UTILIZING GEOGRAPHIC INFORMATION SYSTEMS FOR ROAD MAINTENANCE

A GUIDE TO IMPLEMENTING A SUSTAINABLE PAVEMENT INSPECTION & MAINTENANCE PROGRAM

November 2019

This manual has been developed to benefit public agencies and is intended to provide general guidelines, but does not include or describe every possible road maintenance issue or best practice.

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Public agencies often face steep challenges in allocating resources and personnel to meet the numerous obligations that they have to the public that they serve. This includes not only high priority and high profile improvement projects, but maintenance and upkeep of the public land and roadways which fall within their purview. In many cases, these competing priorities cause agencies to fall behind on routine maintenance, which can lead to roadways that are unsafe and constitute a hazard to drivers. Geographic Information Systems (GIS) can be used to create a GIS based pavement maintenance program that will help organizations identify hazardous conditions and fix deteriorating roads before they become very costly problems (Kmetz 2011).

A Geographic Information System (GIS) is an incredibly useful tool for the analysis and mapping of data in layers onto real world maps and locations to uncover the spatial relationships and solve complex issues. GIS has been implemented as a tool by organizations all over the world to assist them in establishing patterns, relationships and situations, by analyzing the way these layers of data interact in real world locations in order to make informed decisions about the allocation of resources and the funding of projects (National Geographic 1996-2019). See the accompanying resource "What is GIS?" for an in-depth overview of GIS.

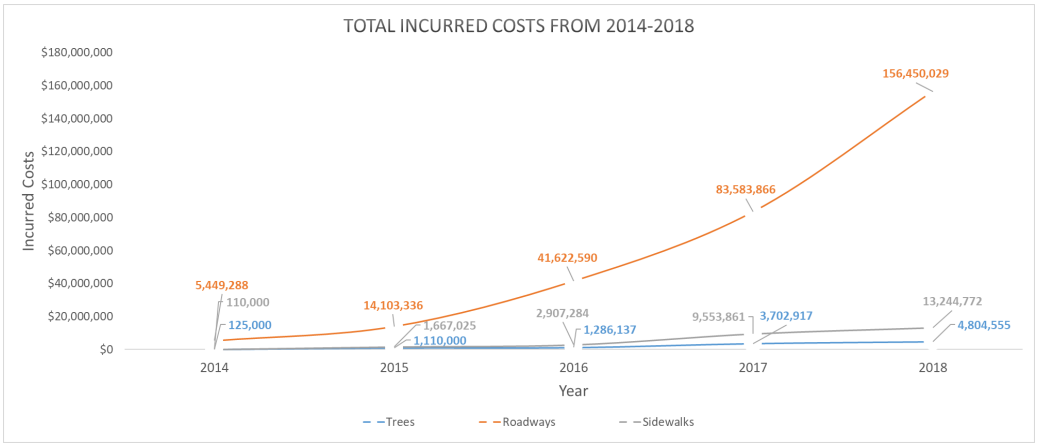
However, in order to successfully implement significant change in an organization, like GIS, it is important to lay the groundwork and a strong foundation on which to launch the initiative. This is accomplished by creating an overall Strategic Plan (see City of Tigard 5 Year Strategic Plan for a sample). The Strategic Plan begins with establishing a sense of urgency, Vision, mission and Business Case for the use of GIS (Kotter 2007).

Establishing a Sense of Urgency and a Business Case for GIS Based Pavement Management

When implementing a large project like GIS in an organization, it is critical to create a sense of urgency as the driving force (Kotter 2007) and develop what is known as a "Business Case" for the change. A Business Case is the reasoning and the justification for the cost and investment that the new project or change will require. Without a solid Business Case to base the project on, it will be very difficult to convince stakeholders to approve the project and to invest the resources needed in order to make the project successful. Similarly, a sense of urgency addresses the question of "Why?", as in, "Why now?" and "Why Us?". Without these two driving forces the project will have great difficulty gaining traction. The establishment of a good Business Case begins with understanding the problems that the organization faces and how GIS can solve those issues.

While some agencies may be wary of the initial cost of development and implementation of GIS in the organization, once implemented GIS provides a very efficient and cost effective way to continue maintenance and upkeep on roadways. A very convincing Business Case for the development of GIS based pavement maintenance can be made based on: the long-term savings that can be achieved by the increased efficiency, prevention of potentially catastrophic losses arising from liability claims and for the increased opportunity for expansion, transparency and communication that GIS enables between departments and with the public.

In terms of actual costs, GIS based pavement maintenance will save the entity a substantial amount of money on the cost of maintenance over time because it is estimated that it costs $1/yd. to maintain a road in good condition and $75/yd. to replace a road (Kmetz 2011). This preventative maintenance will extend the life of the pavement for many decades beyond initial construction. Whereas failing to perform preventative maintenance on roadways will end up costing the entity much more over the long term. Additionally, GIS based pavement maintenance can help protect the entity from lawsuits arising from liability due to claims of dangerous conditions of public property.



In an increasingly litigious environment, public agencies are being named as defendants in cases involving motor vehicle collisions with claims of dangerous conditions of public property or improper road maintenance that are resulting in substantial payments to the plaintiffs. In the 5 years following 2014, liability claims from dangerous conditions of roadways have risen from the order of millions of dollars to over a hundred million dollars per year.

Government immunities can help protect entities from liability for these conditions but recent court decisions are showing that the immunities don't always apply, especially if there was not a reasonable effort to maintain an adequate inspection system that could have identified the hazard. Agencies may be wary of uncovering maintenance issues that they do not have the ability to immediately remedy, because they believe that would remove some of the ability of the immunities to apply, but CA Government Code §835.2 states that an entity could still be found liable if:

1. Condition had existed for a long enough time that the agency should have been aware
2. Whether or not the agency had, maintained and operated a reasonably adequate inspection system that would have discovered the hazard.

This means that an entity must still have a system in place for inspecting the roadways under its control for potential dangerous conditions and take actions to correct the hazards before they cause harm. GIS based pavement management is one of the most effective and efficient ways to conduct regular inspections and preventative maintenance that will show good faith efforts from the entity (Owers and Wilson 2001).

GIS can also help organizations communicate and plan more efficiently across multiple departments. GIS allows users to filter data layers to show as many layers of relevant data as they wish. By having a central GIS database with all a department's work and data stored in it, department planners can see the spatial relationships between the data layers to help inform their decisions. Some or all of this information can be made available on the internet so that the public can access the information and report new hazards, increasing transparency and communication with an entity's constituents. The "Capitalizing on GIS and Asset Management – Implementation Guide" has more information about building a Business Case for GIS based transportation asset management.

All of these are good examples of sound Business Cases for the utilization of GIS, but the way that this message is communicated is also a very important component of the project. The Business Case should be conveyed succinctly with the "Vision Statement."

A Vision Statement is Necessary to Guide the Project

A 'Vision Statement' is defined as: "a one sentence statement describing the clear and inspirational long-term desired change resulting from an organization or program's work." So, essentially, a Vision Statement frames your objective in a concise statement which will help galvanize support for implementing change. Some examples of Vision Statement include:

- Feeding America – "A hunger-free America."
- Habitat for Humanity – "A world where everyone has a decent place to live."
- Boy Scouts of America – "To prepare every eligible youth in America to become a responsible, participating citizen and leader who is guided by the Scout Oath and Law."
- A Potential GIS Vision Statement: "Utilize a Geographic Information Systems guided road maintenance program in order to improve roadway conditions for our constituents and reduce liability."

John. P Kotter, a former professor at Harvard Business School, whose research on implementing organizational change has been highly influential, has found that creating a Vision is essential to maintain momentum and to keep the project within an achievable scope. Kotter cautions against presenting a Vision that is too complicated or vague to be communicated within 5 minutes. Without

a good Vision Statement to act as a guide, the drive to complete the project may lose steam before it has even begun.

Creation of a Vision Statement is important, but creating a strong interdisciplinary "Guiding Coalition" is equally as important.

Building a Guiding Coalition to Steer the Project to Completion

When attempting to implement a major change initiative like GIS, it is essential to have a team comprised of stakeholders from different departments throughout the organization. For example, a team focused on implementing GIS for roadway conditions might include:

- Executive Level – City Manager, CAO, etc.
- Risk Management
- Public Works Department – Directors, Department Heads, Supervisors
- City Engineers and Planners
- IT and GIS Staff

Having stakeholders from each of these different areas contribute to the project in the earliest stages is important because their contributions to the implementation strategy and the Vision will ensure that all the perspectives of the different departments and individuals are accounted for. If only one of the stakeholders attempts to create the plan without input from the rest of the important stakeholders, "blind spots" that cause unforeseen problems during implementation may develop, due to fact that no single stakeholder has all the information about the resources available to the departments or stakeholders involved. Getting a wide range of feedback and input on the front-end during the development of the Vision, scope and strategy will help mitigate these blind spots. Also, having a Guiding Coalition is important for morale because if the project has incorporated feedback from the departments that are going to carry out the day-to-day work, it increases the sense ownership from the supervisors and managers who will be the driving force for the implementation. This ownership will be essential for the continued success of the project in the long term.

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Each of these coalition members may have different levels of involvement throughout the project. For example, those at the executive level are important to help the team understand the budgetary restrictions and to gain the approval for resources, but they may not play as much of a role once the project is being implemented. Whereas the Public Works Department and the GIS staff will likely be involved throughout the entirety of the project.

Once a Guiding Coalition and a Vision Statement have been put together, the final component of a good starting foundation for the project is an implementation strategy. The next section will discuss the process for creating an implementation strategy.

Once the Business Case and Vision Statement have been determined, and a Guiding Coalition has been put together, the next step is the creation of a Strategic Plan that will guide your organization throughout the implementation process. If the Vision and the Business Case answer the question of "Why?" for the initiative, the Strategic Plan answers the question "How?", as in, "How will each of these goals be accomplished?". The Strategic Plan is important for keeping the project on track and in scope, as well as maintaining momentum and sustaining the drive throughout the project. According to the framework laid out by John Kotter (Kotter 2007), to be successful, the Strategic Plan should incorporate milestones and "short-term wins" in order to maintain this momentum and keep employees engaged throughout the lengthy process of implementation.

The most efficient way to create realistic, achievable and significant milestones is to define the key elements of a successful GIS based road maintenance and transportation asset management (TAM) program and then to do a form of "gap analysis" to determine where the organization is currently and what is needed to get the key elements of a successful program. The steps can be broken down as follows:

- Identify the Key Elements of a GIS program
- Assess what the organization's current capabilities are
- Develop a series of goals and milestones to reach the Vision

Key Elements of GIS Implementation

Before beginning to create a Strategic Plan it is important that the Guiding Coalition has a firm understanding of all of the required components of a successful GIS based TAM program so that they can effectively assess and address the needs of the organization. The resource, "Successful Practices in GIS-Based Asset Management" (National Academies of Sciences, Engineering, and Medicine 2015) has two supplemental resources. The first of which, "Capitalizing on GIS and Asset Management - Executive Guide" which can provide those outside of the Guiding Coalition with high level, good foundational knowledge and a framework to work from. A second, more in-depth version, "Capitalizing on GIS and Asset Management - Implementation Guide" will be essential for the Guiding Coalition in the creation of the Strategic Plan because it provides the roadmap for the specifics of the process and as well as the methodology.

The key elements can be broken down into a series of steps which are expanded on in the Implementation Guide:

1. *Establishing geospatial data management standards and policies*: It is important to understand and define exactly what data will be collected and why, so organizations don't spend resources collecting data that will not be

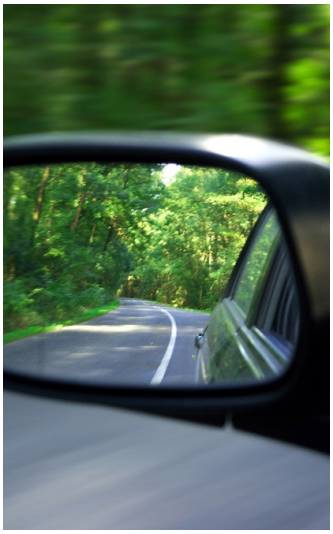
used or that is not formatted correctly for use in GIS.

2. *Acquiring hardware and software necessary for collecting, managing, analyzing and displaying spatial data:* Once the scope of the data collection is defined with standards and policies, it is important to determine what is needed to collect the data and acquiring those resources.
3. *Building a geospatial data infrastructure*: It is important to have the infrastructure for the data already set up before it is gathered so that data upload can be automated from the start.
4. *Collecting, maintaining and managing data:* Once the infrastructure is in place the organization can begin gathering the baseline data to determine the current state of its assets.
5. *Integrating data from external sources*: In order to get the most value out of the GIS based system, it is necessary to be able to incorporate data from other departments, agencies and the public.
6. *Building and providing analysis capabilities:* Once gathered and integrated with other sources, the data can be analyzed to aid in decision making and the creation of a Maintenance Improvement Plan (MIP), which will be discussed in a later section.
7. *Building and sustaining staff expertise*: Staff expertise is important to the longevity and sustainability of the program.

The next step is to use these two resources to help the team understand the different levels of maturity for each aspect of the GIS program and how to evaluate their current capabilities.

Assess Organization's Capabilities and Resources

Using the checklists and worksheets that are in the Implementation Guide (Successful Practices in GIS-Based Asset Management 2015, page 7), the Guiding Coalition can begin to assess current capabilities and compare them to the maturity levels within the guide to determine what their organization's current standing is in relation to the goals set forth in the Vision that they have created. This is the stage where it is important to have input from all of the members of the Guiding Coalition because they can provide insight into what each of their departments' current resources, capabilities and limitations are and what they would need to be successful in reaching the goals. This will help eliminate blind spots down the line, when the plan is being implemented, as well as inform all the team members of how current policies and processes are being implemented.



Many organizations currently utilize GIS in some form, so it is important to find the existing GIS infrastructure and capability within the organization (if any).

Questions to consider are:

- What hardware/software is used?
- What kinds of data are being collected?
- Which personnel have GIS expertise?
- How is the data being stored?
- Who has access to the data?

With this information the Guiding Coalition can incorporate and expand on existing infrastructure into the development of a Strategic Plan for road maintenance and transportation asset management.

If the organization doesn't have current GIS utilization, then they have the ability to determine what their needs and goals are without any constraints placed by existing policies, but they will have the additional burden of creating a GIS program from the ground up. This may involve either hiring staff with GIS expertise or training current staff.

Using the Implementation Guide as a roadmap, the next step is to identify areas in need of improvement.

Develop a Series of Goals and Milestones to Reach the Vision

In order to determine what the milestones and goals are, the agency will need to do a gap analysis and compare the information that they have on their current capabilities and resources and identify the areas that are in need of improvement to reach the Vision. The implementation guide can provide a framework for that assessment comparison via the maturity models for each of the necessary categories as well as some checklists and worksheets that can be customized and modified to suit the needs of your organization (Successful Practices in GIS-Based Asset Management 2015, 25-27).

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This is the stage where the Guiding Coalition develops concrete goals that will define the Strategic Plan (see (City of Tigard Finance and Information Services 2014) for a sample). These goals and milestones should be significant, but no too large and they should be evenly spaced so that the project doesn't lose momentum. The key is to break the larger project into small enough components that each milestone feels like a "win", but is still frequent and achievable. This will keep employee engagement up throughout the project as well as to provide updates to the stakeholders (Kotter 2007).

One of the first goals should be to gather preliminary data about the state of the roadways to incorporate into a Maintenance Improvement Plan (MIP). The MIP is an integral part of a Road Maintenance Program and it will be very difficult to have a successful program without one.

Once a list of goals and milestones have been generated, they can be laid out onto a projected timeline based on available resources and staff. Once the timeline of goals has been established, the Strategic Plan should be written out to keep the project on track and in scope. Once there is a written plan in place, the next step is to allocate resources to the first goals of the project and begin the implementation.

NOTE: The resource "GIS Based Pavement Maintenance: A Systematic Approach" (Kmetz 2011) is integral to understanding the implementation of a GIS based pavement management system. It will be referenced throughout this section and it is strongly recommended that the reader review and become familiar with the document.

One of the first steps in the implementation of the Strategic Plan should be to gather the baseline data that will be used to prioritize the maintenance projects and allocate initial resources for a "Maintenance Improvement Plan" (MIP). Like the Strategic Plan, the MIP is a multi-year plan that allows agencies to have an objective way to rank and prioritize the most effective repairs based on a given operating budget. The MIP allows the organization to identify the roadways with the highest risk, as well as the most cost effective way to utilize the resources available. The "Infrastructure and Facilities Five Year Capital Improvement Plan" for the fiscal years 2018-19 through 2022-23 created by the County of San Luis Obispo is a good reference sample for what a final product may look like, although it is more comprehensive and covers much more than roadway maintenance.

The process involved in developing the MIP consists of four steps. These are:

1. Road condition assessment
2. Prioritization of road improvements
3. Maintenance strategies and improvement recommendations
4. Development of the preliminary cost estimate

The MIP and GIS are two separate tools that work well together, but can be used (albeit less effectively) without the other. The figure below, from Robert Kmetz's paper (Kmetz 2011), shows how the MIP and GIS components work together for GIS based pavement management. The "Best Practices for Road Design and Maintenance" resource developed by PRISM, provides an overview of the process of developing a maintenance improvement plan, as well as information and methodology for gathering data on roadway conditions.

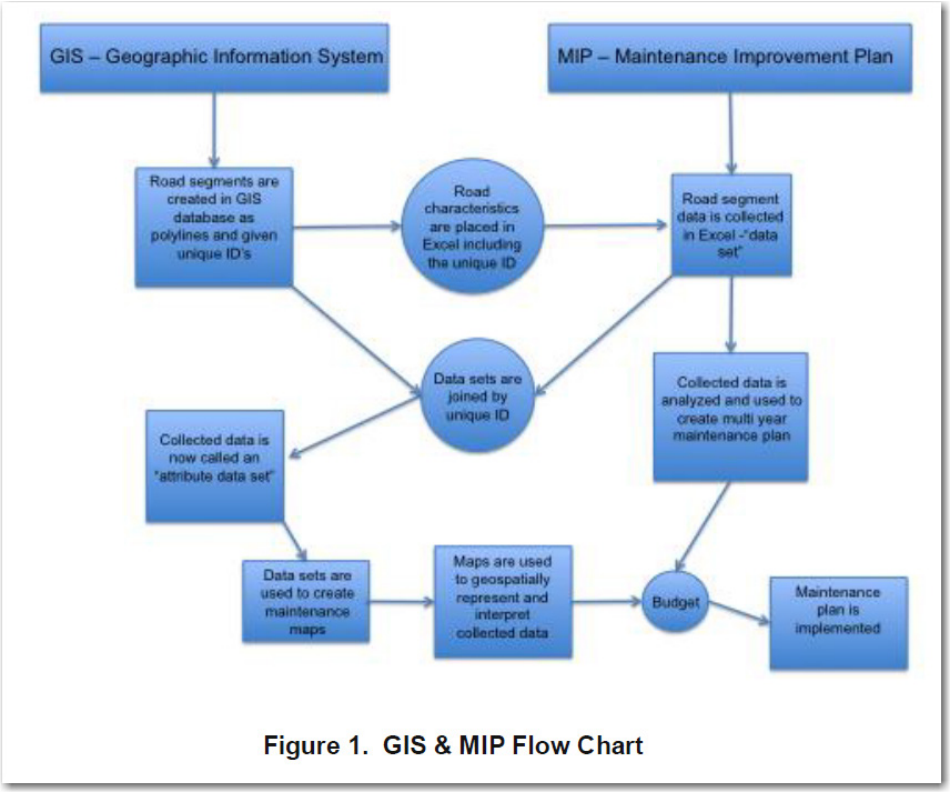


Figure 1. GIS & MIP Flow Chart

Gathering the initial data for the MIP will likely be a long and time consuming process depending on the amount of up-to-date data that the organization currently has available. A likely scenario is that the organization will have to allocate staff and resources to surveying every roadway (including signs, shoulders, etc.) within its jurisdiction to have up-to-date and accurate information about the current state of the roads. This process can be broken down into phases, but the MIP will not be effective until all of the roadways are assessed and evaluated.

However, before data is gathered, it is very important for the success of the project to have a framework for the database that the data will be input into already established to ensure that the data gathered is within the scope of what is needed and in the correct format for input into GIS databases (see Appendix B of the "Capitalizing on GIS and Asset Management - Implementation Guide" for samples of data collection standards). In an ideal situation, this framework will allow field operators to upload the data directly into the GIS platform and database, but the information can be recorded manually and then uploaded later as well. This framework will allow organizations to formulate an inspection schedule that will enable them to be proactive in their roadway maintenance after GIS has been implemented.

At this stage of the project it is essential to solicit input from the GIS expert from the Guiding Coalition to determine the specific software and hardware that will be required to ensure that accurate geolocation information is gathered at the time of surveying. There are a variety of ways to gather this location data; some are more manual than others, but it depends on the agency's available resources and the type of database and framework that the information will be

put into. Examples of data gathering tools and resources listed from simpler and requiring manual data entry to more complex with automated data entry are:

1. **Pen, Paper and GPS**: It is possible to create a spreadsheet using Excel or a similar product and have field surveyors manually write in the information along with basic GPS location information, which can be gathered either from simple GPS devices/mobile phones, or from a more advanced GPS device specifically designed for accuracy.
    a. This solution is likely the least expensive option, but it is also prone to transcription errors by either field workers or when it is transcribed into the database and the accuracy of the location information depends a lot on the quality of the GPS device.

2. **Mobile Apps**: There are many apps that utilize smartphones' GPS capabilities to record information for GIS purposes.
    a. These are a good way to eliminate paper aspects of the process and to reduce errors in transcription. However, the GPS coordinates are only as accurate as the phone is capable of recording. This can range from approximately 5 meters for ideal conditions to 600 meters for areas with limited cellular coverage. While this may not be as expensive of an option, the limitations warrant consideration of a more specialized device and software.

3. **Electronic Survey Devices**: Several companies (Trimble, etc.) make devices and associated software with very accurate GPS data that are specifically designed for use in GIS surveying. These can be utilized by field workers to capture the location on the device itself, as well as pictures and other information. This information can also be automatically uploaded to your database either wirelessly, or it can be uploaded once the field worker returns to the office.
    a. This option is likely to be the most expensive option, but it is the best way to gather accurate data.
    b. At the time of publication of this document, ESRI is a leading edge company with one of the best software solutions for GIS based projects, ArcGIS.

> ***"Working with the experts in the Guiding Coalition (GIS, Public Works, etc.) will ensure that the data gathering plan and technique is both realistically achievable and thorough with the resources available."***

Additionally, this ensures that data from subsequent inspections, as well as new notifications of needed repairs, can be updated into the GIS database in real-time. This helps prevent the formation of a new backlog of roadways that have not been inspected from accumulating after the baseline inspection data is gathered. The framework also ensures that time and resources are not spent gathering information that will not be utilized, by clearly defining for the field operatives who are collecting the data what information is needed. Working with the experts in the Guiding Coalition (GIS, Public Works, etc.) will ensure that the data gathering plan and technique is both thorough and realistically achievable with the resources available.

The resource "GIS Based Pavement Maintenance: A Systematic Approach" (Kmetz 2011) provides some samples of what this data might look like in a spreadsheet form, which you can use to help design your data collection criteria:

Table 1. MIP road data collection spreadsheet

STREET	FROM	TO	SUBDIVISION	CLASS	TYPE	WIDTH	PASER	CONDITION	GIS_ID
151ST ST	LONG COVE	SETTERS		S	Asphalt	42	8	8-Good	151ST_030W_S
156TH ST	COUNT VIKING	SHINING SPRING		S	Asphalt	21	7	7-Satisfactory	156TH_230W_S
156TH ST	DITCH	TOWNE		C	Asphalt	19	6	6-Fair	156TH_500W_C
156TH ST	EVENING ROSE	SPRING MILL		S	Asphalt	24	6	6-Fair	156TH_370W_S
156TH ST	MISTY VIKING	OAK RIDGE		S	Asphalt	21	7	7-Satisfactory	156TH_290W_S
156TH ST	OAK RIDGE	COLUMBINE		S	Asphalt	21	6	6-Fair	156TH_300W_S
156TH ST	PRAIRIE CLOVER	DECLARATION		C	Asphalt	22	7	7-Satisfactory	156TH_430W_C
156TH ST	ROSEMOSS OVERMAN	EVENING ROSE		S	Asphalt	22	6	6-Fair	156TH_340W_S

Table 2. MIP Road data spreadsheet with recommended repair and costs.

Street	From	To	Subdivision	PASER	Class	Type	Width	Condition	Recommended Repair	Cost
151ST ST	LONG COVE	SETTERS			S	Asphalt	42	8-Good	Preservative Seal	$2,851.00
156TH ST	COUNT VIKING	SHINING SPRING			S	Asphalt	21	7-Satisfactory	Preservative Seal	$3,100.00
156TH ST	DITCH	TOWNE		6	C	Asphalt	19	6-Fair	Preservative Seal	$5,500.00
156TH ST	EVENING ROSE	SPRING MILL		5	S	Asphalt	24	6-Fair	Preservative Seal	$1,350.00
156TH ST	MISTY VIKING	OAK RIDGE			S	Asphalt	21	7-Satisfactory	Preservative Seal	$2,250.00
156TH ST	OAK RIDGE	COLUMBINE		5	S	Asphalt	21	6-Fair	Preservative Seal	$2,100.00
156TH ST	PRAIRIE CLOVER	DECLARATION		6	C	Asphalt	22	7-Satisfactory	Preservative Seal	$1,750.00
156TH ST	ROSEMOSS OVERMAN	EVENING ROSE		5	S	Asphalt	22	6-Fair	Preservative Seal	$1,300.00

Table 3. GIS road data spreadsheet

STREET	GIS_ID	OWN	TYPE	CLASSIFICATION	CITY	ST	ZIP
E 156TH ST	156TH_230W_S	PW	STREET	Secondary Arterial	WES	IN	46074
E 156TH ST	156TH_290W_S	PW	STREET	Secondary Arterial	WES	IN	46074
E 156TH ST	156th_210W_S	PW	STREET	Secondary Arerial	WES	IN	46074
E 156TH ST	156TH_250W_S	PW	STREET	Secondary Arterial	WES	IN	46074
W 161ST ST	161ST_430W_S	PW	STREET	Secondary Arterial	WES	IN	46074
E 161ST ST	161ST_320W_S	PW	STREET	Secondary Arterial	WES	IN	46074
E 161ST ST	161ST_220W_S	PW	STREET	Secondary Arterial	WES	IN	46074

Development of Maintenance Improvement Plan

This next section will provide a high level overview of the "Best Practices – Road Design and Maintenance" resource, which provides an in-depth breakdown of the process of developing an MIP. It is strongly recommended that the reader utilize that document in the development of their MIP in conjunction with GIS.

This best practices document was designed to be utilized either with or without GIS capabilities in mind, so the initial steps are very similar to the groundwork that must be laid out for GIS based pavement management. This means that the first steps of "Creating a Development Team" and "Assessment of Available Assets" have already been completed by this stage and the next part of the process can be started. However, it will be important to have the experts in charge of doing or designing the repair work (Public Works Department, Engineers, Architects, etc.) from the Guiding Coalition involved in this phase of the project. Their knowledge of the repair solutions as well as the agency's capabilities will be invaluable.

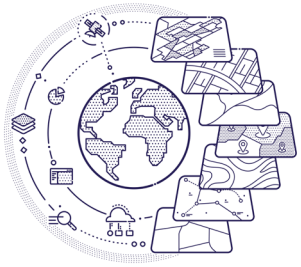
Roadway Assessment

The best way to accomplish a thorough roadway assessment is to create a comprehensive plan to physically survey all of the roads in an organization's jurisdiction for hazardous conditions and maintenance needs. While this can be a very large and time consuming phase of the overall project, it is a critical step that cannot be circumvented. To make it easier, it can be broken up over a period of time, or into systematic phases, depending on the availability of personnel and other assets. There can be a lot of up-front time and expense

associated with this data collection, but once gathered, the data can be used for the entirety of the project and allow the entity to proactively manage road hazards and maintenance going forward.

The best practices document has additional information about how to establish objective evaluation criteria for each aspect of the roadway (road condition, shoulder, vegetation, signage, etc.) that can help organizations come up with a uniform way to compare the conditions of roads.

Prioritization of Road Maintenance



In the next phase, the roadway condition data gathered must be analyzed to establish ranking criteria for prioritizing repairs based on the level of relative risk posed by the hazards. See "Guidance Document for Road Safety Inspections and Defect Categorisation" as well as the "Road Inspection Guidance Manual" for an example of a ranking system that take a variety of factors into consideration for their rankings.

The best utilization of resources will go towards roads that have the highest risk associated with the hazards. The method of determining the relative risk is up to the entity, but the quantitative data gathered in previous steps, such as PASER rating, can provide an objective basis of comparison of the condition of each roadway. However, there are more considerations to take into account when determining the priority ranking. Some things that might be considered in addition to the severity of the hazard or disrepair, are the traffic volume, and the utilization of the roadway. Roads that have higher volume of traffic have a higher risk ranking because of the increase in usage, for example.

Maintenance Strategies and Improvement Recommendations

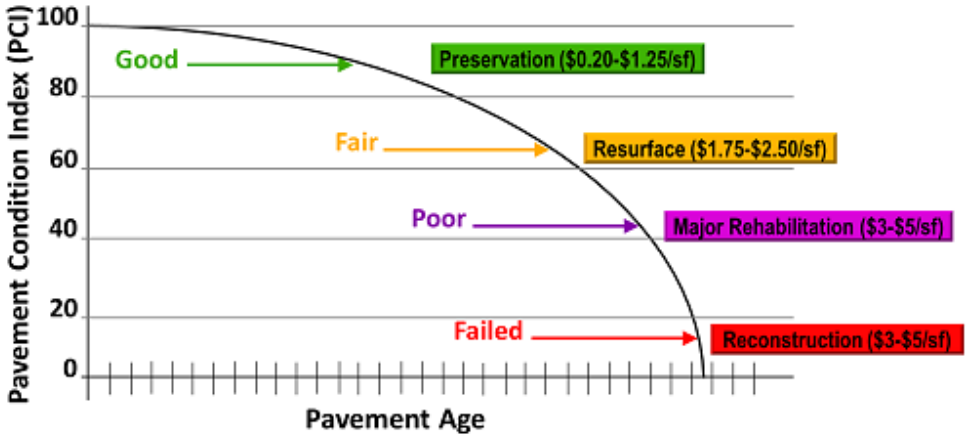
Once a ranking has been assigned to each of the hazards in the roadways the next step is to assess the cost of each repair. This is the point where the Public Works experts from the Guiding Coalition should be consulted. Additionally, Kmetz's paper and the best practices document have information on the types of repairs, their costs and the expected life of each repair.

At this stage, the roadway ranking information should be entered into the GIS Database to create a maintenance map and analyze the info spatially and aid in the final decision of where to allocate resources. Kmetz's paper discusses the specifics of GIS integration.

All of this information combined with the available budget will be used to create a multi-year plan to fix as many high priority hazards as possible in each budget cycle. The best practices document has resources on how to do a Life Cycle Cost Analysis Comparison, and other tools to use to evaluate the best ways to utilize the resources available. A sample of what the final product might look like is the County of San Luis Obispo's Capital Improvement Plan.

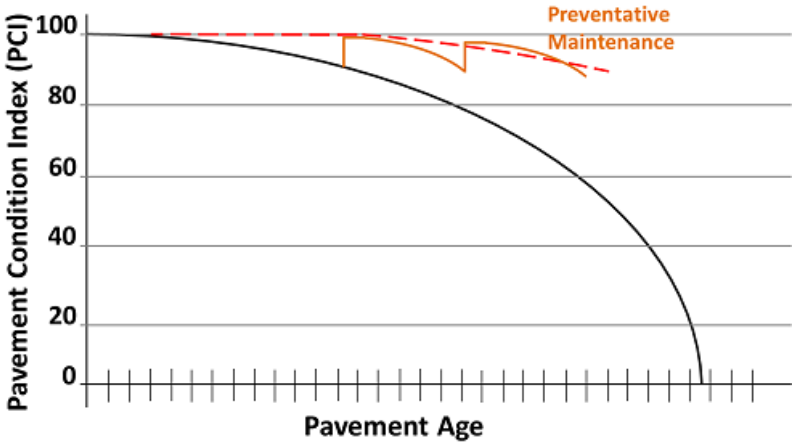
The process of completing the necessary repairs and improvements to the roadways is one of the portions of the overall project that will be the most time consuming after assessing the current conditions. Depending on how many large and costly projects the agency has had to complete over the course of their maintenance improvement plan, it may take several years until the agency may be able to move to a proactive approach. However, having a proactive (rather than reactive) pavement management system is the ultimate goal and the overall "Vision" of the entire GIS project.

Proactive maintenance is achieved by utilizing a thorough inspection schedule using GIS data as a means of tracking and recording the information. Field workers will have the ability to log new hazards and maintenance needs directly into the existing database which can then be visually represented on the GIS map. Additionally, functionality can be added so that members of the public can report hazards and maintenance needs with GPS coordinates from an app or through your agency's website. (see Butte County's website for an example) Once an agency is doing proactive maintenance to extend the life of their roadways instead of replacing severely dilapidated roads, the operating budget for maintenance will be much lower than it was previously because of the reduced cost of preventative maintenance relative to replacement or extensive repair.



Cost Comparison of Option

Preventative maintenance:	$ 29,000
Rehabilitation:	$ 93,000
Reconstruction:	$ 348,500



(Figures from Los Angeles County Public Works website)

To achieve this, the final piece of an effective GIS based pavement management system is the creation of a regular inspection schedule which will update the conditions and priority rankings after the initial survey and assessment of the road conditions. This will reflect new hazards or maintenance needs that occur as well as show the completed work.

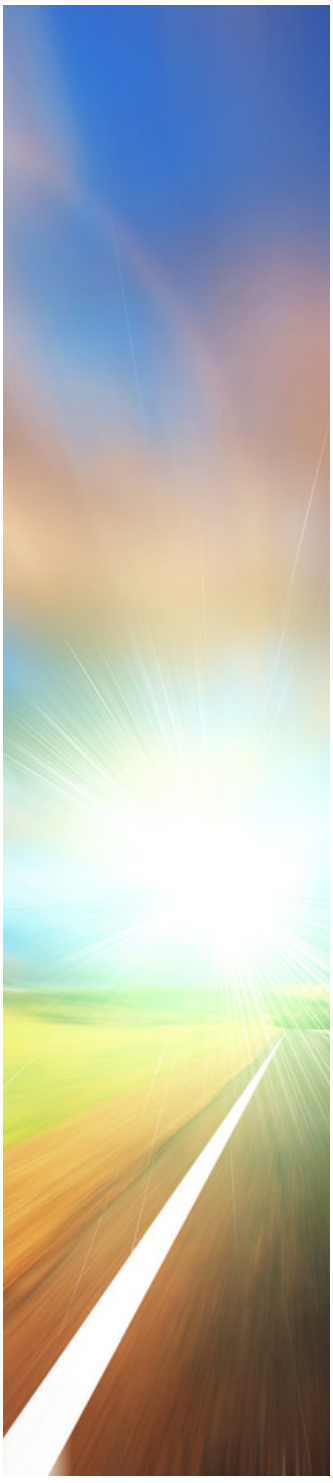
After the initial data is gathered, the inspection schedule can be adjusted based on the needs and classification of the roadway and the condition of the roadway. (See Aberdeen "City Council's Road Safety Inspection Manual" for sample inspection frequency). These inspections are crucial for the continued success of the plan because the roadways will continue to deteriorate and inspections are necessary to continue to update the MIP with the new data regarding conditions.

In addition to roadway conditions, the progress of current projects should be monitored to determine if they have been completed or if their goals were reached. If the project has not been completed, or requires more funds, that will need to be accounted for in the review of the MIP. Project review can also indicate if there are any areas for improvement within the repair/maintenance processes or the overall plan.

Since data can be added in real-time, and will likely be much more rapid than before GIS was implemented, it may be necessary to allocate resources and develop processes for staff to monitor the data that is being input into the system to avoid inaccurate data. It is especially important to monitor the data being entered if the agency has the ability to solicit input from the public, to ensure that duplicates are not added, that concerns are legitimate, etc.

The MIP should be reviewed at least annually and all of the progress data and new data that is gathered should be input into the MIP. This new data allows the entity to adjust the year-by-year improvement schedule with completed projects, project updates and new conditions.

It is critical not to lose momentum in this stage of the project. Kotter stresses the importance of not "declaring victory too soon" and ensuring that the project



will be sustained. It is important not to relent and stop pushing for the project until it has become deeply entrenched in the organization's culture. Otherwise, resistance to change may cause the project to stagnate and then ultimately, regress. (Kotter 2007)

Future Integration and Additional Features

Once the GIS based pavement management portion of the project is completed, and the GIS framework and databases are already in place, the agency can now add more functionality and data to the GIS map. This additional data and functionality will increase the usefulness of the map for the each of the departments and the agency as a whole.

As technology becomes more and more integrated into all different aspects of our lives, it is essential to look forward to newer technologies that can help public agencies in a variety of ways. The emergence of "Smart Cities" with devices and sensors that are connected via the internet is a perfect example of how technology is changing the way that government operates. (https://www.techrepublic.com/article/smart-cities-6-essential-technologies/)

Implementing GIS and adding more ways departments and other stakeholders can interact with that information will increase the value of the GIS system with each new addition. The ability of each department to see the relevant information about locations from other departments overlaid simultaneously on the map, will lead to easier and better decision making. (see ESRI's website for more information about different capabilities of GIS integration). Additionally, the added transparency can increase and streamline the communication with the constituents that agencies serve.

Conclusion

Although it is a monumental undertaking, and may require a significant operational and cultural shift within the organization, GIS based pavement management systems are an extremely effective and cost efficient way of managing roadways and assets. (Kmetz 2011) The implementation of this type of project not only increases efficiency and saves money, it also has the intangible benefits of improved decision making, due to the information being spatially represented with all the relevant data, and improved communication with other departments in the agency and with the constituency.

Additionally, once it is implemented, it is a very important component of modernizing governmental infrastructure and enabling faster and more responsive action to many other issues that public agencies face, ranging from zoning determination, monitoring water and the environment for public health concerns, evaluating emergency response capabilities and reach for fire and other first responders as well as many more uses.

GIS is a currently under-utilized new technology that will enable governments to operate much more efficiently and effectively. Integration with technology will become a necessity in the next decades and GIS is likely going to be one of the essential components of that integration.

STAGE ONE:
LAYING THE GROUNDWORK FOR A SUCCESSFUL TECHNOLOGY CHANGE INITIATIVE

Appendices and Resources:

- Tigard County (Oregon) 5 Year Strategic Plan for GIS
- Leading Change: Why Transformation Efforts Fail
- What is GIS?
- Capitalizing on GIS and Asset Management – Implementation Guide

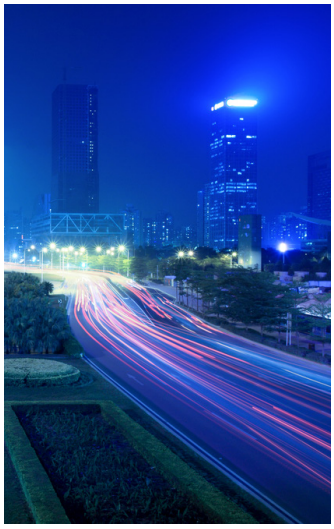
References:

- Kmetz, Robert J. 2011. "*GIS Based Pavement Maintenance: A Systematic Approach*" College of Technology Theses and Projects Paper 36.
- Kotter, John P. 2007. "*Leading Change: Why Transformation Efforts Fail*." Harvard Business Review, January 2007.
- National Geographic. 1996-2019. *Resource Library Encyclopedic Entry GIS (geographic information system)*. Accessed June 4, 2019.
- Owers, Roger S., and Eugene M. Wilson. 2001. *Safety Analysis Without the Legal Paralysis: The Road Safety Audit Program*. Report, Laramie, Wyoming: Department of Civil and Architectural Engineering, University of Wyoming.

STAGE TWO:
ASSESSING ORGANIZATIONAL CAPABILITIES AND CREATING A STRATEGIC PLAN

Appendices and Resources:

- Capitalizing on GIS and Asset Management – Implementation Guide
- Capitalizing on GIS and Asset Management - Executive Guide



References:

- City of Tigard Finance and Information Services. 2014. 5 Year Strategic Plan Geographic Information System (GIS) FY 2014-2019. Strategic Plan, City of Tigard: City of Tigard.
- Kotter, John P. 2007. "Leading Change: Why Transformation Efforts Fail." Harvard Business Review, January 2007.
- National Academies of Sciences, Engineering, and Medicine. 2015. Successful Practices in GIS-Based Asset Management. Report, Washington, DC: The National Academies Press.

Appendices and Resources:

- GIS Based Pavement Maintenance: A Systematic Approach
- Best Practices for Road Design and Maintenance
- County of San Luis Obispo Infrastructure and Facilities Five Year Capital Improvement Plan FY 2018-19 through 2022-23
- Guidance Document for Road Safety Inspections and Defect Categorisation

References:

- Kmetz, Robert J. 2011. "GIS Based Pavement Maintenance: A Systematic Approach" College of Technology Theses and Projects Paper 36.