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NDOT ITS Asset Management

Business Plan

April 2020

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Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
AMOC	Asset Management Oversight Committee
AMP	Asset Management Program
ATMS	Advanced Traffic Management System
Caltrans	California Department of Transportation
CCTV	Closed-circuit television
CDOT	Colorado Department of Transportation
DI	District I
DII	District II
DIII	District III
DMS	Dynamic message sign
DOT	Department of Transportation
EAMS	Enterprise Asset Management System
ESS	Environmental Sensor Station
ERM	Enterprise Risk Management
FAST	Freeway and Arterial System of Transportation
FHWA	Federal Highway Administration
GASB	Government Accounting Standards Board
GDOT	Georgia Department of Transportation
GIS	Geographic Information System
GUI	Graphical User Interface
HAR	Highway Advisory Radio
HPMS	Highway Performance Monitoring System
ITS	Intelligent Transportation Systems
KPI	Key Performance Indicator
LADOTD	Louisiana Department of Transportation and Development
LCC	Lifecycle Cost
LCP	Lifecycle Planning
MAP-21	Moving Ahead for Progress in the 21st Century Act
MIRE	Model Inventory of Road Elements
MTBF	Mean Time Between Failure
NCHRP	National Cooperative Highway Research Program
NDEX	National Data Exchange
NDOT	Nevada Department of Transportation
NHS	National Highway System
NSRS	Nevada Shared Radio System
ODOT	Oregon Department of Transportation
PDOT	Pennsylvania Department of Transportation
RB	Risk-Based

ROI	Return on Investment
RTC	Regional Transportation Commission
RWIS	Road Weather Information System
SDOT	Seattle Department of Transportation
SDP	Strategic Deployment Plan
SHRP 2	Second Strategic Highway Research Program
SLI	Signal, Lighting and ITS
SNV	Southern Nevada
TAMP	Transportation Asset Management Plan
TIG	Transportation Intelligence Gateway
TIM	Traffic Incident Management
TRB	Transportation Research Board
TSMO	Transportation Systems Management and Operations
UDOT	Utah Department of Transportation

1. Background

Intelligent Transportation Systems (ITS) Asset Management is a strategic approach for agencies to collect, store, manage, and analyze asset data in an effective and efficient manner that will help improve the user experience. Several agencies currently collect data, but not all take advantage of data integration or use those data for decision making.

The Nevada Department of Transportation (NDOT) recognizes the importance of focusing on the uses of data, creating processes and procedures at decision-making levels, and tailoring the data for integration into the decision-making process. This includes, but is not limited to, meaningful data collection and analysis, performance measurement and maintenance, and a health index of NDOT's ITS assets. To this end, NDOT has developed this Business Plan to provide an overview of current NDOT ITS asset management strategies, federal reporting requirements, overlaps and gaps analysis, and a three-year implementation plan for Statewide ITS Asset Management.

In addition, the ITS Asset Management Business Plan is developed in alignment with the NDOT Transportation Systems Management and Operations (TSMO) Program and has used the program's strategic goals as a guide to enhance traveler's experience by connecting TSMO to Asset Management. This is NDOT's first step toward developing a comprehensive TSMO Asset Management Program (AMP) that will help support the implementation and emerging needs of TSMO strategies and will help advance the TSMO Program.

The NDOT ITS Asset Management Business Plan provides a strategic and systematic framework in operation, maintenance, and enhancement of the state's ITS assets with focus on economic and engineering analysis based on meaningful data collection, performance measurement, and health index over the lifecycle of the assets.

2. Strategic Elements

ITS assets play an integral role in Nevada transportation as the state's transportation systems become more connected and integrated. Recognizing the importance of ITS and technology, and in order to use them to their full potential, NDOT has developed ITS asset management strategic elements to help guide health, lifecycle planning, risk-based management, and performance monitoring of the ITS assets based on the state's transportation priorities.

Understanding that ITS assets play a key role in advancing TSMO strategies, the ITS asset management strategic elements are defined in a manner that are aligned with TSMO Strategic Elements (NDOT Statewide TSMO Program, 2020). The ITS asset management strategic elements include Vision, Mission, Goals and Objectives, and ITS Asset Lifecycle Framework, which are described in the following sections.

2.1. ITS Asset Management Vision and Mission

Within the context of health index, maintenance, and performance measurement, the NDOT ITS Asset Management Vision and Mission are described as follows:

ITS Asset Management Vision	Support delivery of a connected society and economic vitality through real-time operation, maintenance, and performance-based decision making for ITS assets.
ITS Asset Management Mission	Establish a systematic process of operating, maintaining, and improving ITS assets to enable Nevadans to move safely, efficiently, and reliably based on the health index of the assets.

Drawing from the ITS Asset Management Vision and Mission, and in alignment with TSMO Strategic Goals and Objectives, the ITS Asset Management Goals and Objectives are defined as follows:

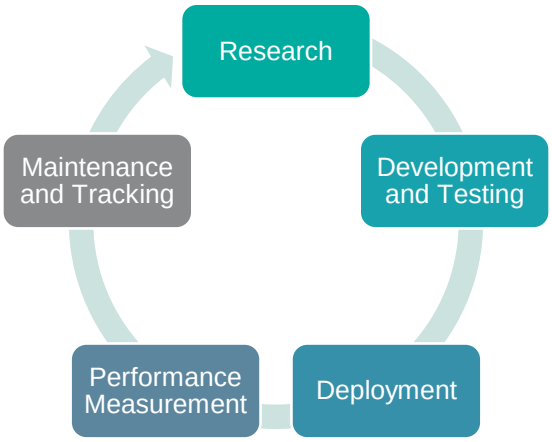
ITS Asset Management Strategic Goals	ITS Asset Management Strategic Objectives
Enable Safer Transportation	Develop crash avoidance, performance measures, and notification mechanisms (such as warnings, messages, automated responses, etc.).
Enhance Mobility and Reliability	Increase system efficiency through improved traffic management, work zone and incident management, freight, transit, and road weather management.
Minimize Environmental Impacts	Use technology to manage traffic flow and congestion by efficient use of data to avoid congested routes, discover available alternate routes, use public transit, or reschedule trips.
Enhance Information Sharing	Develop standards, applications, and technologies that enhance information sharing among stakeholders, users, and devices.
Promote Technology and Innovation	Foster innovation and technology advancement and leverage strategic partnerships (public and private) to enable ongoing targeted technology deployment for TSMO integration.
ITS Assets Preservation	Develop specific measures and goals to identify the health status and maintenance requirements for ITS infrastructure and devices.

2.2. ITS Assets Lifecycle Framework

NDOT recognizes the importance of developing a lifecycle framework that will guide the focus of ITS Asset Management efforts for advancing TSMO strategies and deployments. The NDOT ITS Assets Lifecycle Framework (see Figure 1) was designed with consideration to not only ITS Assets Management, but also the statewide TSMO roll out and the future development of the TSMO AMP. The framework includes five phases, as follows:

- Research: In alignment with the ITS projects and TSMO strategies, this phase is the initial step in conducting research to identify types of assets and technologies required to support implementation of these projects.
- Development and Testing: Drawing from findings in the research phase, this phase will be a transitional phase from research to testing the identified ITS assets.
- Deployment: This phase will include adopting the systems and devices, deploying them, and developing performance measures.
- Performance Measurement: In this phase, performance measures will be applied to evaluate improvements, asset performance, and health monitoring.
- Maintenance and Tracking: This phase involves deploying maintenance plans throughout the lifecycle of the technology and tracking it to ensure the identified goals, objectives, and performance measures are used in the decision-making process.

Figure 1: ITS Assets Lifecycle Framework



This strategic framework will enable the optimal allocation of efforts and resources for the effective management, operation, maintenance, and preservation of NDOT's TSMO and ITS assets. It integrates engineering, planning, and economic principles to support the decision-making process at a strategic level, while also providing a clear direction for the development of ITS Asset Management Business Plan. The following sections will describe the business plan's components in further detail.

3. Literature Review and Federal Reporting Requirements

Recent advances in technology show that developing and following asset management practices provides a strong base for any organization to grow and advance. Effective asset management practices can optimize the performance of assets and help develop and provide cost-effective solutions for transportation facilities. However, if there are no effective measures followed for maintaining these assets, it results in increased safety risks, decreased system reliability, higher maintenance costs, and lower system performance (Asset Management Resources, 2016).

This section provides information on Federal Highway Administration (FHWA) requirements for asset management, Transportation Research Board (TRB) findings, and strategies used by other state Departments of Transportation (DOT) in ITS asset management, along with a detailed review of management techniques.

3.1. Federal Reporting Requirements

The FHWA has defined standards for effective transportation asset management. These standards are applicable to all assets, including pavements, bridges, and ITS. While the FHWA does not provide separate guidelines for management of ITS assets, the standards mentioned are applicable to all assets, including ITS. Guidelines to be followed by agencies for successful asset management include establishing performance goals, covering an extended time horizon, and analyzing cost as well as engineering. Following this framework will assist agencies in maintaining their respective assets and monitoring their performance over time, resulting in lower investment requirements.

The primary focus of the practice of asset management is the performance and health index of the assets included. Maintaining details of all the agency assets provides easily accessible information for the system users, stakeholders, and government officials who can monitor and modify the inventory as per the engineering principles. These details can also assist officials in making economic decisions based on the present condition of the asset.

The FHWA (Asset Management Overview, 2017) states that the core principles of asset management are:

- Policy Driven: Resource allocation goals are based on a well-defined set of policy goals and objectives.
- Performance-Based: Policy objectives are translated into system performance measures that are used for both day-to-day and strategic management.
- Involve Analysis of Options and Trade-Offs: Decisions on how to allocate funds within and across different types of investments are based on analysis of how different allocations will impact achievement of relevant policy objectives.
- Based on Quality Information: The merits of different options with respect to an agency's policy goals are evaluated using credible and current data.
- Monitoring Provides Clear Accountability and Feedback: Performance results are monitored and reported for both impacts and effectiveness. (Asset Management Overview, 2017)

As defined by the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on Highways, Planning Subcommittee on Asset Management:

> "Transportation Asset Management is a strategic and systematic process of operating, maintaining, upgrading, and expanding physical assets effectively throughout their lifecycle. It focuses on business and engineering practices for resource allocation and utilization, with the objective of better decision making based upon quality information and well-defined objectives". (Asset Management Overview, 2017)

As mentioned earlier, asset management aims to (1) maintain the present conditions and health of assets, (2) conduct lifecycle analysis, and (3) monitor the performance of assets over time. If organizations will maintain proper records of condition, perform analysis of useful life, and monitor assets, they will be able to generate cost-

effective solutions for repair and eventual replacement. Developing and maintaining the inventory of assets will assist transportation professionals in making wise investments that, in turn, provide positive results.

Considering the importance of asset management, FHWA encourages state DOTs and private organizations to develop a Transportation Asset Management Plan (TAMP) for effective asset management. FHWA identifies asset management as a tool in the transportation industry to store and maintain information on various assets and forecast long-term expenditures based on present conditions. The TAMP, once developed, can be a very effective tool that brings together different aspects of asset management and improves overall performance. It includes all tactical sub-elements and delivers the strategic goals and objectives. (Transportation Asset Management plans , 2017)

Looking over the long-term advantages of a TAMP, FHWA requires each state DOT to develop and maintain a risk-based asset management plan for roadways on the National Highway System (NHS) to improve or maintain the condition of the assets and the system performance. State DOTs are required to integrate each asset within their jurisdiction's infrastructure in the risk-based asset management plans. TAMP strategy was further supported by the Moving Ahead for Progress in the 21st Century Act (MAP-21) legislation passed in 2012. Asset management is defined by MAP-21 as a strategic and systematic process of operating, maintaining, and improving physical assets through an identified sequence of cost-effective maintenance, repair, rehabilitation, and replacement actions that will ensure a good workability over the lifecycle of any asset. (Transportation Asset Management plans , 2017).

The FHWA states that an asset management plan of any state should be approved by the Secretary of the State and should include:

- A summary listing of the pavement and bridge assets on the NHS in the state, including a description of the condition of those assets
- Asset management objectives and measures
- Performance gap identification
- Lifecycle cost and risk management analysis
- A financial plan
- Investment strategies

Most of the state DOTs adopting the TAMP practice include pavement and bridges into their plans. When the department is confident in maintaining and updating its TAMP on a regular basis, it might be a good initiative to integrate ITS assets into the record for further improvements. Recent advancements show that many state DOTs have started to include their ITS assets into their TAMPs for cost-effective management. Section 3.1.3 summarizes some of the practices followed by state DOTs to manage their ITS assets. NDOT is one of the state DOTs that includes ITS assets into its TAMP. Section 3.3 describes strategies used by NDOT for ITS asset management.

3.2. Transportation Research Board

Recent advancements in transportation principles suggest that it is valuable to integrate asset management principles and processes with TSMO strategies. The following reports show various ways that asset management can be included in a TSMO plan:

National Cooperative Highway Research Program (NCHRP) 20-07 Task 359—Next Generation National TSMO Research Framework

The advancement of TSMO programmatic development and implementation has been heavily supported by national transportation research. The national best practice in freeway traffic management and traffic incident management (TIM) techniques and technology systems were established largely because of research conducted by the TRB Freeway Operations Committee. In addition, the second Strategic Highway Research Program (SHRP 2) focus area on Travel Time Reliability produced valuable tools, including the capability maturity model, performance data analysis, and TIM training resources.

According to the TRB (Transportation Research Board, 2016), aspects to be considered when developing a TSMO plan should include:

- Topics, program areas, and projects
- Process and schedule for ongoing management of the plan
  - Updating the plan
  - Coordination of research projects
  - Tracking of deployment and implementation efforts
  - Quantification of benefits and costs associated with the research efforts
- Provisions for stakeholder involvement and oversight
- Concepts for funding and resourcing research projects

NCHRP 07-21 (Active)—Asset Management Guidance for Traffic Control Devices, Barriers, and Lighting

Traffic and safety assets are necessary for enhancing traffic safety, but asset management systems and approaches are not as clearly defined for these assets as they are for other transportation assets. Previous research has shown that, among agencies, there is little consistency regarding the development and maintenance of traffic and safety asset inventories, as well as a system to maintain, modify, restore, or replace the assets. Due to the scarcity of resources for managing traffic and safety assets, it is crucial that the resources are effectively allocated. NDOT will expand on this to include the department's ITS assets as well as other transportation assets.

The intention of this research was to develop asset management guidance for agencies with regard to select categories of traffic and safety assets that they own and maintain. The selected categories include signs, traffic signals, markings, barrier systems, and lighting. Particular attention is placed on asset management processes, procedures, and tools intended to aid DOTs in achieving maximum efficiency in the operation of their traffic signal systems. According to the TRB (Transportation Research Board, 2015), for each category of assets, the guidance should address:

- Rationale for justifying the establishment of an asset management program to agency decision makers, including responses to typical concerns
- Suggested uses of the information provided by an asset management system by maintenance, safety, traffic, and budgeting staff (including lifecycle cost analysis, benefit-cost analysis, cross asset budget allocations, systemic and local safety analysis) and illustrative examples of these uses
- Recommendations for establishing performance measures and targets at minimal and desirable levels
- Definitions of the critical and desirable data needed to generate the performance measures and for other analyses and the attendant levels of data quality, precision, accuracy, and timeliness
- Methods of weighting different types of assets within an asset category (e.g., regulatory, school, guide, and warning signs) for budgeting and response prioritization purposes
- Methods of collecting and updating the necessary data, including costs and other impacts to the agency
- Methods of storing and managing the data, including costs and other impacts to the agency
- Methods for estimating the remaining service or functional life of the asset
- Challenges and benefits of uniform usage of the asset management system across an agency, between agencies, and over time.

The TRB stated that, "… a number of agencies have made progress in areas such as establishing asset inventories, developing approaches for determining what asset data to collect and store, taking advantage of new automated approaches for data collection, and relating needs for maintaining and improving traffic and safety assets to safety and operational performance." An overall guideline for asset management can be found in Volume 2 of the AASHTO *Transportation Asset Management Guide*. The guidelines describe several examples of successful implementation. In addition, resources like the FHWA Model Inventory of Road Elements (MIRE) provide ways to approach standardization of data management practices. Further research is required to develop thorough and pragmatic guidance for managing traffic and safety assets based on research and best practices.

3.3. State of the Practice Nationwide

In the process of developing a new technique/standard or for updating an existing technique for asset management, it is good practice to review the standards followed by different organizations for the same purpose. To determine an approach to be followed for developing/updating a technique, such reviews of similar practices can be helpful. The following section describes some of the approaches adopted by state DOTs for managing their respective ITS assets.

Innovative strategies have been adopted by different state DOTs around the nation to manage assets and align with FHWA requirements. The following examples summarize some of the approaches undertaken by the respective organizations regarding ITS asset management. This research indicates that some of the state DOTs have made efforts to try to align with Map-21 requirements as well. The majority of DOTs have integrated pavement and bridge assets into their respective TAMPs, while NDOT has chosen to also include ITS assets within its TAMP. Some of the strategies adopted by different organizations to manage their ITS assets include:

- California Department of Transportation (Caltrans) – Includes all ITS assets into an annual Asset Management Performance Report. The report predicts the performance of the ITS assets for the upcoming five years based on results obtained after monitoring their current performance. Caltrans has developed a baseline to monitor the performance of the assets and based on results provides different solutions to solve the problem encountered (Enhancing Transportation: Connecting TSMO and Asset Management, 2018).
- Utah DOT (UDOT) – UDOT's TAMP has developed a roadmap that helps guide users with a comprehensive plan for asset management. Some of the key points in this plan include: performance-based management, performance gap identification, lifecycle planning, risk management analysis, a financial plan, investment strategies, and some advice on how to continue improving asset management. The assets described in the plan include three different tiers, and advanced traffic management system (ATMS) devices as well as signal devices are part of Tier 1. This plan identifies a target of 95 percent operational for ITS devices and signals (FHWA, September 2019).
- Florida DOT – Officials use a software-based ITS facility management system for day-to-day maintenance and monitoring of ITS devices that includes preventative maintenance, diagnostics, and asset management. (Enhancing Transportaion: Connecting TSMO and Maintenance, 2018)
- Georgia DOT (GDOT) – GDOT has developed a long-term plan to asset management and even though it is heavily focused on pavement and bridges, it can be extended to ITS assets. This plan includes several strategies such as performance targets, lifecycle planning, financial plan, and investment strategies for asset management. More specific to ITS, the Standard Operation Procedures Manual provides guidelines, roles and responsibilities, several ITS software, ITS assets status, history, and work order dashboard. GDOT also developed a checklist of activities to follow for ITS asset management, from identifying goals and objectives down to coordinating with other agencies. Also included are steps to discuss performance measures, requirements, quality assurance, coordination with other departments, and coordination with other agencies. (FHWA, September 2019).
- Seattle DOT (SDOT) – Provides all information concerning ITS utilities, along with other road and bridge assets. Users can access detailed information about SDOT's assets through its asset management web map. This map is updated on a weekly basis and represents information concerning transportation assets, including ITS assets, dynamic message signs (DMS), and traffic cameras at their respective locations. Along with this Asset Web Map, users also can access SDOT's asset inventory in a status-and-condition report for a given year. The report describes the framework and efforts to align with MAP–21 requirements (Asset and performance Management, 2015).
- Pennsylvania DOT – PDOT includes ITS assets in the TAMP. Along with the inventory of ITS assets in its jurisdiction, lifecycle cost considerations and replacement costs for each ITS device are included in the TAMP as well. The TAMP does not adopt any special performance measures but relies on the devices' effective life to determine replacement needs. Users can refer to the appendix of the TAMP for detailed information of ITS assets under PDOT (Transportation Asset Management Plan, 2014).
- Louisiana Department of Transportation and Development (LADOTD) – The LADOTD has a comprehensive asset management plan that covers pavement conditions as well as ITS assets. ITS management is maintained in collaboration with ARCADIS using methods such as performance

measurement, online dashboard with a graphical user interface (GUI), filters, a geographical interactive map, monthly review reports, device inventory, routine maintenance page, etc.

- Oregon DOT (ODOT) – Implements Exor Transportation Intelligence Gateway (TIG) to assemble all data from different sources, which in turn produces the Highway Performance Monitoring System (HPMS) extract for the FHWA. This tool also is used to transfer data from the Exor system to geographic information system (GIS) applications, including ITS. This tool has helped the productivity of ODOT to leverage corporate asset data and try to align with MAP-21 requirements (Transportation Information Gateway Collaboration Project , 2014).
- Arizona DOT (ADOT) – ADOT's TAMP is taking steps toward ITS asset management using examples and practices currently laid out for pavement and bridges. However, the Arizona Statewide Intelligent Transportation System Architecture serves as an informational source for any scoping, planning, stakeholders, inventories, services, roles and responsibilities, needs, interfaces, standards, agreements, and projects that are involved with ITS, showcasing the integration of ITS asset management between AZDOT and all stakeholders involved in ITS assets and infrastructure (FHWA, September 2019) (AZDOT, n.d.).
- Colorado DOT (CDOT) – Colorado is one of the few states that includes ITS assets in its risk-based (RB) TAMP, which includes an inventory of ITS assets, along with their condition. This 2013 TAMP provides details of MAP-21 requirements and how the RB TAMP addresses each requirement (CoDOT - RB TAMP , 2013).

3.4. Limitations

Applied strategies do not always provide the desired results; hence, it is necessary to be as precise as possible in performing different tasks. According to the FHWA (Asset Management Overview, 2017), common issues raised by local governments regarding transportation asset management include:

- Getting management and staff commitment is an important requirement for successful adoption of asset management philosophy and principles.
- Building and maintaining the asset inventory is a necessary first step, and it may be accomplished by progressively drawing on available information while conducting infield surveys.
- Asset condition assessment and valuation may be accomplished at several levels of sophistication without compromising the value of the asset management program as a decision-making tool.
- Asset management "programs" may be based on simple spreadsheets, as well as sophisticated database management packages, to match the needs and resources of the agency.
- Condition monitoring and maintenance of asset inventory data are essential to maintaining the validity of the asset management program, and they require a continual commitment from management.
- Intermodal comparisons—i.e., establishing priorities among different functional asset classes for resource allocation—can be supported by the asset management program.
- Standards regarding satisfactory or acceptable levels of service for infrastructure assets may vary substantially from one community to another.
- Sharing information among departments and establishing common databases are effective ways to reduce the costs associated with the implementation of an asset management program and improve the quality of management information. Existing data, such as property assessment records, can be used as a basis for setting up the asset management program.
- Asset management tools need to be simple if they are to be used over an extended period; the tools need to be easily understandable, adaptable to the user's specific interests, and easy to operate without entailing lengthy, tedious activities for data entry, formatting, and other routine operations.

Similarly, many difficulties are faced in organizing ITS assets. Various issues encountered by state DOTs include:

- Organizational culture may be one of the most significant obstacles to advancing asset management in an agency.
- No one model can serve as the panacea in moving forward with asset management.
- Agencies that are taking substantive steps to do good asset management differ in their use of the modified approach or Government Accounting Standards Board (GASB) 34 reporting.
- Agencies that have evaluated the Self-Assessment Tool developed by the NCHRP have found it helpful in identifying gaps in their approach to asset management or have endorsed it as a useful starting place for agencies interested in beginning asset management.

4. Review of Current NDOT Data Platforms, Governance, and Management

A comprehensive review of the current data platforms, governance, and management of the ITS assets was undertaken to provide a better understanding of what specific needs the current solutions are addressing, as well as what changes are necessary to transition into more effective TSMO asset management. Findings in the following sections were used to further determine overlaps and gaps and to help develop the basis of a good management strategy for TSMO and ITS assets.

The following sections include a review of TAMP, Enterprise Asset Management, AMP, and National Data Exchange (NDEX).

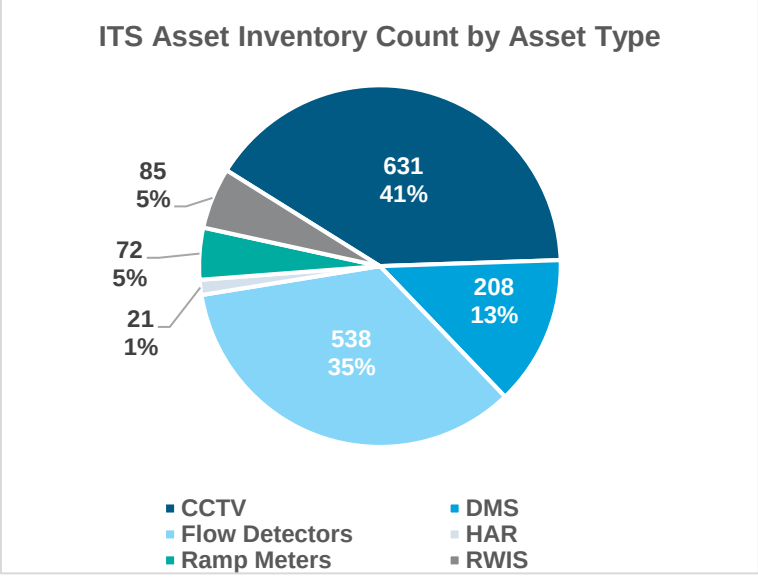
4.1. NDOT TAMP

NDOT has documented various platforms that allow staff to review and update the information for the general public to track progress. For asset management, NDOT has prepared a TAMP to align with FHWA requirements. It includes management techniques of pavements, bridges, and ITS assets. This study being focused on ITS outlines NDOT's strategies for ITS asset management included in its most recently published TAMP. The following ITS assets are addressed in NDOT TAMP:

- Closed-Circuit Television (CCTV)
- Dynamic Message Signs (DMS)
- Road Weather Information System (RWIS)
- Flow Detectors
- Ramp Meters
- Highway Advisory Radio (HAR)

Inventory counts can be found in Figure 2, below.

Figure 2: ITS Asset Inventory



Source: NDOT TAMP

NDOT has developed asset management techniques for pavements, bridges, and ITS assets. This section focuses only on the ITS assets. Lifecycle analysis, risk management, and financial investment and strategies were various factors considered for ITS assets in the TAMP. The condition of certain assets and management of the assets for the next 10 years was included as well. TAMP content has been developed based on the guidelines of FHWA TAMP requirements and will be updated on a regular basis.

MAP-21 legislation supported TAMP and encouraged states to include a 10-year investment strategy that enables them to make progress toward state performance targets and national goals. Following MAP-21, Fixing America's Surface Transportation Act further supports the requirements for a TAMP.

For proper maintenance and development of the TAMP, NDOT has formed an Asset Management Oversight Committee (AMOC) to provide guidance and direction during the TAMP update process. AMOC will lead NDOT's initiatives and make sure that the department stays on track to improve the condition of its transportation assets. Implementation of an Enterprise Asset Management System (EAMS), development and implementation of protocols to monitor and assess maintenance of ITS assets, and implementation of a statewide enterprise GIS system are the three major short-term asset management improvement initiatives highlighted in the fully compliant TAMP.

4.1.1. Lifecycle Planning

Asset value is preserved, and total cost is minimized through asset management practices. These practices recommend effective treatment strategies throughout the entire lifecycle of an asset. Lifecycle planning (LCP) analysis of ITS assets is crucial to minimize costs. Implementation of an ITS device requires understanding and knowledge of both the initial cost and maintenance costs during the duration of its service life.

For TAMP purposes, the conditions of the ITS assets were based on manufacturer's recommended service life. Good, low risk, medium risk, and high risk are the four conditions used to identify ITS assets. Table 1 below shows the classification for each condition.

Table 1: ITS Asset Condition

	Age of Device
Good	< 80% of manufacturer's recommended service life
Low Risk	> 80% of manufacturer's recommended service life < 100%
Medium Risk	> 100% of manufacturer's recommended service life < 125%
High Risk	> 125% of manufacturer's recommended service life

Based on the condition of the device, four different maintenance activities are performed: inspection, minor repairs, major repairs, and replacement. As stated in the fully compliant TAMP, the four activities can be defined as:

- Inspection: Involves routine maintenance of the device or asset, typically performed annually or biannually based on device type
- Minor Repairs: Typically performed on-site and these include small repair activities, i.e., adjust loose cables, replace battery, and upgrade firmware
- Major Repairs: Typically requires the device to be sent back to the maintenance shop or factory for repairs and it also may involve the replacement of one or more key parts to ensure satisfactory device functioning
- Replacement: Complete removal and replacement of the device

In addition to the four types listed above, the NDOT Traffic Operations Division utilizes a process and schedule for preventative maintenance for all ITS assets. The goal of the preventative maintenance program is to service the ITS devices with the goal of keeping them in a good operating condition throughout the lifecycle of the device.

In some cases, NDOT will allocate maintenance or inspections to other agencies. For example, NDOT provides funds to the Regional Transportation Commission (RTC) of Southern Nevada (SNV) for inspections and maintenance of devices in southern Nevada. This allows for timely service.

Table 2 shows the correlation between the current condition of the device and the resulting condition after each maintenance activity.

Table 2: Maintenance Activity Impact Matrix

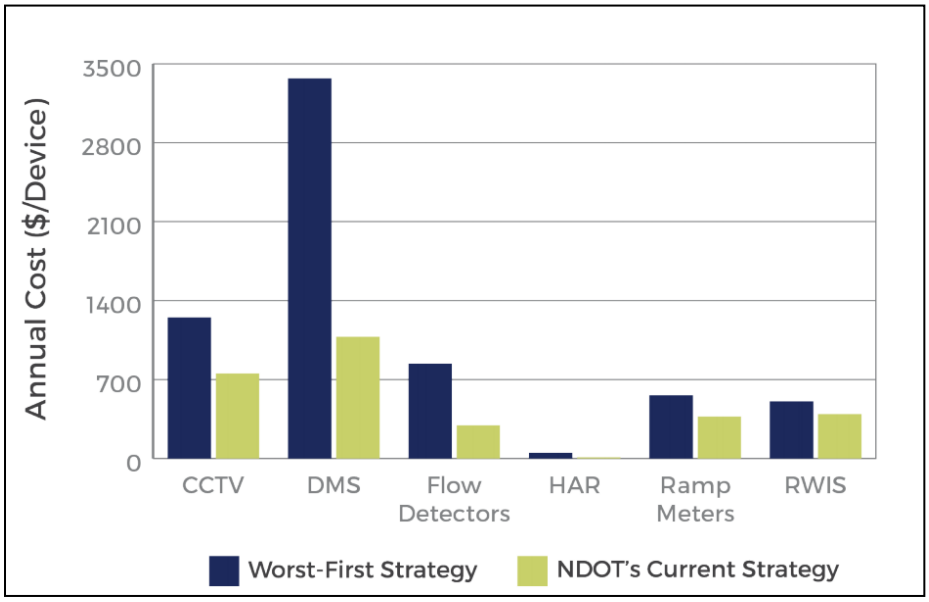
Current Condition	Resulting Condition After			
	Inspection	Minor Repair	Major Repair	Replacement
Good	Good			
Low Risk	Low Risk	Good		
Medium Risk	Medium Risk	Medium Risk	Low Risk	
High Risk	High Risk	High Risk	Medium Risk	Good

In addition, NDOT has already developed device-specific maintenance activity categories and health conditions and will be integrating these measures into AMP.

To determine the effectiveness of NDOT's ITS asset maintenance strategy, an LCP analysis was conducted against a "worst-first" approach, or scenario in which no inspection or maintenance occurs, only replacement after failure. A visual comparison of the two lifecycle management strategies is found below in Figure 3. The comparison shows that the annual maintenance cost is significantly higher using the "worst-first" strategy.

Thus, the overall idea of conducting a network-level LCP analysis is to identify the most cost-effective, long-term investment strategies to keep the infrastructure in serviceable and operational condition.

Figure 3: Summary of ITS Asset Lifecycle Planning Analysis Results



4.1.2. Risk Management

The development of a TAMP typically involves an assessment of risks that could impact the DOT's intended outcomes for each device. The risk management analysis is conducted primarily to articulate what does or could impede NDOT's asset management objectives, disclose any uncertainties that must be addressed by NDOT to achieve its long-term goals, identify any decisions that could damage the public perception of NDOT, and prioritize investments to mitigate risks.

Various risk factors exist, from extreme weather events to operational hazards such as a vehicle collision. These risks can prevent NDOT from meeting its goals. A comprehensive risk analysis will consider a variety of risks at all levels. The three classification levels are agency risks, program risks, and project risks, with agency risks being considered as the highest level of risk within the DOT.

To ensure that risks are considered consistently and monitored regularly, NDOT has embarked on the implementation of an Enterprise Risk Management (ERM) program that extends the risk analysis conducted for the TAMP to a broader array of strategic, program, and activity risks.

NDOT considered various risk management factors while developing its investment plans, resulting in savings of $1.1 million overall.

4.1.3. Financial Plans and Investment Strategies

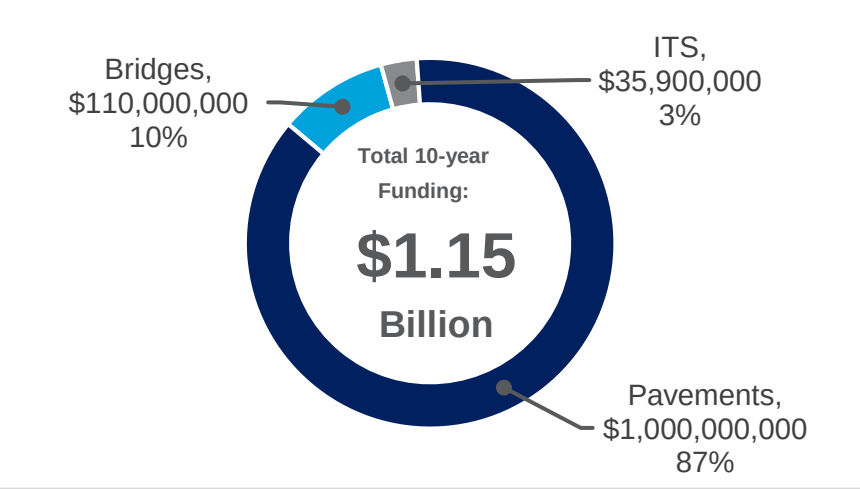
NDOT's revenue is estimated to be approximately $770 million annually, of which it expects to spend $140 million toward maintenance and asset management services. The investment in ITS assets is projected to remain steady over the next 10 years. However, a 2-percent inflation rate has been applied to future maintenance and preservation costs, as the costs to address needs are predicted to increase each year and NDOT's purchasing power is expected to decline due to inflation.

Table 3 shows expected annual investments on ITS asset management activities over the next 10 years. As seen in Figure 4, NDOT intends to allocate 3 percent of maintenance and asset management funds toward ITS between 2017 and 2026.

Table 3: Expected Annual Budget for ITS Maintenance

	Work Type	Budget ($ Million)										
		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	Total 2017-26
ITS	Maintenance	$3.59	$3.59	$3.59	$3.59	$3.59	$3.59	$3.59	$3.59	$3.59	$3.59	$35.90

Figure 4: Expected Budget for Pavements, Bridges, and ITS



The $3.6-million annual investment is disbursed among the three districts. Based on the volume of assets each district maintains and manages, District I (DI) will require 57 percent of the total investment, District II (DII) will require 27 percent, and District III (DIII) will receive the remaining 16 percent.

There are no formally adopted performance measures for ITS assets, but NDOT is looking to adopt and integrate ITS assets into the EAMS software in the near future. At present, the performance measures of ITS assets depend on the lifecycle recommended by the manufacturer. Based on this, all the repair and rehabilitation are carried out to keep the assets in working condition.

Several meetings with the ITS asset group helped NDOT adopt an investment strategy that, in turn, provided an appropriate response to the aging equipment and devices. To predict the deterioration of the devices, a simple MS Excel-based spreadsheet tool was developed to determine the 10-year investment requirements to maintain the current levels of service. The ITS asset investment strategy consists of first determining the device condition, defining general procedures and protocols, computing the associated cost, and identifying the appropriate activities. Then, NDOT determines maintenance and repair activities. This strategic approach will be used to maintain the current levels of service for ITS devices.

4.1.4. Asset Management Enhancements

Maintenance is required for all assets on a timely basis. ITS assets also require repairs over their lifecycle. It is necessary to keep track of such activities, which then assists in determining investment needs. NDOT AMP has developed specific capabilities to keep track and maintain detailed records. These capabilities include, but are not limited to:

- Improve tracking of contracted maintenance activities: It is crucial to track maintenance activities performed by external contractors. The existing maintenance management system does not provide required accuracy in generating the results. This factor is being studied and will be replaced by a maintenance management module within the EAMS software that will generate the required accuracy for tracking maintenance activities.
  - NDOT is expanding the maintenance tracking to cover not only contracted maintenance, but also maintenance activities performed by NDOT staff.

- Develop protocols to ensure consistency in maintenance and management of ITS assets: Recent changes made by NDOT offer more autonomy and responsibility for each district in maintaining ITS assets within their respective jurisdictions. Also, the funding will be provided to each district based on the number of assets being maintained. To confirm alignment in inspection methods, maintenance protocols, and other maintenance strategies between all three districts, maintenance agreements have been prepared by NDOT, which each district is required to follow when using the allocated funds to maintain ITS assets.

Along with this requirement, NDOT will develop a verification process to check whether each district is upholding the maintenance agreements. This process also will notify and provide information to the central office to determine whether any changes are required to the maintenance agreements.
  - NDOT is working on amending the agency's current maintenance agreements towards a performance-based agreement for those ITS assets to align with the TAMP.

- Establish a statewide GIS database: Significant resources were invested by NDOT to develop a statewide enterprise GIS database that provides access to statewide asset inventory along with its current condition. It is expected to begin implementation followed by its in-house training. When it is in practice, NDOT officials will be able to use the new system to improve the existing management and reporting process.

Section 4.3 further elaborates on the NDOT AMP capabilities.

4.2. Enterprise Asset Management System

NDOT's ITS asset inventories were incomplete, not accessible department-wide, and stored in separate databases. Primary importance was placed on developing a complete and easily accessible asset inventory that could be accessed by all officials. The NDOT TAMP mentions that the IT division will implement the Agile Assets Infrastructure asset management software. Initially, asset inventories for pavements, bridges, and hydraulic structures will be included, followed by the integration of other assets such as ITS. This EAMS solution will result in reduced risk, enhanced system usability, and increased staff efficiency through data integration across the organization. Training programs will be conducted within NDOT to have a successful transition from the existing database system to the EAMS platform.

In the meantime, the Traffic Operations Department is working on setting policies and procedures to mandate the use of AMP for ITS asset management at a statewide level. This will assist stakeholders to more efficiently operate and manage their ITS assets, as well as providing the department with an easier transition into EAMS in the future.

4.3. NDOT AMP and NDEX

NDOT maintains and updates its database containing information on different ITS assets. This database is updated automatically for each ITS asset based on a pre-determined time interval. It thus becomes necessary to review all the sources of information to determine if there are any overlaps or gaps.

NDOT maintains a database for all ITS assets within its jurisdiction. Users can get detailed description of any asset at its respective location. All the information for ITS assets is stored and updated in the NDEX database. Along with NDEX, other sources of data are available as well. NDOT staff can get access to additional asset information after logging in with predefined credentials. Table 4 briefly describes the type of information generated and maintained in the database for each ITS asset.

To elaborate further, there are four sources of information currently available to NDOT, including field devices, KITS, NDEX, and AMP. KITS is the system that controls the field devices and collects data such as status, location, and sensor information. At defined intervals, this data is transferred to NDEX and is available to users through the Data Visualization Module that has been created for NDEX. AMP contains detailed system and device information for inventory, workorder, preventative maintenance, and asset management such as maintenance schedules and performance measures. The AMP dashboard can be accessible by registered users. The AMP dashboard has the capability to generate reports which can be modified based on the users' defined information.

Table 4: ITS Asset Information Available from NDEX

Device	Database Information
CCTV	• CCTV inventory and statistics • Location and its functions, such as camera name, ID, URL, type of image, etc. • Device monitoring • Communication performance statistics by district • Information regarding previous dates/range
Flow Detector	• View inventory and statistics of detectors in a tabular form • Displays statistics by lane, such as volume, occupancy, speed, type of sensor for the last update • Communication performance statistics by center, including percentage working trend, total # of detectors, total # of lanes • Visual representation of communication summary over the past 24 hours
DMS	• Device status, message, message number, and source along with detailed message logs • Access the DMS statistics based on the date of interest • Visual representation of communication status, distribution of communication status, and % working trend
Mobile RWIS/ Environmental Sensor Stations (ESS)	• Statistics and communication preferences information such as air temperature, wind speed, gust speed, and direction, and other similar atmospheric factors • Communications performance statistics to view the status over the past 24 hours • Basic inventory of ESS in each district
HAR	• Statistics and communications performance information such as device status, message, message beacon status, and detailed message logs • Displays inventory and the communication status of HAR in each district
Incidents	• Detailed reports of incidents across the state including graphical representations of incidents and type of incidents for each district • Number of incidents corresponding to each event for all three districts • Event types including accident, construction, incident, other, special event, and weather • Detailed reports by entering the incident parameters to enable analysis of the cause of an incident and determination of precautionary measures
Ramp Meter	• Statistics and communication performance • Displays the last updated information of the selected meter including device status, last communication time stamp, implemented action, implemented plan/rate, and vehicles per green • Statistics, communications performance statistics for ramp meters by district • Visual representation of communication status in each district
RWIS	• Accessible to both the general public and agency users • Agency users can access detailed information at specific locations • Information such as temperature, wind, gust, humidity, etc. • View additional columns in tabular format such as surface temperature, pavement temperature, soil temperature, surface status, and surface freeze points

Wrong Way Driver Systems will be added along with data measures and visualization features in the future.

5. Stakeholder Engagement and Needs Assessment

Effective engagement of stakeholders is a critical element in defining and shaping their needs and translating the needs into goals. This helps develop the basis of an effective strategy, identify focus areas, and assist the stakeholders in their decision-making process.

In developing this Business Plan, DI, DII, DIII, and the RTC SNV Freeway and Arterial System of Transportation (FAST) were considered to be the main stakeholders in this process because of their involvement in day-to-day operations and maintenance of TSMO and ITS assets, as well as their vested interest in the success of the organization.

The aim to engage the stakeholders at the early stages of the planning process was to understand their operating environment, identify their needs and challenges, identify their top priorities in operations and maintenance of TSMO and ITS assets, and have first-hand knowledge of what it takes to deliver these types of projects. To this end, a survey questionnaire was developed and sent to the stakeholders with specific questions aligned with the goals and objectives of their engagement. The survey questionnaire is included in Appendix A of this document.

The survey questionnaire included questions in the following six areas:

1. Performance measurement and data collection plans for the operation and maintenance of the assets
2. Repair and maintenance plans of the assets
3. Efficiency and/or redundancy of TSMO and ITS assets
4. Current platforms and data collection methods
5. Priorities for data collection and operation and maintenance of the assets
6. Challenges and needs, and required system capabilities

The responses and interviews revealed the following findings in each area:

1. Performance measurement and data collection plans for operation and maintenance of the ITS assets

   Except DIII, stakeholders have not developed specific performance measures for the operation of the ITS assets within their territories. However, they all have developed goals and scheduled performance measures for performing preventative maintenance. Stakeholders have developed data collection plans for the ITS assets for their districts, but they are not used for operations performance measurement.

2. Repair and maintenance plans of the ITS assets

   Stakeholders currently have plans and processes to follow for the repair and maintenance of the assets (such as preventative maintenance). More specifically, DII has developed a checklist for technicians to use as the basis of repair activities, thereby providing a clear direction on required actions for preventative maintenance. Stakeholders' responses indicated that—even though there are no specific plans and processes for performance measurement, operations and maintenance, and repair of the assets—the perception is that most of the devices are operational and maintained effectively. However, RTC FAST has indicated that they do not have access nor utilize AMP or NDEX. Therefore, there is no way to reliably verify if the ITS devices are operational.

3. Efficiency and/or redundancy of ITS assets

   It was determined that, due to the absence of a structured approach in data collection, DII and RTC FAST are experiencing redundancy between some of the ITS devices and are willing to address this through a more effective data collection plan. Another important finding was that they are not aware of potential redundancies within the fiber and ITS communication network. In addition, some ITS (such as trailblazers in DI, HAR and truck ramp meters in DII) are currently not operational because of different parameters, such as districts' priorities, hardware, electrical issues, etc. DIII confirmed that there are no redundancies of ITS assets in the district; however, HAR and RWIS devices are obsolete.

4. Current platforms and data collection methods

RTC FAST indicated that the agency is not utilizing any of the currently available platforms for ITS asset management and is utilizing a different strategy for data collection and management of the ITS assets due to the lack of knowledge about available resources. However, DII and DIII are utilizing NDOT TAMP, the AMP, and the NDEX Dashboard. Stakeholders also have acknowledged their awareness of the transition into EAMS for TSMO and ITS asset management in the future.

5. Priorities for data collection, operation, and maintenance of the ITS assets

- Data collection priorities:
  - Refine the information in TAMP so that it is more user-friendly
  - Condition of the devices
  - Uptime/downtime frequency
  - Have access control on the AMP dashboard
  - List power sources for ITS devices
  - Lifecycle plans and management
  - Perform data collection for troubleshooting purposes

- Operation and maintenance priorities:
  - Create procedures and protocols for installation and maintenance of new technologies for gained efficiency
  - Have a maintenance checklist for emerging technologies
  - Create an overall ITS fiber plan
  - Respond to the need for a testing phase prior to full deployment and adoption
  - Create corridor-specific ITS Strategic Deployment Plans (SDP)
  - Ability to communicate with the devices
  - Troubleshooting and emergency repairs

6. Challenges and needs, and required system capabilities

- Challenges and needs:
  - Simplification of the solutions, strategies, and software, such as 511 and KITS software, etc.
  - Network communication
  - The need for a complete inventory of the assets
  - Inability to sole source ITS devices
  - Local staffing and resources
  - Incompatibility of old software with new technology
  - Best practices in equipment and technology procurement

- Required system capabilities:
  - Consolidation of software and solutions
  - Flow detector and breakdown of classification
  - Location information of the assets
  - Weekly performance, health reports, and monitoring of ITS devices
  - Troubleshooting functionality
  - A decision support system

Further analysis of overlaps and gaps are described in Section 3.4, following a review of the current NDOT platforms, governance, and management of the assets.

6. Overlaps and Gaps Analysis

The findings from the stakeholders' survey responses and the review of the existing NDOT asset management strategies were used as the basis of the overlaps and gaps analysis. This information helped determine what specific elements should be taken into consideration for ITS Asset Management implementation and roll-out at a statewide level, as well as alignment of current ITS Asset Management strategies with future TSMO AMP. Considering the ITS Asset Management Strategic Goals and Objectives, this business plan performs overlaps and gaps analysis of needs and requirements in the following areas:

- Existing and needed data sets and capabilities
- Overlapping data within existing asset management systems and platforms
- Alignment with TSMO data collection and utilization framework
- Alignment with federal reporting requirements

For each area, a description of the analysis has been provided, along with recommendations that will be considered during the development of the ITS Asset Management Implementation in Section 8.

6.1. Existing and Needed Data Sets and Capabilities

NDOT, through AMP, is currently collecting data sets on the majority of the ITS devices. Review of the NDOT's existing ITS management systems and platforms indicates that formalized data collection plans and parameters are lacking at a statewide level. Development of data collection plans in alignment with NDOT's ITS assets needs and priorities, TSMO needs and priorities, and federal reporting requirements will establish a unified direction in data collection for both NDOT and the stakeholders.

Under three main categories of Nevada Shared Radio System (NSRS), ITS and Signal, Lighting and ITS (SLI), the existing data sets within AMP include the following:

- Location information (e.g. channel, adjacent site, district number, site manager/owner, deployment status)
- Work order reports (e.g. location, problem, responsible party, due date, status, etc.)
- Lifecycle plans
- License information, expiration date, and system ID
- Power and communication details
- Equipment information and specification (e.g. serial number, model, warranty expiration date, etc.)
- ITS device name, category, and status
- Licensing, manufacturer, and specification
- Device update requirements

For a complete list of all data parameters within the AMP, please refer to Appendix D.

6.1.1. Suggestions

It is suggested that NDOT would develop formalized data collection plans and reports for integration into AMP. In addition, the AMP data parameters should be reviewed to identify missing data from the existing fields. More details have been provided in Section 8. These plans and reports will be developed in alignment with the following:

- Lifecycle management plan per device
- Health index reporting
- Assets critical to sustained performance (assets prioritization)

Based upon the study of best practices and stakeholder surveys, the additional needed data sets and capabilities at minimum shall include the following:

- Troubleshooting and emergency repairs strategies and recommendations
- Risk management analysis
- Performance reports and gaps identification
- Maintenance checklist for devices
- Preventative maintenance and diagnostics
- Financial reports and automated replacement costs
- Generate automated frequent reports
- Health index and routine maintenance reports
- GUI, filters, and geographical interactive map

6.2. Overlapping Data Within Existing Asset Management Systems and Platforms

The study reviewed the existing NDOT asset management systems, as well as stakeholder survey responses, to determine areas of interoperability and increased functionality. The reviews determined that, even though there is no redundancy in data collection between AMP and NDEX, RTC FAST using their own data collection strategies has resulted in overlapping and redundant data collection. In addition, and as discussed in Section 5, DII and RTC FAST are experiencing redundancy between some of the ITS devices and are unaware of potential redundancies within the fiber and ITS communication network.

Similar to the first focus area, there is a lack of formalized data collection and generation processes and parameters. NDOT is addressing this challenge with providing access to NDEX and AMP to the stakeholders and in the future will mandate users to follow agency's processes and procedures for ITS asset management. Another recommendation is for NDOT to fully integrate NDEX and data visualization capabilities into AMP through a single user log in. More specific recommendations are as follows.

6.2.1. Suggestions

NDOT shall consider development of formalized data collection plans and reports for integration into AMP. This will be undertaken in alignment with:

- ITS assets performance measurement plans and reports
- Enhanced AMP and NDEX integration
- Provide access to the AMP for stakeholders
- Development of a single maintainable asset data source that can be used across several systems
- Identification of types of data produced from each asset and/or device and for what purpose
- Development of data integration plans
- Development of data collection specific to TSMO strategies and performance measures
- Development of formalized adopted data language

6.3. Alignment with TSMO Data Collection and Utilization Framework

Currently, the existing data collection and utilization frameworks are focused on specific ITS assets and devices. TSMO strategies use a tool box of ITS assets and devices for safety and mobility improvements. Therefore, there is a need to establish a framework that would collect and use the data for performance-driven decision making.

6.3.1. Suggestions

- Development of TSMO AMP
- Development of data collection specific to TSMO strategies and performance measures
- Alignment of data collection and utilization framework with TSMO performance measurement program
- Development of analysis to measure not only the performance of individual devices, but also the impact of each device on the transportation network operation

6.3.2. Alignment with Federal Reporting Requirements

Review of federal reporting requirements indicated that there is not a focus on specific ITS and/or TSMO asset operations and maintenance. However, with the increased uptake of TSMO at a national level and reporting requirements on safety, mobility, and reliability improvements, development of specific plans for TSMO and ITS asset performance will help NDOT not only meet strategic goals at a statewide level, but also enable any future federal reporting needs.

6.3.3. Suggestions

- Development of ITS asset health reports and performance measurement
- Development of a framework that aligns with TSMO strategies to future proof NDOT's TSMO asset management system

The suggestions identified in this section will help shape the NDOT ITS Asset Management Implementation Plan. The details are described in Section 8 of this document.

7. NDOT TSMO Asset Management Data Collection and Performance Measures Development

NDOT recognizes the importance of developing standardized data collection and performance measurement plans for the management of ITS assets. This also will help formalize the processes and procedures for data collection and performance measurement of TSMO assets and emerging technologies.

The following sections include information on requirements for protocols, licensing, quality control plans, data collection, storage, archiving, and analysis, as well as dissemination and performance measurement framework. This information has been utilized in development of the Implementation Plan that was discussed in Section 4 of this document.

7.1. Protocols

A standard maintenance protocol is required to fully ensure consistency across the various NDOT assets and locations. With a standard protocol in place, it will create asset management standards for NDOT to manage the assets and capture and measure the asset performance across the entire state, down to a particular asset and manufacturer.

Typical protocol attributes would include:

- Inspection schedule
- Inspection requirements
- Replacement schedule
- Seasonal-based requirements
- Asset data to be recorded

7.2. Licensing Requirements

For the new asset management system, NDOT must ensure that the vendor providing the solution has a flexible and commercially acceptable licensing model. Any new system must adhere to NDOT's current standards on software licensing. Licensing is an effective method of balancing the requirements of infrastructure and support for the number of users accessing the system. The more users, the greater the cost of hosting the system and the higher the number of potential support calls and system maintenance.

There are several licensing models and the top three are listed as follows:

- Perpetual Licensing: This is the simplest model; the regular "buy then use forever" approach.
- Subscription-Based Licensing: Software as a service, most preferred for cloud-based solutions, only pay for what you need.
- Concurrent Licensing: Cost-effective method for purchasing licenses. Based on total number of users on the system and not on specific user login.

Other licensing types:

- Floating Feature Licensing: For specific features within the software application, certain features would have a maximum number of concurrent users, but the base system is available.
- Consumption-Based Licensing: Typically billed post-use and based on the number of users accessing the system, must allow for tracking of users and features accessed.
- End-Date Based Licensing: When you want your licenses to be valid up to a fixed date then stop working, you can use End-Date Based Licensing.

- Feature-Based Licensing: Restriction of features for any license code or account means you have fine-grained control over what aspects of your software each user can access.

7.3. Quality Control Plans

For an asset management quality control plan to perform efficiently, it must be aligned and integrated into NDOT's strategic asset management plan and objectives. The quality control plan must ensure that the organization's goals and objectives are adhered to and this plan contributes to their delivery.

The asset management quality control plan is the action plan that the relevant maintaining parties will follow, with the inclusion of the defined protocols to ensure continued consistency of the maintained asset. The plan must include detailed written instructions that leave no misinterpretation and flow diagrams visualizing the steps to be followed. This will be concluded with a list of data to be captured in a layout as is required by the new asset management system. Depending on the asset type, complexity of the asset, or asset function, differing levels of details will be required.

Prior to commissioning a new asset type, a new plan for that particular asset type must be defined and included within the asset management quality control plan. This will be based on the manufacturer's specifications and alignment to the asset management strategic plan. For any new asset, special consideration must be made to monitor the asset's performance before the first scheduled maintenance activity and then it must be adjusted as required.

All the individual plans included within the asset management quality control plan are constantly available for review. The individuals undertaking the activity must understand first-hand the effectiveness of the plan, and a mechanism needs to be in place to allow this feedback to change the plan, as needed, for maximum benefit to the asset and NDOT. Following a failure of the asset that could have been prevented if the plan was improved, this information must be included in a subsequent review of the plan. In addition, there needs to be a periodic review of the asset management quality control plan by management and stakeholders to ensure the plan is still in line with the strategic view and any statewide safety improvements.

Quality plans should define and include:

- End-to-end process and any sub-steps
- References to any documented standards, manufacturer instructions, local practices, company procedures
- Data to be captured
- Process to instigate a change in process for improvement
- Process for a defect or quality issue is discovered with an asset
- Objectives of the plan
- Training requirements
- Responsibility matrix, including authority levels, resources
- Suitable testing, inspection, examination, and audit programs at appropriate stages
- Performance standards and how performance will be captured
- Training needs
- Testing requirements and specific tools needed
- Audits
- Communication to relevant parties of changes to the process and/or safety issues with an asset
- Schedule of reference documents

7.4. Data Collection

To populate the AMP (and the future EAMS) database with assets and ongoing maintenance activities of the system, and to ensure all the data within the system is up to date, ongoing data collection must be performed. There are three ways data can be collected—manually, automated, and remotely.

7.4.1.1. Manual Collection

Requires individuals to visit every asset and capture its geographical location and asset condition. The asset condition survey requires an intensive labor effort. Details are best captured on a portable computer and transmitted directly into the master system. This will include any manual data entry of the assets as well.

7.4.1.2. Automated Collection

By the use of technology such as data dashboards, third-party data interfaces, global positioning system, camera, lasers/LIDAR, data can be captured using a level of automation. This is best for fixed assets and would only capture certain asset types that are recognizable by the system.

7.4.1.3. Remote Collection

The majority of ITS assets have connectivity to a control/management system that monitors the status of the equipment. The asset management system would use this connectivity to capture the asset status. On a system failure, the primary host system would automatically generate a record in the asset management system against the asset, giving cradle-to-grave accountability.

7.4.1.4. Data Attributes

Using any of the above methodologies, the data types to be captured are as follows:

- Source, owner, granularity, frequency of collection, uses for prioritized data sets
- Existing and needed data, e.g., asset inventory, location, and condition
- Traffic, safety, mobility (volume/speed), and accessibility
- Work order information data, downtime, installation, and replacement/obsolescence dates
- Technical specifications (time resolution [5 min, 30 min])
- Spatial resolution (1/3-mile, 5 miles, etc.)
- Inventory of the assets (internally available and any external if needed)

For the initial creation of records in the asset management system, the system will need to have the ability to import data from multiple data formats. This will comply with NDOT's current system or systems for capturing asset data.

7.5. Data Storage

Any data stored on the asset management system must adhere to NDOT current standards for data storage. As per industry best practices, a second copy must be kept in a separate location—either in a physical location or cloud based. All relevant metadata will be stored for effective record retrieval.

Data will be stored in an efficient manner as to maximize the use of storage and remove any additional unneeded costs. The data storage facility will maximize its green energy credentials.

The asset management system must have the ability to continue to function if the data storage facility goes offline for a maximum of a 24-hour period.

7.6. Data Archiving

As per NDOT's current standards, the asset management system must have the ability to archive records over a pre-determined date. To ensure performance of the system is kept at a manageable level, assets that have been de-commissioned will have the details of the record archived from the main asset management system. Data on any asset older than a pre-defined period also will be moved into an archive area. This will not include all the data, but any attached files that have the potential to impact the overall system performance.

The system will keep a reference to the asset for a predefined period of time. In addition, when the system is replaced or made redundant, all the data from the system is to be kept in dual secure locations for a pre-determined period of time.

A process must be created to manage how the data are to be recovered from the archive and either re-populated into the asset management system or viewed using another software tool to access the relevant information.

All archived data will be stored at two separate locations to ensure data redundancy.

7.7. Data Analysis and Dissemination Framework

NDOT will need the capability to export the asset management data into other software tools used by NDOT. This will require the data to be extracted in various formats.

Within the asset management system, a high level of data analysis will be achievable. This analysis of the data will be of the type that enables users of the system who are responsible for an asset type or location area to fully understand the characteristics and performance of an asset or assets.

The output of data analysis will show trends in asset performance and how, for example, certain asset maintenance schedule changes affect the asset.

Typical data analysis will include:

- Maintainer schedules
- Maintainer performance
- Maintainer attributes
- Asset by maintainer
- New asset reliability
- Assets reliability across regions

The asset management system will disseminate the data and reports to a pre-determined set of users; these users and reports/data types will be a configuration setting in the system. The system also will include auto-generation of alerts based on set criteria.

The standard system reports will use a dissemination matrix to determine which set of reports/data is sent to which individual or groups.

A maintainer will have access to the system to perform data analysis, but this will be limited to the location and assets maintained.

7.8. Performance Measurement Reporting Framework

Having an effective performance measurement reporting framework will enable NDOT to improve asset performance, reduce asset downtime, and improve asset availability across the state.

The asset management system will record any deficiencies against the individual asset as one of the asset attributes. This record will capture the root-cause analysis of any unplanned downtime of the asset.

Typical attributes of asset availability are as follows:

- Time/date of failure
- Time/date of rectification
- Root cause of failure
- Cost of the rectification
- Type of failure
- Failure impact rating on Return on Investment (ROI)

Each of the above data sources will be captured per unplanned downtime of the asset and a historical set of data will be recorded per event. This will enable Key Performance Indicators (KPI) to be created for the asset and asset types. KPIs will form part of the core reporting features and a trigger of a KPI being either hit or missed, depending on the KPI type, will result in an alert being raised in the system and communicated to the responsible party or parties automatically. These alerts are designed to allow intervention by an asset owner or maintainer prior to the negative availability of an asset that could impact the performance of the transportation network.

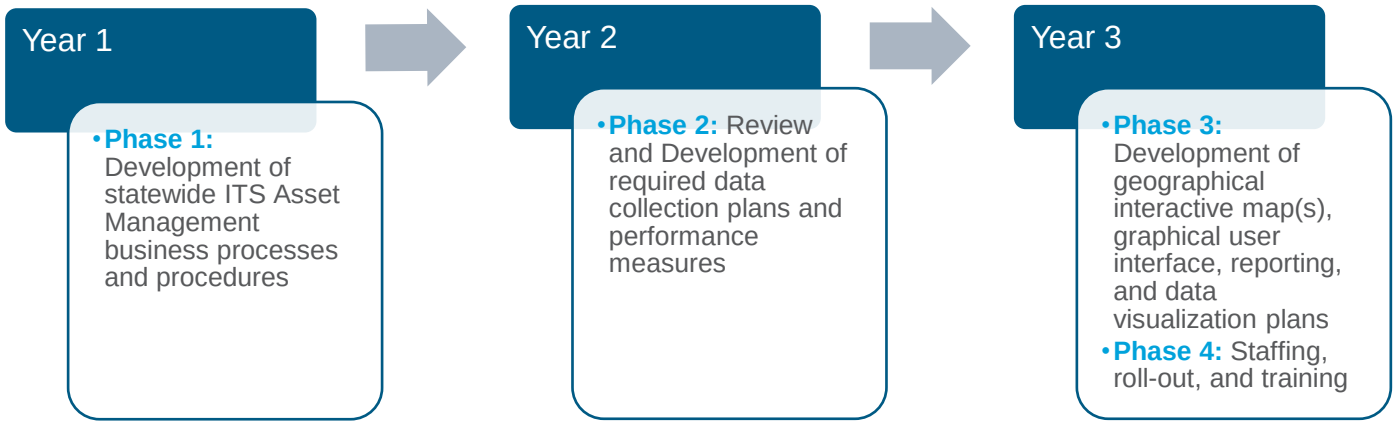
All KPIs will have a set benchmark based on either contractual requirements of the maintainer or internal reporting requirements. The output of these KPIs and the data used to create the reports will allow NDOT to perform detailed analysis of asset, maintainer, manufacturer, and regional performance.

As each asset is recorded into the system, a Mean Time Between Failure (MTBF) will be added to the asset record. These values typically are provided by the asset manufacturer. NDOT can validate these values against actual MTBF records in the system. These data can be used to provide feedback to the suppliers of the equipment. If the equipment fails within the warranty period, or the MTBF doesn't match the supplied documented values, then NDOT has a potential performance-driven case against the supplier/manufacturer.

8. ITS Asset Management Program Implementation Plan

This section will describe the step-by-step actions recommended to undertake in implementation of NDOT ITS AMP. Using the literature review, gaps analysis, and NDOT's priorities, this Business Plan recommends a four-phased approach within a three-year timeframe, as illustrated in Figure 5.

Figure 5: NDOT ITS Asset Management Implementation Phased Approach



The following section includes a brief description of the elements within each phase.

8.1. Phase 1: Development of Statewide ITS Asset Management Business Processes and Procedures

In alignment with the ITS Asset Management Lifecycle Framework and Strategic Goals and Objectives, processes and procedures should be in place to ensure consistent ITS Asset Management approach at a statewide level. In addition, this will ensure stakeholders' contribution in data collection and performance measurement and monitoring in a manner that would best support the progress of the state's TSMO strategies and implementation.

Based upon the NDOT's current asset management approach and stakeholders' input, the following action items have been developed under three main categories of Stakeholder Engagement, Financial Resource Management, and Quality Control Plans, and are suggested to be integrated into current ITS Asset Management business processes and procedures.

8.1.1. Stakeholder Engagement

Stakeholder engagement plays a key role in development of a consistent statewide ITS AMP. The action items suggested to assist with stakeholder engagement are as follows:

- Provide stakeholders' access to AMP and NDEX.
- Regularly scheduled meetings with stakeholders to coordinate asset management activities (e.g. new local and/or federal reporting requirements, share information among agencies, discuss performance targets, etc.) and discuss local/regional opportunities and challenges.
- Mandatory monthly reporting requirements of the ITS assets status, condition, and health index for stakeholders. Work with stakeholders to develop a list of measures that should be included within the monthly reporting requirements. At a minimum, the report will include measures such as assets' age, deployment year, last scheduled maintenance, next scheduled maintenance, uptime/downtime, lifecycle

cost analysis, number of devices at a high-risk level, etc. to determine replacement needs and required resources.
  - For example, generate automated reports that are available to be viewed on the dashboard and will be automatically archived.
- Establishment and adoption of a formalized data and performance measures language (e.g. naming convention, data point orders, clear definition/standard for power plants, etc.) to standardize asset management language at a statewide level.
  - Host data business plan workshop with FHWA for the mobility data.
- Assess the possibility of integrating other platforms that include asset management components such as Waycare, Web Relay System, INRIX, 511, KITS, AMP, etc.
- Coordination with the AMOC.

8.1.2. Financial Resource Management

Providing a clear understanding of required financial resources for operation and maintenance of ITS asset is critical in sustained performance. More importantly, it will ensure efficient contribution of ITS assets into achieving the TSMO strategic goals and objectives. The following action items are suggested to enhance NDOT's current financial resource management:

- Review and update of funding plans.
  - How to allocate funds for ITS maintenance and construction based upon analysis of the impact on achievement of relevant goals and objectives (e.g. allocating a larger budget to identify status of existing assets versus construction of new assets).
- Development of investment strategies such as Assets Prioritization Tool, Operations and Maintenance Prioritization Tool, etc. to assist with resource and funding allocation decision-making process.
  - Define prioritization criteria and business priorities to use for development of prioritization tools.
  - This element should align with the TAMP ITS Lifecycle Cost (LCC). It has a funding element built in for annual ITS maintenance for each device type and for a 10-year asset maintenance budget.
- Develop formalized processes for research and deployment of emerging technologies.
- Develop formalized processes for allocation of funds to emerging technologies (at both testing and deployment phase).
- Review and update of lifecycle planning tool and preventative maintenance plans.
  - Currently, the conditions of the ITS assets are based on manufacturer's recommended service life. Good, low risk, medium risk, and high risk are the four conditions used to identify ITS assets.
    - To enhance the lifecycle planning tool, it is suggested that NDOT review and integrate the already developed device-specific lifecycle plans into AMP. The new lifecycle plans should be integrated to allow automated reporting on lifecycle analysis for each device.
    - To enhance the maintenance activities for preventative maintenance, it is suggested that NDOT develop device-specific KPIs for Inspection, Minor Repairs, Major Repairs, and Replacement of ITS Devices. This will create an additional check list for operators to assess the health of ITS devices not only based on the standard manufacturers' recommended performance measures, but also the overall operational performance of the device using the following steps:
      1. Develop device-specific KPIs using current operational performance data.
         a. In developing the new KPIs, some elements to take into consideration include: location of the device, frequency of use, mean time between failure (MTBF), downtime, etc.
      2. Develop new definition for Good, Low Risk, Medium Risk and High Risk asset conditions based on the KPIs.
         a. For example, possible KPIs for CCTV camera asset condition definitions could be as follows:
            i. **Good:** 0% image burn, full functionality available (e.g. PTZ), 100% within manufacturer's recommended working environmental condition.
            ii. **Low Risk:** 10% image burn, full functionality available, below manufacturer's recommended working environmental condition.
            iii. **Medium Risk:** 15% image burn, intermittent loss of functionality, at manufacturer's recommended working environmental condition.

iv. **High Risk:** over 15% image burn, full loss of functionality, above manufacturer's recommended working environmental condition.

3. Develop a Maintenance Activity Impact Matrix per device, using the new KPI's and the device-specific asset condition definitions.
4. Perform preventative maintenance based on the new results. This may change the current maintenance activities.
5. Measure the cost savings based on the adjusted asset lifecycle plan.
6. Develop lifecycle plan analysis based on the cost savings to assist with resource allocation.

**The KPIs will need to correlate with the TAMP Maintenance Activity Matrix.*

- Review and update risk management analysis tool by defining risk factors and degree of impact at three different levels of agency risks, program risks, and project risks.
- Develop financial reports and automated replacement cost calculations per device.

8.1.3. Quality Control Plans

Development of Quality Control Plans for operation and maintenance of ITS assets such as:

- Reference to any documented standards, manufacturer instructions, local practices, company procedures
- Process for adding new devices and associated/required details such as as-builds, user manuals, specifications, technical memo, etc.
- Process to instigate a change in maintenance of the devices
- Process for when defective or quality issues are discovered with an asset
- Standardized process for maintenance hierarchy based on the asset's performance priorities
- Responsibility matrix, including authority levels, resources, etc.
- Suitable testing, inspection, examination, and audit programs at appropriate stages
- Performance standards and how performance will be captured
- Training processes and requirements
- Testing requirements and specific tools needed
- Processes of audits and audit frequency
- Communication to relevant parties of changes to the process and/or safety issues with an asset
- Schedule of updates for reference documents
- Development of a dissemination process/framework

8.2. Phase 2: Development of Required Data Collection Plans and Performance Measures

Considering the current data collection plans and performance measures, this phase, at minimum, includes the following.

8.2.1. Data Collection Plans

- Review data collection mechanism to ensure accuracy of data collection (such as KITS, manual data collection, automated data collection, etc.)
- Mapping of all the capabilities of AMP, NDEX, incident management sources (such as Waycare), Web Relay System, etc. to determine redundancy within the systems and opportunities for optimization
- Review and completion of assets inventory, including identification of missing and redundant assets
- Define what 'operational' means for each device and align the operational data collection with that definition
- Update data collection plans and protocols to include the following:
  - Identification of gaps in data to enhance analysis of operation and performance issues
  - Development of a single maintainable asset data source
  - Standardized data collection per device and frequency
  - Technical specifications (time resolution [5 min, 30 min])
  - Spatial resolution (1/3-mile, 5 miles, etc.)
  - Deficiencies for scheduled repairs or parts

  - Power: outage, uptime, downtime, list of power sources
  - Maintenance: number of work orders, number of troubleshooting events, maintenance checklist, number of emergency repairs, breakdown classification, etc.
  - Assets utilization
  - Inspection schedule data
  - Inspection requirements data
  - Replacement schedule
  - Seasonal-based requirements
  - Location of pedestals
- Develop storage and archiving plans
- Development of data prioritization tools (in alignment with AASHTO data principles)

8.2.2. Performance Measurement and Analysis

- Review and update current performance goals and baselines
- Performance measurement reports for:
  - Assets utilization
  - Maintenance frequency per device
  - Percentage of functionality of assets critical to sustained performance
  - Maintenance cost per linear mile (aligned with the LCC per device type and maintenance activity to maximize integration with TAMP, AMP, EAMS, and LCC)
  - Maintenance cost on critical corridors
  - Operating condition of assets on critical corridors
  - Budgeted versus actual maintenance cost of the assets
  - Planned versus actual lifecycle replacement of the assets
  - Percentage of integrated assets per region
  - Percentage of uptime/downtime
  - Percentage of network communication issues
  - Percentage of successful operation of emerging technology assets at testing phase
  - Number of new assets added to the inventory annually
  - Actual observed assets lifecycle versus the manufacturer's recommended lifecycle
  - Failure duration versus rectification duration

8.3. Phase 3: Development of Geographical Interactive Map(s), GUI, Reporting, and Data Visualization Plans

Considering the existing capabilities within AMP and NDEX, the following steps are suggested to enhance the current system and user experience:

- Integrate available GIS data into one platform (e.g. GIS Tool of ITS SDP)
- Integrated troubleshooting, maintenance, and operation strategies (such as pop-up notifications with suggested solutions)
- Develop corridor-specific asset maintenance maps
- Develop corridor-specific ITS strategic deployment maps
- Define attributes and create a table of attributes per device on GIS
- Data visualization of operations and maintenance performance measures through NDEX
  - Possible integration of data visualization dashboards (such as Power BI) that can be easily viewed and accessed by the stakeholders
- Development of customizable reporting templates for each stakeholder
- Frequent reports (weekly, monthly, quarterly, etc.) of performance measures

8.4. Phase 4: Staffing, Roll-out, and Training

For a successful collaborative ITS AMP, it is crucial to provide the stakeholders as well as the staff with sufficient resources. This may require additional staffing with specific skillsets, or educational opportunities for stakeholders. This phase will also help NDOT develop a strong basis for future new position requests as well as staffing and workforce development for the future TSMO AMP. Staffing, roll-out, and training phase will, at a minimum, include:

- Identify staffing needs and skillsets required for operation and maintenance of ITS assets for both IT group and stakeholders
- Identify staffing needs and skillsets required for operation and maintenance of emerging technologies
- Schedule trainings and workshops for stakeholders to educate them on how to utilize the AMP and NDEX
- Develop recurring meeting plans with stakeholders to address their needs and challenges in utilizing AMP and NDEX
- Create the Nevada ITS Asset Management Working Group; this group will later transition into TSMO Asset Management Steering Committee

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Appendices

Appendix A. Stakeholder Survey Questionnaire and Responses

District I

NDOT Asset Management and Performance Measures Survey Questionnaire

1- Has your District developed performance measures for the ***operation*** of the ITS assets (For example, up time and down time for power for the asset, utilization of the asset, etc.)?	Yes	No
If yes, please list the performance measures. I am not aware of any performance measures for this developed by District 1, Michelle, Lynn or FAST might have more info.		
2- Has your District developed performance measures for the ***maintenance*** of the ITS assets (For example, scheduled repairs, scheduled and documents preventative maintenance, etc.)?	Yes	No
If yes, please list the performance measures. I am not aware of any performance measures for this developed by District 1, Michelle, Lynn or FAST might have more info.		
3- Have you developed data collection plans for the ITS assets in your District?	Yes	No
4- Are the strategies/solutions you are using sufficient to help you effectively operate and maintain the ITS assets in your District?	Yes	No
If no, what capabilities are missing? I feel we at District 1 are not involved enough in operating and maintaining these assets, to answer yes, Michelle, Lynn or FAST can speak better to needs than I can.		
5- Has your District developed a repair and maintenance plans for your ITS assets in your District?	Yes	No
If no, what strategies are you using for repairing and maintaining your ITS assets? Again, this is probably best answered by Michelle, Lynn or FAST		
6- Are there any redundant ITS assets in your District? Again, this is probably best answered by Michelle, Lynn or FAST	Yes	No
7- Are there ITS devices in your District that are currently not operational? Again, this is probably best answered by Michelle, Lynn or FAST	Yes	No
8- Which one of the following are you using to operations and management of your ITS NDOT ITS Asset Management Dashboard? • NDOT NDEX Dashboard • NDOT Enterprise Asset Management System • NDOT Maintenance Asset Management System • None of the above If you answered "None of the above" to question 4, what other strategies/solutions are you using? Again, this is probably best answered by Michelle, Lynn or FAST		
9- List your top three priorities in ***ITS assets data collection*** (for example, condition of the devices, utilization, uptime, maintenance, etc.). Again, this is probably best answered by Michelle, Lynn or FAST		

10- List your top three priorities for ***operation and maintenance*** of your ITS assets (For example, proper utilization of the asset, effective communications to and from the asset, deployment of new technologies, etc.) Again, this is probably best answered by Michelle, Lynn or FAST
11- List the top three capabilities that your ideal ITS Asset Management platform/dashboard should have to help you effectively operate and maintain your ITS assets in your District (For example, regular status updates for maintenance purposes for the asset, regular status updates for performance measures from the asset, customizable dashboard, etc.) Again, this is probably best answered by Michelle, Lynn or FAST
12- List your top 3 challenges in operations and management of your ITS assets. Again, this is probably best answered by Michelle, Lynn or FAST

District II

Has your District developed performance measures for the ***operation*** of the ITS assets (For example, up time and downtime for power for the asset, utilization of the asset, etc.)?	Yes	No x
If yes, please list the performance measures. Mainly rely on the NDEX website, nothing specific, no utilization of the assets		
Has your District developed performance measures for the ***maintenance*** of the ITS assets (For example, scheduled repairs, scheduled and documents preventative maintenance, etc.)?	Yes x	No
If yes, please list the performance measures. Goals of preforming preventative maintenance in a worksheet for ITS contract No scheduling of repairs, but have a goal of troubleshooting		
Have you developed data collection plans for the ITS assets in your District? Yes but it could be better and they would like to improve upon it	Yes x	No
Are the strategies/solutions you are using sufficient to help you effectively operate and maintain the ITS assets in your District? Most of the devices are up and maintained effectively	Yes x	No
If no, what capabilities are missing?		
Has your District developed a repair and maintenance plans for your ITS assets in your District? Refer to #2 answer, they have a checklist for the technicians to perform so they have clear direction on what to do for preventative maintenance.	Yes x	No
If no, what strategies are you using for repairing and maintaining your ITS assets?		
Are there any redundant ITS assets in your District? Probably Such as Travel Time signs and dms because they are very similar And coms and fiber They also don't know where there are areas of redundancy with power and communications such as fiber and cellular	Yes x	No
Are there ITS devices in your District that are currently not operational? Ex. HAR, truck ramp heater	Yes x	No
Which one of the following are you using to operations and management of your ITS NDOT ITS Asset Management Dashboard? • NDOT NDEX Dashboard -yes • NDOT Enterprise Asset Management System - yes, but came live today • NDOT Maintenance Asset Management System - EAMS is intended to take over this • And they also use the TAMP • None of the above If you answered “None of the above” to question 4, what other strategies/solutions are you using?		
List your top three priorities in ***ITS assets data collection*** (for example, condition of the devices, utilization, uptime, maintenance, etc.). AMP needs to be refined where it can be easier to use in the field through a phone app ITS device up/downtime Who last touched the device, where it is physically, and where the power is coming from potential to link ITS devices to other data sources for trouble shooting purposes Lifecycle of entire devices before we put it out on the field		

List your top three priorities for ***operation and maintenance*** of your ITS assets (For example, proper utilization of the asset, effective communications to and from the asset, deployment of new technologies, etc.) Having procedures and protocols for installing and maintaining the device Maintenance checklists for new devices such wrong way driver Having an overall ITS fiber plan Being able to test new devices before we put devices out on the freeway Corridor specific ITS SDP plans		
List the top three capabilities that your ideal ITS Asset Management platform/dashboard should have to help you effectively operate and maintain your ITS assets in your District (For example, regular status updates for maintenance purposes for the asset, regular status updates for performance measures from the asset, customizable dashboard, etc.) Flow detector and breakdown of classification Utilization of ITS devices by incidents A decision support system A weekly health report A platform where you see all devices where they're located and shoe device status and provide information to other agencies Everything being consolidated into one dashboard		
List your top 3 challenges in operations and management of your ITS assets. The need to keep things simple, anything that we can do to consolidate, we should do it such as kits and 511 KITS has been a huge problem to use software Not having a complete inventory of all of our assets Not being able to sole source is a huge problem when it comes to ITS devices		

District III

Our ITS asset management program has just started three years ago when I became supervisor. Because we are so rural it has been a struggle to get network communications to all our equipment in the field then to develop a method of collecting the data that was affordable to our current budget and at the accuracy we need to make good informed decisions with regard to up times, power consumption, failure alerts, confirmation of operation. Our district budget is not strictly for ITS assets but the NSRS radio system, Carlin Tunnels, facility battery back up plants for A/C and D/C operations, network radio solutions and repairs.

The last few years we have made great use of the ITS Contract and have removed and replaced complete sites to bring ITS assets within compliance to today's standards and network requirements. This is an extremely difficult task as the 17 to 11-year-old assets are in bad shape infrastructure wise, out of compliance to MUTCD, underpowered for network requirements, or technology is no longer supporting the particular ITS assets such as the HAR radio system and RWIS core equipment. This core equipment can only be replaced at $23,000 for a HAR radio and $60,000 for the RWIS system of which we have 12 HAR and 32 RWIS. As you can see the repair and Maintenance of just these two systems is likely not to happen.

The complete list of ITS assets is as follows with sites that still need major repairs.

Chain Beacons	36	20 need replacement
HAR Beacons	30	30 need replacement
Road Closed	2	2 need replacement
HAR Transmit	12	11 need replacement
RWIS		35 34 need replacement
Cell Modem	35	35 are working
DMS		21 21 are working
CCTV		40 12 need replacement
Detector Stat	9	9 are working
Fiber Huts		5 5 are working
ITS switches	205	205 are working
Net Micro		170 17 need replacing
Web Relay		170 170 are working

To solve the issue of individual site analysis and function we developed the Web Relay project and put it into use. The data collected has been extremely helpful in identifying problems as well as alerting us of failures and up times. We have an ability to see the logs for how long a device has been used, on/off times, environmental, power consumption, email alerting, and remote reset monitoring. As far as we know District 3 is the only district taking advantage of the Control by Web Relay System. This system is tied all the way back to Elko Roads Operations so that the operators can see in real time the activation and confirmation of devises connected to this network. We have a long way to go but the plan is simple and achievable. Now that you have a good understanding of what we in District 3 must deal with I will attempt to answer your questions. Just realize that until we achieve 100% network connectivity a lot of this work is done manually.

1. Yes, all ITS Assets need to be operational 24/7 and available for use. Solar controlled assets must have a three-day autonomy in cloudless days.
2. Yes, all assets are looked three times a year for preventive maintenance. We have just started using AMP to document preventative maintenance and update pictures of the sites, so we know what is there and how long. Also, we record voltages and condition of equipment. Operate the equipment locally and remotely through the network. Document any deficiencies for scheduled repairs or parts that need to be ordered.
3. Any time we are in an area we also do periodical checks for operation.
4. Yes, now that the AMP system is in place, we will be using that as our format. In the past we record keeping was very sparse.
5. No, we need the help of headquarters to rebuild ITS assets in the section of roads that are being repaired through contract. When a section of road is being looked at for repair my department is not being contacted as to what ITS assets are in that section and what is there condition.

6. Yes
7. No
8. No
9. We are using AMP, NDEX
10. Networking, Power, Utilization
11. On/Off state, effective comms, date/time used
12. Last maintained, customizable, in or out of network operation
13. Record keeping, notification of outages, funding

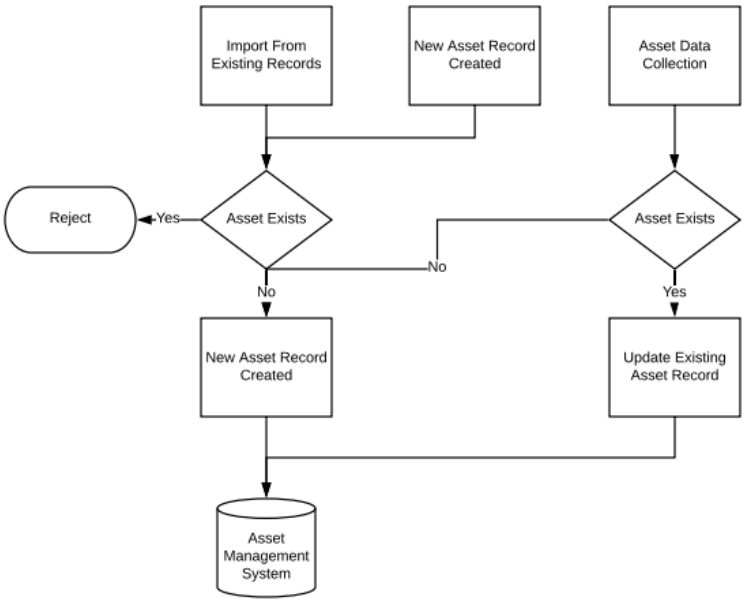
NDOT Asset Management and Performance Measures Survey Questionnaire

1- Has your District developed performance measures for the ***operation*** of the ITS assets (For example, up time and down time for power for the asset, utilization of the asset, etc.)?	Yes	No
If yes, please list the performance measures.		
2- Has your District developed performance measures for the ***maintenance*** of the ITS assets (For example, scheduled repairs, scheduled and documents preventative maintenance, etc.)?	Yes	No
If yes, please list the performance measures. Scheduled PM's		
3- Have you developed data collection plans for the ITS assets in your District?	Yes	No
4- Are the strategies/solutions you are using sufficient to help you effectively operate and maintain the ITS assets in your District?	Yes	No
If no, what capabilities are missing? Some devices should have health monitoring in place		
5- Has your District developed a repair and maintenance plans for your ITS assets in your District?	Yes	No
If no, what strategies are you using for repairing and maintaining your ITS assets?		
6- Are there any redundant ITS assets in your District?	Yes	No
7- Are there ITS devices in your District that are currently not operational? trailblazers	Yes	No
8- Which one of the following are you using to operations and management of your ITS NDOT ITS Asset Management Dashboard? • NDOT NDEX Dashboard • NDOT Enterprise Asset Management System • NDOT Maintenance Asset Management System • None of the above If you answered "None of the above" to question 4, what other strategies/solutions are you using?		
9- List your top three priorities in ***ITS assets data collection*** (for example, condition of the devices, utilization, uptime, maintenance, etc.). 1. Condition of devices2. Frequency of downtime 3. Life Cycle		
10- List your top three priorities for ***operation and maintenance*** of your ITS assets (For example, proper utilization of the asset, effective communications to and from the asset, deployment of new technologies, etc.) 1.Ability to communicate with devices 2. Troubleshooting emergency repairs 3. New tech for gained efficiencies		

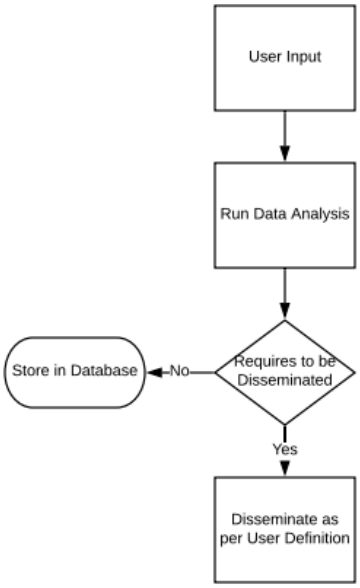
11- List the top three capabilities that your ideal ITS Asset Management platform/dashboard should have to help you effectively operate and maintain your ITS assets in your District (For example, regular status updates for maintenance purposes for the asset, regular status updates for performance measures from the asset, customizable dashboard, etc.) 1.Device health monitor 2. Troubleshooting functionality 3. Ease of use
12- List your top 3 challenges in operations and management of your ITS assets. 1.Staff to device ratio 2. Legacy software not compatible with new device technology. 3. Best practices in equipment and technology procurement

Appendix B. Asset Management Flow Charts

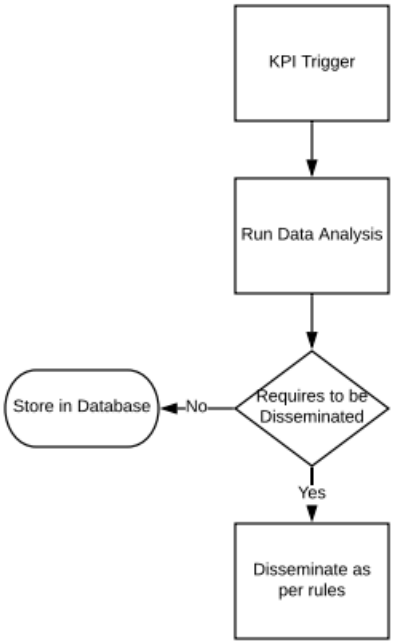
Data Collection



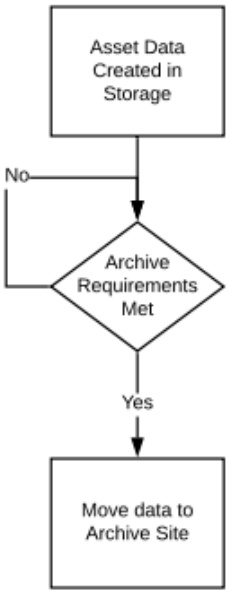
Analysis of Data Collected



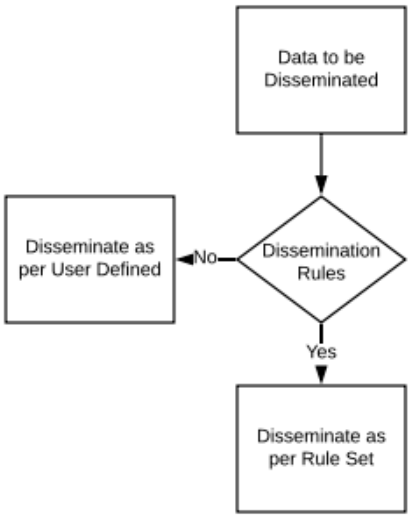
Analysis of KPIs



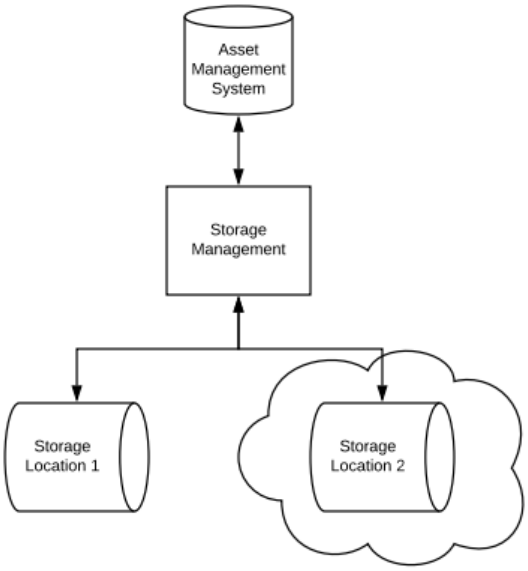
Data Archiving



Data Dissemination



Data Storage



Appendix C. Descriptions of Inspection and Maintenance Activities by ITS Device Type

Device	Inspection	Minor Repairs	Major Repairs	Replacement
CCTV	Performed twice a year. Standard factory recommended preventative maintenance (PM) performed on all devices. PM activities include: cleaning cabinet and device, changing filters, checking connections, ensuring proper functionality, run manufacturer recommended tests. One to two person crew required for inspection which takes about 2 hours per device.	Repairs typically performed on site, takes 4 to 8 hours. Typical repairs include: adjusting loose camera and cables, repairing camera lowering device, encoder programming, and configuring devices.	Repairs typically require device to be sent back to shop or factory for major repairs. Typical repairs include: zoom repair, camera features repair, gyro and motor repair, CCTV and lowering device cable repairs. Repairs can take anywhere from 1 day to 1 week.	Replacement is typically required when the device/ parts are no longer serviceable or become obsolete. Typical parts needing replacement include: camera, encoding device, cabinet. Replacement can take anywhere between 3 to 6 weeks.
DMS	Performed once a year. Standard factory recommended PM performed on all devices. PM Activities include: replacing filters and lamps, checking interior lighting, checking visible damage to sign structures and electrical connections, checking functionality of cooling fan, backup UPS, and lubricating engines in cabinet. Inspection takes 2 hours per device, one person crew.	Repairs typically performed on site, takes 4 to 8 hours. Typical repairs include: replacement of power supply box, changing batteries	Repairs typically require device to be sent back to shop or factory for major repairs. Typical repairs include: changing LED boards (for new signs), controller replacement. Signs will be down when repairs are being performed. Repairs can take anywhere from 1 day to 1 week.	Replacement is typically required when the device/ parts are no longer serviceable or become obsolete. Replacement is usually required when the sign/cabinet is damaged after accidents. Replacement can take anywhere between 3 to 6 weeks.
Flow Detectors	Performed once a year. Standard factory recommended PM performed on all devices. PM Activities include: fine-tuning configurations, calibration, checking connections, verifying device functionality. Inspection takes 2 hours per device, one person crew	Repairs typically performed on site, takes 4 to 8 hours. Typical repairs include: wire repairs, re-aiming, unit reconfiguration, and surge protection.	Repairs typically require device to be sent back to shop or factory for major repairs. When unit goes down, some parts will need to be replaced as required. Repairs can take anywhere from 1 day to 1 week.	Replacement is typically required when the device/ parts are no longer serviceable or become obsolete. Typically involves replacement of accompanying devices (as needed). Replacement can take anywhere between 3 to 6 weeks

Device	Inspection	Minor Repairs	Major Repairs	Replacement
HAR	Performed once a year. Standard factory recommended PM performed on all devices. PM Activities include: device cleaning and testing connections. Inspection takes 2 hours per device, one person crew.	Repairs typically performed on site, takes 4 to 8 hours. Typical repairs include: replacing card and motors, firmware upgrades.	Repairs typically require device to be sent back to shop or factory for major repairs. When unit goes down, the entire system needs to be taken out for repair. Repairs can take anywhere from 1 day to 1 week.	Replacement is typically required when the device/ parts are no longer serviceable or become obsolete. Typically involves replacement of accompanying devices (as needed). Replacement can take anywhere between 3 to 6 weeks.
Ramp Meters	Performed once a year. Standard factory recommended PM performed on all devices. Inspection takes 2 hours per device, one person crew.	Repairs typically performed on site, takes 4 to 8 hours. Typical repairs include: controller replacement, load bay replacement, lamp replacement.	Repairs typically require device to be sent back to shop or factory for major repairs. Typical repairs include: cabinet replacement, pole repair, detection system repair. Repairs can take anywhere from 1 day to 1 week.	Replacement is typically required when the device/ parts are no longer serviceable or become obsolete. Replacement is usually required when intersection designs are updated (freeway widening, ramp reconfiguration etc.) Replacement can take anywhere between 3 to 6 weeks.
RWIS	Performed once a year. Standard factory recommended PM performed on all devices. PM Activities include: device cleaning and testing connections. Inspection takes 2 hours per device, one person crew.	Repairs typically performed on site, takes 4 to 8 hours. Typical repairs include: replacing card and motors, firmware upgrades.	Repairs typically require device to be sent back to shop or factory for major repairs. When unit goes down, the entire system needs to be taken out for repair. Repairs can take anywhere from 1 day to 1 week.	Replacement is typically required when the device/ parts are no longer serviceable or become obsolete. Typically involves replacement of accompanying devices (as needed). Replacement can take anywhere between 3 to 6 weeks.

Appendix D. Existing Data Parameters Within AMP

NSRS Site Information			
• System ID	• Site Name	• Responsibility	• Site Manager/Owner
• License	• Expiration Date	• License 2	• License 2 Expiration
• RF Site	• IMC Node	• Frequency Set Name	• Notes
• Master Tune	• Not Tunable	• Under Construction	• Reband
• Repack	• STA	• Backhaul Carrier	• T1 or DS0
• Power Plant	• Agreement	• BLM/USFS	
License			
• Parent System ID	• Form Link Parent System ID	• Feature ID	• License
• Expiration Date	• Title		
Channel			
• Parent System ID	• Channel 1	• Title	
Adjacent Site			
• Parent System ID	• Adjacent Site 1		
NSRS Site Equipment			
• Attached To	• Site	• Status	• Retirement Reason
• Equipment Type	• Parent Asset	• Asset Name	• Manufacturer
• Serial Number	• Make	• Model	• Asset Tag
• Received On	• Warranty Expiration Date	• Comments	
NSRS Radio Work Order			
• Attached To	• Description	• ID	• Linked Radio
• Reporting Date	• Time	• Reporting Agency	• Reporting Party (Registered)
• LID Number	• Vehicle Unit Number	• Alias	• Problem
• Assignment	• Due Date/Time	• Supervisors Comments	• Work Order Status
• Radio Type	• Problem Type	• Observed Symptoms	• Radio Site
• Was site a local repeater with a second radio or user?	• Did site communication with other users in a different geographic area?	• Were communications with dispatcher affected?	• Affected communications?
• Was attempt made to switch to different site?	• If so, which site?	• If so, did same problem exist?	• Has radio and associated equipment been verified?
• If mobile radio, is antenna vertical on vehicle?	• Resolution Date	• Resolution	• Documentation

Radio System Service Request			
• Service ID	• Parent System ID	• Attached To	• Work Order ID
• Requester	• Request Date/Time	• Issue Description	• Highway
• Mile Marker	• Contact Number	• Site	• Assigned To
• Created By	• Created Date		
Radio Site Work Order			
• System ID	• Parent System ID	• Attached To	• Description
• ID	• Reporting Date	• Time	• Reporting Agency
• Reporting Party (Registered)	• Problem	• Assignment	• Due Date/Time
• Supervisors Comments	• Work Order Status	• Problem Type	• Observed Symptoms
• Was site a local repeater with a second radio or user?	• Did site communicate with other users in a different geographic area?	• Were communications with dispatcher affected?	• Affected communications?
• Was attempt made to switch to different site?	• If so, which site?	• If so, did same problem exist?	• Has radio and associated equipment been verified?
• If mobile radio, is antenna vertical on vehicle?	• Resolution Date	• Processed Open	• Resolution
• Created By	• Created Date	• Processed Closed	• Latitude
• Longitude			
Radio Site Work Order			
• Site Alias	• Traffic Operations Name	• Cabinet Name	• Devices
• District	• Electrical Source	• Light Voltage	• Solar Controller Type
• Battery Type and Quantity	• AC Battery Charging Type	• Notes	
ITS Devices			
• Attached To	• CSS/NDEX Name	• Update Required	• Cabinet (Historical)
• Device Category	• Old Device Name	• Device Name	• Site Name (New)
• Device Description	• PDU	• Location	• Room
• Notes	• Manufacturer	• Model	• Serial Number
• Communications Type	• Circuit ID #	• On/Off Code	• CSSID
ITS Work Order			
• Attached To	• ID	• Reporting Party (Registered)	• Problem Location
• Detailed Problem Description	• Due Date (Date/Time)	• Work Comment	• Assigned Tech
• Status	• Processed Closed	• Severity	

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Atkins NA
WS Atkins, Inc.
2270 Corporate Circle
Suite 200
Henderson, NV 89074-7755

Tel: +1 702 263 7275/+1 800 483 6244
Fax: +1 702 263 7200

NEVADA DOT
SAFE AND CONNECTED

1263 South Stewart Street
Carson City, Nevada 89712