. The data was processed into roadway lane-mile unit costs, providing the ability to customize unit costs based on a facility's number of lanes. Some data, such as signals, was developed into a cost per centerline mile.

Maintenance Approach Considerations

O&M strategies differ across the region, presenting a challenge for developing regional cost factors. Even though an asset may be very similar between agencies, the strategies employed for maintaining

that asset may be very different. For example, one agency may prefer more frequent, but less intrusive asphalt pavement surface treatments for rehabilitation that decreases the need for major reconstruction. One such plan would be:

- Fog seal at 3, 6, and 9 years (all roadway functional classifications)
- Arterial roads – microseal at 12 years and every 5-7 years thereafter, up to 20-25 years total pavement life, then mill and overlay
- Local roads – slurry seal at 15 years, then every 5 years, with 2-3 slurries prior to mill and overlay, up to 25-30 years total pavement life, then mill and overlay

Another agency may prefer less often, but more substantial rehabilitation efforts. An example of this type of plan would be:

- 10-12 years after construction – slurry seal
- 7-8 years after slurry seal – slurry seal again
- 7-8 years after 2nd slurry seal – mill and overlay

It should be noted that many agencies report needing to mill and overlay at 12-20 years after a roadway is constructed, often depending upon the quality of the initial construction and roadway section. Also, most agencies reported crack sealing as needed.

Differing target levels of maintenance and average age of infrastructure cause significant variations in O&M costs. For example, extensive landscaping and aging pavement (network average age greater than 15 years) would require a higher maintenance budget. On average, pavement maintenance for "mature" networks costs approximately two to three times as much per lane mile as a "new" network.

Many of the smaller agencies do not track their expenditures by category and, due to budget restrictions, have typically adopted a budget based maintenance approach, with only the most critical items getting addressed as funding is available.

O&M Cost Limitations

Few agencies in the MAG region have detailed O&M expenditure data for freeway and rural arterials to develop unit cost factors. In some cases, these agencies have already developed their own net unit cost factor, which includes all maintenance activities, which was used in the model. Typical costs for freeways and rural arterials were developed using ADOT and MCDOT reported information.

During the in-depth interviews, agencies were asked to provide detailed O&M information; however, some of the information reported was not used to generate the cost factors. For example, if an agency reported being especially underfunded in a specific category, and their O&M budget per unit was a fraction of the average, it was excluded to help develop realistic cost factors.

In addition, some of these agencies were unable to divide their expenditures into the cost factor categories chosen for this study; for example, if traffic signal and street light maintenance were tracked by the agency and budgeted together. In this case, these reported budget costs were not used in developing the model, but the costs (in this example, traffic signals and street lights) were considered as part of an overall reasonableness check of the model.

O&M cost factors were developed by maintenance activity and functional classification. These cost factors were compiled into a matrix presenting the cost factors, and a model was generated utilizing the cost factors. In turn, this allows the model to indicate costs by location (rural or urban) and by roadway functional classification (freeway or arterial), with the ability to include collector and local roads in the arterial cost estimate, to represent the network as a whole.

Existing Network Data

In order to develop unit costs by lane mile or centerline mile, agencies participating in the in-depth interviews were asked to provide information regarding their network, including total lane miles, lane miles by functional classification (if available), centerline miles, and centerline miles by functional classification (if available). The lane mile data is presented in ***Table 1***. Some agencies were unable to provide this data; in this case, the cells were left blank.

TABLE 1 – NETWORK LANE MILES

Municipality	Total Lane Miles	Arterial	Collector	Residential	% Arterial	% Other
Chandler	1,977					
Gilbert	1,915					
Glendale						
Goodyear	1,050					
Mesa	3,275	1,098	369	1,808	34%	66%
Peoria	1,403	391	180	832	28%	72%
Phoenix	15,475	5,456	3,044	6,975	35%	65%
Scottsdale	2,813					
Surprise	1,197	239	253	705	20%	80%
Tempe	1,241	447	107	687	36%	64%
				Average percentage	29%	71%

Several cost factors, such as signals and street lights, were developed using centerline miles because the costs are generally the same regardless of the number of lanes. As indicated in ***Table 1***, all agencies were able to provide total lane miles; however, several were unable to provide centerline miles. ***Table 2*** summarizes the agencies that were able to provide both, as well as the centerline miles as the ratio of total lane miles to centerline miles. This ratio is indicative of the number of lanes per centerline mile.

TABLE 2 – TOTAL LANE MILES TO CENTERLINE MILES RATIO

Municipality	Total Lane Miles	Centerline Miles	Total Lane Miles/Centerline Miles
Mesa	3,275	1,283	2.6
Peoria	1,403	581	2.4
Phoenix	15,475	4,825	3.2
Surprise	1,197	517	2.3
Tempe	1,241	472	2.6
		Average ratio	2.6

Data regarding network centerline miles is in ***Table 3***. If an agency was unable to provide data, the cells were left blank.

TABLE 3 – NETWORK CENTERLINE MILES						
Municipality	**Centerline Miles**	**Arterial**	**Collector**	**Residential**	**% Arterial**	**% Other**
Chandler						
Gilbert						
Glendale	782					
Goodyear						
Mesa	1,283	224	156	903	17%	83%
Peoria	581	93	72	416	16%	84%
Phoenix	4,825	728	609	3,488	15%	85%
Scottsdale						
Surprise	517	78	89	350	15%	85%
Tempe	472	88	41	343	19%	81%
				Average percentage	16%	84%

Based upon the average percentages in ***Tables 1, 2, and 3***, the percentage of lane miles and centerline miles by functional classification was estimated for the agencies that did not provide these values. For example, if an agency provided total lane miles and no additional network data, that number would be multiplied by 0.29 (the average value from ***Table 1***) to estimate the arterial lane miles in their network. That same agency's centerline miles would be estimated by dividing the lane miles in their network by 2.6 (the average value from ***Table 2***). This number would be multiplied by 0.16 (average value from ***Table 3***) to obtain an estimate arterial centerline miles. Estimating network mileage when otherwise unavailable enables the O&M data provided to be adjusted to the network size when determining an average per lane mile or per centerline mile cost. Otherwise, O&M expenditure data would have to be excluded from the study, thus restricting the data pool.

O&M cost factors were developed for four roadway functional classifications:

- Urban Freeway
- Rural Freeway
- Urban Arterial
- Rural Arterial

Some maintenance items, such as landscaping and signal maintenance, are typically only performed along arterial roadways, thus these cost factors were estimated assuming no allocation of cost to collector or local roads. However, most O&M costs apply to the complete roadway network (arterial, collector, and local roads). In order to account for this, an estimation factor was required. As arterial roads experience the highest traffic volumes, thus causing different usage and maintenance prioritization, costs were not allocated evenly by network mileage. Reviewing the O&M budgets, most agencies did not track their costs by roadway functional classification; however, a few agencies track their pavement maintenance budgets both by expenditure and functional classification. These agencies spend approximately 60% of their total pavement maintenance budgets on maintaining arterial roads.

As such, unless more definitive information was available, it was assumed that 60% of any maintenance item applied to the complete network was expended on arterial roadway maintenance, with the remaining 40% allocated to local and collector roads. These factors were used to develop the "arterial only" and "complete network" costs in the matrix used to populate the model, and are explained below.

As the Group 1 agencies were asked to provide detailed O&M information, it was possible to estimate O&M cost factors in two different ways. "Arterial only" cost factor estimates were developed by taking an agency's budget per maintenance item, estimating the portion used for arterial maintenance (typically 100% or 60% as described) and dividing it by the total arterial centerline miles or arterial lane miles (as appropriate for the budget item). "Complete network" cost factor estimates were developed by taking an agency's budget per maintenance item and dividing it by either the centerline or lane miles in the complete roadway network (arterial, collector, and local roads). In this way, the cost factor estimates can be used to estimate the maintenance cost associated with the arterial road itself, or the arterial road along with the associated and the collector and local roads.

3. Pavement Management Summary

A Summary Matrix of pavement maintenance practices is presented in ***Table 4***. The matrix references various pavement rehabilitation methods, defined below in order from the least to most aggressive treatment.

- **Fog Seal** – Fog sealing is a combination of mixing approximately fifty percent water in an asphalt emulsion and applying it to the pavement.
- **Slurry Seal** – Slurry sealing is performed by spreading a mixture of asphalt, water and fine aggregate over pavement.
- **Microseal** – Microsealing is performed by spreading a mixture of polymer-modified asphalt, water and fine aggregate on pavement. Microsealing is also sometimes referred to as microsurfacing.
- **Mill and Fill** – Mill and fill operations involve removing a layer of pavement and replacing it with new pavement. After milling the existing asphalt, a tack coat is placed to seal cracks and voids between the new and existing pavement layers and to adhere the new pavement to the existing pavement.

TABLE 4 – PAVEMENT MANAGEMENT SUMMARY				
Agency	**Software**	**Assessment Frequency**	**Rating System/Approach**	**Additional Comments**
ADOT	Highway Pavement Maintenance Application (HPMA) PECOS	Annual	International Roughness Index (IRI) Present Serviceability Rating (PSR)	Pavement preservation activities are planned five years in advance, based on technical indicators. The effects of new construction and reconstruction projects on pavement preservation requirements are also taken into account in pavement preservation programming. Extensive coordination is maintained to avoid overlapping pavement treatments, such as roads being restriped shortly before a pavement overlay project.
Apache Junction	iWorQ	Annual	Remaining Service Life (RSL)	Five main distresses are measured: fatigue, transverse cracking, longitudinal cracking, patches, and edge of pavement cracking. Raveling and other indices are also monitored. Inspectors use a guide to rate pavement. Software is used to recommend maintenance activities based on ratings. Pavement preservation measures are prioritized and coordinated with crack sealing.
Avondale	iWorQ	2 years	Not Available	Experience has indicated that past patterns of pavement maintenance have had a significant effect on current pavement conditions.
Buckeye	Microsoft Excel	Continuously check, update informally	Pavement Surface Evaluation and Rating (PASER)	The roadway maintenance approach is focused on obtaining grant funding for major arterials, while maintaining the highest traffic volume residential roadways. Pavement maintenance program focuses on keeping the greatest number of residents satisfied.

TABLE 4 – PAVEMENT MANAGEMENT SUMMARY (CONT'D)				
Agency	**Software**	**Assessment Frequency**	**Rating System/Approach**	**Additional Comments**
Carefree	Microsoft Word & Microsoft Excel	4-5 years	Modified Version of the Transportation Research Board Process	Through field inspection, 10 categories of pavement defects are scored. Defects are weighted based on severity and importance. Unique roadway and pavement conditions are noted. A three step approach to the operations and maintenance program is used; (1) identify defects, (2) prioritize needs, and (3) assess program options versus budget funding.
Cave Creek	No Formal System	Informal-routine	Informal system - Chip seal five miles of roads a year when funding is available. Other improvements are prioritized based upon available funding	Pavement management software is being researched and reviewed. Many of the available packages seem to be too complex to fit the pavement management needs of a small system.
Chandler	Proprietary road matrix software by Stantec	3 years	Pavement Quality Index (PQI)	Developers provide a one year final inspection on new roadways, at which time the developer may be required to apply the first seal coat. Pavement life is targeted at 25-30 years before the first mill and overlay.
El Mirage	Microsoft Excel	Goal – 2 years Current – 4 years	Pavement Surface Evaluation and Rating (PASER)	Projects are planned in order to maximize use of available funding. In order to achieve economies of scale, larger projects are performed, limiting the variety of activities in a given year. For example, one year all available funding may go toward one arterial; the next year, crack sealing and fogging the network.

TABLE 4 – PAVEMENT MANAGEMENT SUMMARY (CONT'D)				
Agency	**Software**	**Assessment Frequency**	**Rating System/Approach**	**Additional Comments**
Fountain Hills	No Formal System	7 years	Seven Zones-treat one annually	Maintenance is performed on a seven year cycle between seven zones. Each year, one zone is crack and slurry sealed or micro-paved. Roads are typically 40 years old and the majority have never had significant treatments.
Gila Bend	No Formal System	Informal	Informal	Establishment of a formal system is under consideration.
Gilbert	CHEC software switching to GBA	3-4 years	Pavement Condition Index (PCI)	Pavement management program makes extensive use of the Pavement Condition Index. There is an ongoing effort to demonstrate to decision-makers how pavement preservation funding levels affect the Pavement Condition Index.
Glendale	Lucity	5 year goal	Pavement Condition Index (PCI)	Pavement preservation projects are included in the Capital Improvement Program, which utilizes General Obligation funds. The Structural Index (SI) is tracked on arterials to provide a basis for pavement management activities.
Goodyear	Lucity	3 year goal	Pavement Condition Index (PCI)	Because the majority of roads are relatively new, they are typically in good condition, which tends to increase the system average Pavement Condition Index. Recent rapid growth in the size of the roadway system may result in increased future maintenance program funding needs that may not be apparent due to the high current average PCI.
Litchfield Park	Microsoft Excel	5 years	Pavement Condition Index (PCI)	All roads in the network were assessed in 2006 and 10-year maintenance activities recommended. Roadway segments are reviewed annually to determine if recommended treatments are still warranted, or if a roadway's condition has worsened enough that it needs more than the original prescribed level of maintenance.

TABLE 4 – PAVEMENT MANAGEMENT SUMMARY (CONT'D)				
Agency	**Software**	**Assessment Frequency**	**Rating System/Approach**	**Additional Comments**
MCDOT	Proprietary Software - Roadway Management System (RMS)	Arterials- annual Others- Biannual	Pavement Condition Rating (PCR) and International Roughness Index (IRI)	The pavement management process focuses predominantly on roadways classified as arterials. The roadway maintenance program does not maintain or manage landscape features.
Mesa	Modified MicroPAVER	Annual	Pavement Condition Index (PCI)	An activity-based budget process is used, tying pavement maintenance activities to strategic goals. Roadway operations and maintenance funding is kept separate from the Capital Improvement Program and major pavement projects are prioritized depending on funding levels. Typically a 20-30 year pavement life is experienced.
Paradise Valley	In House Program*	4 years	Pavement Condition Rating (PCR)	Maintenance is performed on a 15 year cycle between 15 sections. Each year, one section is milled and overlaid. Roads are typically crack sealed every 7-8 years.
Peoria	Hansen Asset Management Software, Microsoft Excel for pavement condition	Bi-annual	Pavement Condition Index (PCI)	To maximize benefits from available funding, maintenance activities focus on arterial projects with greater or longer term impact. Projects are prioritized to maintain high levels of safety, while some lower rated pavements may not be treated due to funding limitations. Major pavement rehabilitation, when necessary in the future, may face funding issues.
Phoenix	Lucity	Bi-annual	Pavement Condition Index (PCI) and SCI	Specially equipped vans are used in the pavement assessment process to measure and record roadway Pavement Condition Index data. Reconstruction of pavements is not programmed, placing an emphasis on periodic/routine maintenance activities to preserve pavement quality over the long term.

TABLE 4 – PAVEMENT MANAGEMENT SUMMARY (CONT'D)				
Agency	**Software**	**Assessment Frequency**	**Rating System/Approach**	**Additional Comments**
Queen Creek	MicroPAVER and Microsoft Excel	Goal- 3-5 years 10 year actual	Pavement Condition Index (PCI)	The majority of roads are relatively new, with an average age less than ten years, resulting in a relatively high Pavement Condition Index. The basic approach is to crack seal the roads annually, with a fog seal every three years. Slurry seals are used when there is significant cracking.
Scottsdale	Lucity	4 years	Pavement Condition Index (PCI)	Pavements are rated using the Pavement Condition Index, with intersections assessed separately. Data is recorded and tracked using GIS polygons rather than lane mile units, which is aimed at providing a more precise measurement of pavement areas.
Surprise	Hansen Pavement Management software	4 years	Overall Condition Index (OCI)	While most of the roads in the network are relatively new, efforts are aimed at adequate maintenance to continue high levels of pavement quality in the future. Typically roads are assessed every four years, using the time in between to perform improvements. The pavement management system is continually updated as improvements are performed, but new defects may not be documented until the next periodic assessment.
Tempe	Roadmatrix	3 years	Pavement Quality Index (PQI)	Avoiding a "worst first" repair prioritization approach, pavement maintenance strategies focus on consistent minor maintenance to preserve pavements, deferring the need for major maintenance projects. High standards are targeted, but if a road falls into poor condition, maintenance may be stopped and the road is later reconstructed. Predictable funding sources are being sought to maintain a strong pavement management program, instead of bonding or reliance on State shared revenues.

TABLE 4 – PAVEMENT MANAGEMENT SUMMARY (CONT'D)				
Agency	**Software**	**Assessment Frequency**	**Rating System/Approach**	**Additional Comments**
Tolleson	Microsoft Excel	Ongoing	Pavement Condition Index (PCI)	An inventory of roadway network conditions is maintained in Microsoft Excel and used to assess which streets need reconstruction, mill and overlay, etc. A ten-year pavement maintenance plan is being formalized, and repairs are beginning on the lowest rated parts of the network.
Wickenburg	No Formal System	Informal	Informal, need based prioritization	Projects are identified through an informal pavement condition assessment. In FY 2010 and 2011, $100,000 from the Capital Improvement Program was available for roadway maintenance in addition to HURF. The local power grid, which is municipally owned, helps fund the Capital Improvement Program.
Youngtown	No Formal System	Informal	Informal, need based prioritization	A slurry seal was done on all roads In 2004. A specific annual roadway operation and maintenance program is not part of the budget process. Community Development Block Grant funding, or other funding, has been used as it becomes available in the past for roadway maintenance projects. HURF funds typically cover costs to fix vandalism or matching for grants.

*as last reported

4. Pavement Management Challenges Summary

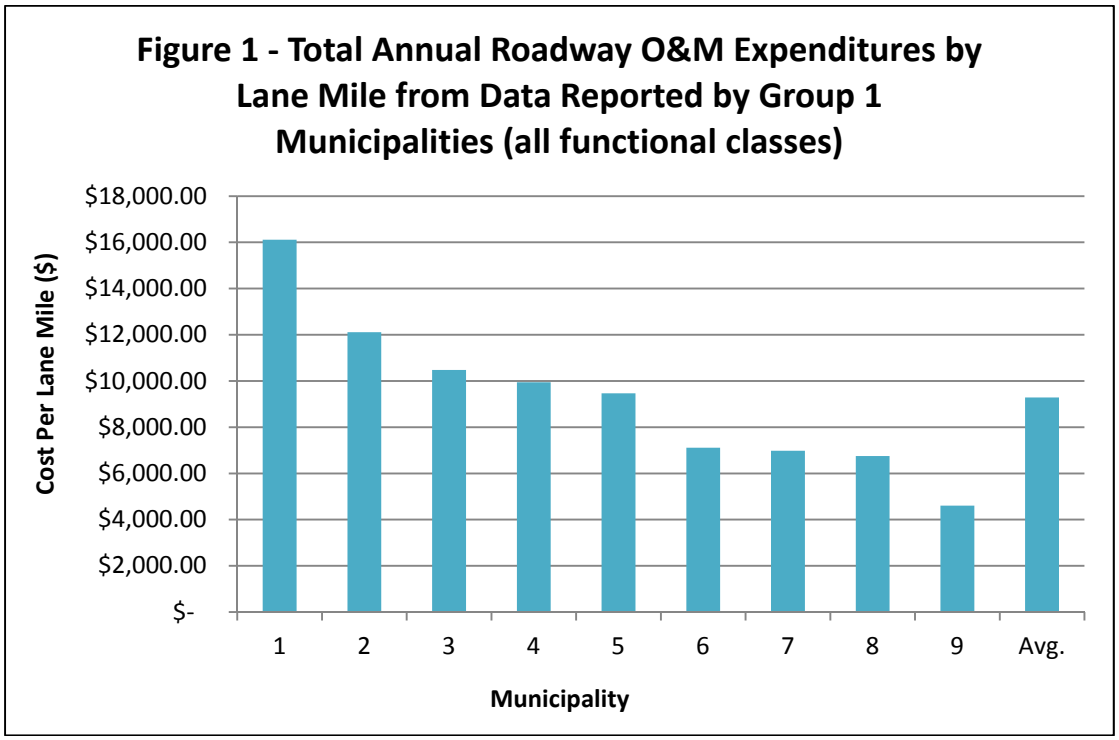
Although the roadway systems of MAG member entities vary significantly in size, age, and network composition, they face many of the same pavement management challenges. A summary of the key challenges from the interviews are:

- Budgets for general roadway operational items, such as traffic lights and street lights, cannot readily be reduced, so a higher percentage tends to be taken from the pavement maintenance budget.
- Pavements deteriorate quickly if not properly maintained. Falling behind on preventative maintenance plans can lead to higher future expenses and a significant backlog of preventative maintenance projects.
- The characteristics of roadways within a municipality can vary significantly, including factors such as traffic load forecasts, pavement age, roadway base composition, underlying soil quality, pavement depth, material quality, etc. These variations, along with limited availability of roadway design and pavement records, make pavement management highly challenging.
- Explaining the technical aspects of pavement management to decision-makers is a major challenge, such as describing pavement degradation and rating systems, quantifying how differing pavement maintenance budgets affect long term pavement maintenance, and demonstrating the need for proportionate growth in maintenance budgets along with new development.
- Budget issues facing municipalities have affected staffing levels in pavement maintenance programs, reducing the frequency of pavement assessments and the number of internal maintenance projects, while increasing reliance on contracted labor.
- Federal funding for pavement preservation can help overcome municipal budget shortages, but due to various federal project requirements, it costs significantly more to do a project using federal funds, with some agencies estimating a 40 percent increase in cost.
- Pavement maintenance project programming faces a variety of challenges, including inconsistent funding levels from year to year, the need to divide projects up into multiple years to match funding availability, ADA ramp requirements, and competing priorities with other municipal activities that make it difficult to get funding in addition to HURF.
- Operational issues related to pavement management that may increase project costs include: dealing with the time lapse between assessment and repair, restrictions regarding time of day/week for construction activity, and pavement cuts by utilities and the telecommunications industry.

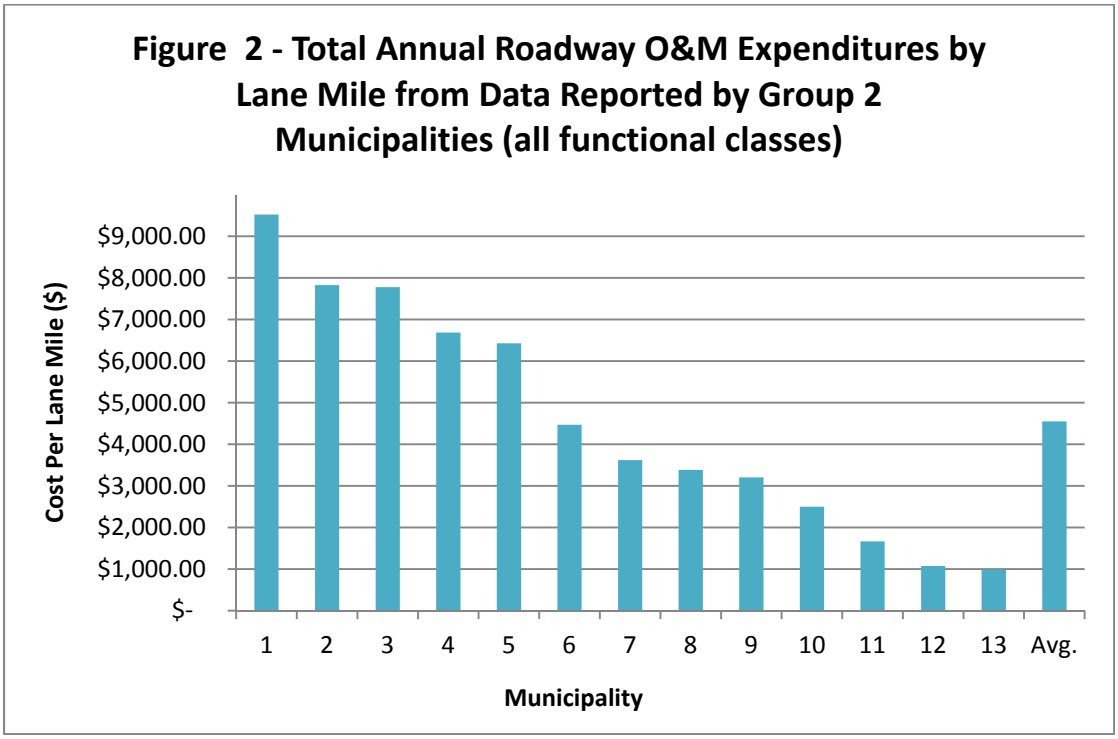
5. Typical Agency Expenditures

As part of the data gathering efforts associated with this Study, the total O&M expenditures were identified for all agencies in the MAG area. The data presented represents a "typical" budget year, which was based upon agency interviews and reported data for expenditures between 2007 and 2011. It was determined that a typical annual total of $277 million was expended for street O&M and $52 million for freeway/highway O&M in the region.

To help identify the region's O&M expenditure patterns, the range of per lane mile expenditures experienced by municipalities were arrayed. Note that the data is presented in no particular order by agency – the chart is organized from high to low. The bar at the right side labeled Avg. represents an un-weighted average.



The total annual expenditure by lane mile, as developed from data provided by agencies, is summarized in ***Figures 1 and 2***. This data includes all functional classes – arterial, collector, and local. As shown in ***Figure 1***, the average annual maintenance expenditure for a lane mile for Group 1 agencies is $9,285. This average is generally indicative of the region as a whole. Group 1 agencies own and maintain 85% of the municipal lane miles and represent 91% of the population (2010 Census data) in municipal areas of the MAG region. Group 1 agencies typically expend greater O&M funding per lane mile, largely due to pavement maintenance. As shown in ***Figure 2***, the average annual maintenance expenditure for a lane mile among Group 2 agencies is $4,550.



The O&M cost information provided presented trends among both Group 1 and Group 2 agencies. Agencies with mature networks typically tend to have higher O&M costs than those with relatively "new" networks, largely due to pavement maintenance costs. Among Group 2 agencies, those with higher costs per lane mile were typically larger agencies or those with the fewest lane miles.

6. Operations and Maintenance Cost Factors

The matrix shown in ***Table 5*** was developed for use in the model after analysis of data gathered.

Table 5 – Operations and Maintenance Cost Reference Matrix[3]		
ITEM:	ANNUAL COST (PER LANE MILE):	ANNUAL COST (COMPLETE NETWORK) [4]:
FREEWAYS:		
Rural Freeways:		
ADOT Rural O&M Cost	**$5,409.01**	**-**
Urban Freeways:		
ADOT Urban O&M Cost	**$26,187.73**	**-**
ITEM:	ANNUAL COST (ARTERIAL ONLY):	ANNUAL COST (COMPLETE NETWORK) [4]:
ARTERIALS:		
Rural Arterials:		
MCDOT Rural O&M Cost	**$6,441.82**	**-**
Urban Arterials:		
Concrete[1]	**$908.44**	**$1,514.07**
General[1]	**$1,723.25**	**$2,393.40**
Landscaping[2]	**$10,283.67**	**$10,283.67**
Pavement[1]	**$4,455.28**	**$7,425.46**
Signals[2]	**$10,663.64**	**$10,663.64**
Signing[2]	**$1,056.68**	**$6,493.03**
Storm Drains[2]	**$1,860.69**	**$3,101.15**
Street Lights[2]	**$3,480.17**	**$20,875.07**
Striping[1]	**$1,323.79**	**$2,074.61**
Sweeping[2]	**$3,920.34**	**$8,753.44**

(1) - Cost of Maintenance Item per Lane Mile
(2) - Cost of Maintenance Item per Centerline Mile
(3) - Based on average available reported budget information (2007-2011)
(4) - Complete network includes the O&M costs associated with arterials plus collector and local roads

As more data points were available for urban arterials than the other functional classifications, a more detailed cost estimate was developed. Because of the widely varying roadway networks, as well as

different approaches to funding, budgeting, and reporting O&M costs among agencies in the region, the cost factors in ***Table 5*** were not derived by simply averaging costs across agencies. Instead, they generally represent an average or typical cost of the most thoroughly documented costs reported in each category. In the matrix above, maintenance costs for arterials are divided into two categories – "arterial only" and "complete network." In both instances, the proposed arterial lane miles would be used to generate estimated O&M costs. The "arterial only" cost represents the O&M estimate for the arterial roads only; selecting "complete network" allows the model to estimate O&M costs associated with the arterial, plus the collector and local roads that would likely be present in conjunction with the arterial.

7. Interactive Cost Factor Model

An Interactive Cost Factor Model was developed, which can be used to develop composite roadway O&M costs based on functional classification and facility characteristics. This model provides drop down menus for a variety of factors, such as street lighting, that allow the user to add these costs to develop a composite roadway O&M cost.

The cost factors in the model can be adjusted in the future to accommodate changes in O&M expenditures. Additional O&M factors may be added later if desired.

Planning efforts typically focus on arterials roads and freeways; therefore, the costs have been established primarily for rural and urban arterials and freeways. In addition, the model permits urban arterial cost estimates using the complete network or just the urban arterials themselves by inputting the arterial mileage and selecting the "complete network" drop down menu. Urban freeway costs can be modeled to include rubberized asphalt replacement.

Model Verification

After the information gathered during the interviews was processed, it was cross-checked against data in other urban areas of the country with similar climatic conditions, to ensure that the cost factors represent reasonable estimates. This comparison is presented later in the report. The model was also tested against the existing MAG network and the overall annual reported budgets, in order to assess the capabilities of the model and possibly refine input assumptions (see section 7.B).

A sample run of the model is shown as ***Figure 3.***

Figure 3 – Interactive Cost Factor Model – Sample Run

March 14, 2012

Operations & Maintenance Cost Estimate [3]

Instructions: Grey cells are optional, yellow cells are required. Use the drop down menus to select the description that best fits the facility of interest. If an urban arterial is selected, use the drop down menus below to select the percentage of the typical cost to apply to the estimate.

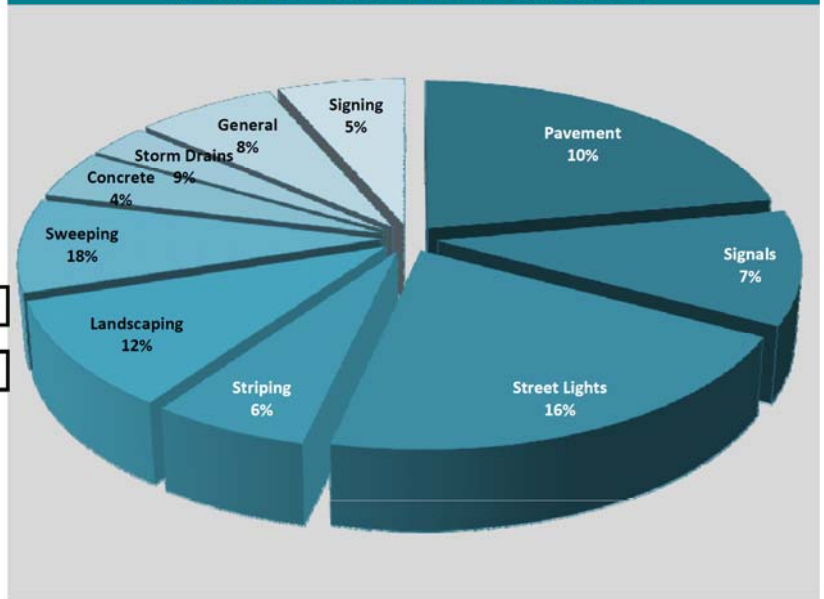
Facility Information	
Cost Estimate ID:	Test Model
Length (miles):	2
Number of Lanes:	3
Prepared by:	DB
Date:	3/14/2012

Facility Type:	Arterial
Facility Location:	Urban
Complete Network [4]:	Yes
Rubberized Asphalt	No

Total Estimated O&M Cost: $ 200,785.26

Total Estimated Cost per Lane Mile: $ 33,464.21

Estimated "Urban Arterial" Maintenance Cost Breakdown



Maintenance Item	Pavement[1]	Signals[2]	Street Lights[2]	Striping[1]	Landscaping[2]	Sweeping[2]	Concrete[1]	Storm Drains[2]	General[1]	Signing[2]
Applicable?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Unit Cost (3)	$ 7,425.46	$ 10,663.64	$ 20,875.07	$ 2,074.61	$ 10,283.67	$ 8,753.44	$ 1,514.07	$ 3,101.15	$ 2,393.40	$ 6,493.03
% Cost Estimated	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Sub-total/CLM	$ 22,276.39	$ 10,663.64	$ 20,875.07	$ 6,223.84	$ 10,283.67	$ 8,753.44	$ 4,542.20	$ 3,101.15	$ 7,180.20	$ 6,493.03
Sub-total/Item	$ 44,552.77	$ 21,327.28	$ 41,750.14	$ 12,447.69	$ 20,567.34	$ 17,506.88	$ 9,084.41	$ 6,202.30	$ 14,360.40	$ 12,986.06

(1) - Cost of Maintenance Item per Lane Mile
(2) - Cost of Maintenance Item per Centerline Mile
(3) - Based on average available reported budget information (2008-present)
(4) - Complete network includes the O&M costs associated with collector and local roads

A. Regional Comparison

The model results were cross-checked against costs in other urban areas of the country with similar climatic conditions, population base, and network size, to ensure that the cost factors represent reasonable estimates. Two Texas cities, Plano and Arlington, were selected for comparison. Census and weather data for these cities, as well as those comprising the MAG region, was collected to assure a reasonable comparison and is presented in ***Table 6***. It should be noted that both Plano and Arlington tend to be "mature" cities, and, as described in the preceding sections, were expected to experience higher pavement maintenance costs. However, as one of the goals of the model was to determine long-term O&M costs, this was the preferred approach.

TABLE 6 – AREA POPULATION AND TRAVEL TIME DATA

Municipality	2010 Population*	2000 Population*	Mean travel time to work (in minutes)**
Arlington	365,438	332,969	25.5
Plano	259,841	222,030	26.1
Avondale	76,238	35,883	26.8
Chandler	236,123	176,581	25.0
Gilbert	208,453	109,697	28.0
Glendale	226,721	218,812	26.7
Goodyear	65,275	18,911	31.0
Mesa	439,041	396,375	25.8
Phoenix	1,445,632	1,321,045	25.5
Peoria	154,065	108,364	27.8
Scottsdale	217,385	202,705	22.5
Surprise	117,517	30,848	33.4
Tempe	161,719	158,625	20.9

*Census data obtained January 18, 2010 at http://quickfacts.census.gov/qfd/states/48/4804000.html
**Mean travel time to work (minutes), workers 16+, 2005-2009, as reported by Census

As seen in ***Table 6,*** the majority of the MAG region has experienced significant growth over the past ten years, with all but four cities experiencing a population boom with an increase from 30-100%. Arlington and Plano experienced growth rates of 9.75% and 17%, respectively.

Weather

Weather can have a significant impact on pavement maintenance requirements and life span. The weather for the Phoenix area was compared to the weather in both Plano and Arlington. Factors that could vary include those related to freezing temperatures (potholes, salting roads, snow plows, etc.), rainfall (storm drain and landscaping), and sun exposure. ***Table 7*** shows the seasonal highs and lows (in degrees Fahrenheit) experienced in Phoenix, Arlington, and Plano.

TABLE 7 – SEASONAL TEMPERATURES EXPERIENCED*

Municipality	Winter		Summer	
	High	Low	High	Low
Phoenix	Upper 60s	Upper 30s – low 40s	Over 100	Mid 70s
Arlington	Mid 50s	Mid to upper 30s	Upper 90s	Mid 70s
Plano	Mid 50s	Mid to upper 30s	Upper 90s	Mid 70s

*Weather data obtained January 18, 2012 at www.weather.com

As Phoenix, Plano, and Arlington experience comparable highs and lows throughout the year, their exposure to heat and cold are similar. The Texas cities experience significantly more rainfall, so separate landscaping and storm drain costs will be applied to normalize the costs to the MAG region.

Arlington

The City of Arlington owns and maintains approximately 3,000 lane miles. Arlington's Maintenance Fund expenditures, presented in ***Table 8*** below, do not include landscaping or storm water. Arlington is an urban city that is full of activity, home to the Cowboys, Rangers, and the University of Texas at Arlington.

TABLE 8 – ARLINGTON O&M EXPENDITURES			
FY 2010	FY 2011	FY 2012	Average
$19,830,910	$20,959,657	$19,066,412	$19,952,326

Based upon this information, the average maintenance cost per lane mile, excluding storm drain and landscape maintenance, is $6,651. Adding the Group 1 landscape and storm drain cost factors to this cost, the average cost per lane mile is $7,486.

The average cost per lane mile for Group 1 municipalities is $9,285. While the maintenance cost expenditures for Arlington are somewhat lower than the Group 1 average, the expenditures are very near the mid-point of the Group 1 distribution (see ***Figure 1)***.

Plano

The City of Plano owns and maintains 1,016 centerline miles of streets (factored to 2,717 lane miles based upon conversion values calculated for the MAG region and presented in section 2, Project Approach). The factored value was cross checked with additional literature published by the City which indicated it maintains "more than 2,700 lane miles of pavement." This is consistent with the factored value, and was deemed acceptable for use in this study. Plano's recent O&M expenditures from their published budget are shown below in ***Table 9.***

TABLE 9 – PLANO O&M EXPENDITURES				
Category	**FY 2008-09**	**FY 2009-10**	**FY 2010-11**	**Average**
Public Works Administration*	$163,568	$156,252	$144,511	$154,777
Streets	$3,114,808	$3,138,500	$2,992,099	$3,081,802
Signals	$1,178,788	$1,222,878	$1,216,369	$1,206,012
Signs & Markings	$1,066,949	$1,132,377	$1,121,040	$1,106,789
Totals	$5,524,113	$5,650,007	$5,474,019	$5,546,380

*1/3 of the Public Works administration budget was included as this covers water, wastewater, and transportation

Plano includes many of its maintenance projects in its CIP costs. The ***Table 10*** presents these projects and costs associated with the FY2011 budget.

TABLE 10 – PLANO O&M PROJECTS INCLUDED IN CIP	
Project	**Cost**
Barrier Free Ramps & Sidewalks	$500,000
Computerized Signal System	$250,000
Independence Pkwy. Corridor Improvements	$650,000
Intersection Imp. – 2008 (3 intersections)	$454,000
Legacy Drive Corridor Improvements	$102,000
Meadows Addition, Phase I	$260,000
Park Boulevard Corridor Improvements	$399,000
Parker Road Corridor Improvements	$90,000
Ridgewood Street Reconstruction	$796,000
Roadway Median Landscaping	$200,000
Split Trail	$855,000
Street Reconstruction	$100,000
Total	**$4,656,000**

* Screening wall repairs were not included

By combining the CIP and reported maintenance costs, Plano's typical maintenance year expenditure is $10,202,380, or $3,755 per lane mile.

Plano's maintenance program does not include landscape or storm drain costs. These cost factors for the Group 1 agencies are $10,284 and $3,101 per arterial centerline mile, respectively.

Adjusting Plano's O&M costs to include landscape and storm drain costs, using Group 1 cost factors, Plano's cost per lane mile is $4,590 per lane mile (based upon 2,717 lane miles). This places Plano at the lower end of the range of per lane-mile costs for Group 1 (see ***Figure 1***), and near the mid-point of the range of per lane-mile costs for Group 2 (see ***Figure 2***). The average Group 1 O&M cost per lane mile is $9,285 and that for Group 2 is $4,550.

B. Test Application

Overall

When all of the freeway and arterial lane miles by type (rural/urban) from the MAG Federal Functional Classification database were input into the model, the cost generated was 81% of the total agency expenditures for reporting agencies. Mileage data was only input for agencies that reported maintenance costs.

8. Conclusion

Many of the MAG member agencies experience similar O&M challenges. Many agencies struggle to find consistent funding, while other agencies are challenged by rapidly growing networks, which have not been met with equally fast-growing budgets. Various pavement maintenance approaches are employed, but most agencies typically address the most high-traffic roadways first, and then turn their attention to less traveled roadways.

The model is generally a good indicator of anticipated O&M costs for newer roadway systems, as the majority of the networks in the region are relatively "new." In order to use the model to estimate long-term costs or costs for a mature roadway network, some factors, such as pavement maintenance, may need to be adjusted. Further, as new pavement maintenance practices evolve, construction pricing changes, and other changes occur, maintenance cost factors used to develop the model will need to be updated.

The model generated total regional annual roadway maintenance and operating expenditures in line with actual expenditures experienced in the MAG region. In addition, per lane-mile costs estimated by the Study were compared to those experienced in Arlington and Plano, Texas. This comparison indicated that costs reported by Arlington fell near the mid-point of the distribution of per lane-mile costs for Group 1 agencies, and those reported by Plano fell near the mid-point of the range of per lane-mile costs for Group 2.