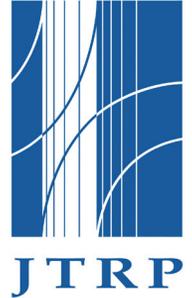


JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION
AND PURDUE UNIVERSITY



LEVEL OF SERVICE PROGRAM FOR INDOT OPERATIONS

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JOINT TRANSPORTATION RESEARCH PROGRAM

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16. Abstract <p>INDOT has used an inspection program named Maintenance Quality Survey (MQS) to perform a state-wide inspection of their roadway assets, right-of-way to right-of-way. This inspection requires two two-person teams approximately 18 months to complete as it determines the condition of individual features and produces a grade for each one. Results from this program were used to define a work program.</p> <p>INDOT uses the software Work Management System (WMS) for their operations. A WMS feature that has not been utilized is the Level of Service (LOS). LOS establishes performance standards for activities and then uses an inspection program to evaluate compliance with these standards.</p> <p>The objective of this project was to develop a LOS program at INDOT that utilizes WMS. One key component of this program is a statistical based inspection program that inspects and grades random roadway segments. The development of this inspection program required determining the number of samples per sub-district, the features to inspect, defining the pass/fail criteria for each feature, and field training and testing. Another key part is to develop the required WMS LOS data tables.</p> <p>Outcomes from the LOS program will be an improved inspection program, a data driven tool that can be used to perform LOS analyses resulting in improved work planning. Looking at operation activities from a LOS perspective provides opportunities to balance resources better and improve the planning aspect. One benefit being experienced with the implementation of the inspection program is inspection personnel time savings in collecting the LOS data.</p>			
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EXECUTIVE SUMMARY

LEVEL OF SERVICE PROGRAM FOR INDOT OPERATIONS

Introduction

In 2008 the JTRP study SPR-3130, *Performance Based Contracting for Roadway Maintenance Operations*, revealed the state agencies that have developed a Level of Service (LOS) program benefit. A LOS program can evaluate and determine maintenance performance values for the components of the Indiana Department of Transportation's road network. In other words, it can be the report card for calculating performance. Additionally, once a LOS has been defined, budget numbers can be developed and associated with a particular LOS for each element. This is very helpful in determining budget impacts on maintenance operations. When budgets are changed, the impact on operations can be quantified and described. If INDOT looks at using more private contractors to assist in maintenance, a LOS program is essential in determining cost estimates, their performance and corresponding levels of compensation.

Findings

INDOT developed Maintenance Quality Survey (MQS), an inspection or survey program. MQS was used to rate the condition of INDOT's assets in nine roadway services categories and three traffic categories. The inspections created various reports used to direct and guide the work program. MQS is a visual inspection of all six districts' assets and was performed from a moving vehicle using two teams of two inspectors. It took on average 18 months to inspect the complete network. All roads in the state were on a 2-year cycle for MQS inspections.

The MQS approach provides a complete evaluation in these asset areas requiring 2 years of resources. A survey of other state agencies reveals that most other states are using a random

sampling approach to collect the same information. Of the nineteen agencies that responded to the study information request, eighteen use the random segment approach. This approach inspects randomly selected segments that represent the overall population at a certain level of confidence. Most of these inspection programs are attempting to achieve 90%–95% confidence in the results. If properly performed, this approach can deliver similar inspection results as the MQS program at lower costs.

Implementation

At the time this report was submitted, INDOT had implemented the LOS field inspection program. INDOT has plans to utilize the data created through this project in the Work Management System (WMS) LOS module.

The LOS inspection program is operational with the two inspection teams and requires 160 segments per sub-district. With 36 sub-districts, the total number of inspection segments at INDOT will be 5,760. Based on daily productivity results (80 inspections for both teams), the estimated time to complete the inspections is 15 weeks, which is approximately 4 months. The previous MQS inspection program took approximately 18 months to complete. Therefore, the LOS inspection program is potentially saving 14 months of time.

Assuming a 14-month time savings for the inspection teams, a cost saving can be calculated. INDOT's finance section estimates the hourly rate for a highway technician to be \$31/hour. Each team is comprised of two technicians, so the total time saved is $4 \text{ technicians} \times 37.5 \text{ hours/week} \times 14 \text{ months} \times 4 \text{ weeks/month} = 8400 \text{ hours}$. The potential cost savings is $8400 \text{ hours} \times \$31/\text{hour} = \$260,400$. Travel and per diem costs will be less as well, and could be calculated after a complete inspection cycle has been performed. When the WMS functions are utilized, INDOT will have in place a complete LOS program that utilizes a random sampling approach and computer capabilities that provide the necessary reports and data to operate a comprehensive LOS program for INDOT operations.

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1. INTRODUCTION

In 2008 the JTRP study SPR-3130, *Performance-Based Contracting for Roadway Maintenance Operations*, (1) revealed the state agencies that have developed a Level of Service (LOS) program benefit in several ways. A LOS program can evaluate and determine maintenance performance values for the components of INDOT's road network. In other words, it can be the report card for calculating performance. Additionally, once a LOS has been defined, budget numbers can be developed and associated with a particular LOS for each element. This is very helpful in determining budget impacts on maintenance operations. When budgets are changed, the impact on operations can be quantified and described. If INDOT looks at using more private contractors to assist in maintenance, a LOS program is essential in determining cost estimates, their performance and corresponding levels of compensation.

2. PROBLEM STATEMENT

In 2003 another JTRP project, SPR-2358, *Maintenance Quality Assurance Program* (2), developed inspection criteria and an inspection program that are essential pieces of a LOS program. Results of this project form the foundation for a LOS program. Using the knowledge and understanding collected from the two previous projects provided a good foundation for this study.

Since the completion of these two previous projects, INDOT implemented the software from Agile Assets, Work Management System (WMS) to control and manage operations. WMS possesses the ability to setup and run a LOS program. This project was performed with the goal of establishing the WMS LOS feature for INDOT's use.

Key requirements for establishing this LOS program are:

- An inspection program that defines the appropriate inspection items and their criteria
- An inspection program that uses randomly selected segments
- Developing the necessary data tables to establish the WMS LOS feature
- Training and implementation of the inspection program and WMS LOS feature

This report describes each of these key requirements as well as the needed documentation to support the WMS LOS program.

3. OBJECTIVES

Over the last five years parts and pieces of a comprehensive LOS program have been developed and tested for INDOT. With the implementation of the web-based WMS making it possible to document and provide cost data to a LOS program, INDOT has in place the necessary LOS components. Historically,

INDOT has used various means to establish levels of service for Maintenance and Traffic, and currently WMS is the application used to document the performance and allocate the resources using the work plans developed by district and sub-district management. Prior to the implementation of WMS, each individual sub-district and Traffic Office created a plan using Performance Standards and Quantity Guidelines that were provided in policy and manually entered into each location's database. The WMS LOS functionality was purchased with the initial product and INDOT was instructed to only use the functionality after accumulating three years of asset quality data. INDOT has been archiving MQS asset quality data and the WMS Section created preliminary LOS scenarios, and this study will develop the collection procedures, solidify the LOS parameters, and establish the standard index and application processes.

By developing a LOS program INDOT Operations will have a management tool that can be used to develop work programs more efficiently and with more budget certainty and definition. This will give INDOT improved flexibility in developing operation budgets and creating physical descriptions of budget decisions. Therefore the objective of this project is to work with Operations to create a LOS program and to implement at the district level.

4. FINDINGS AND DELIVERABLES

This section will start with a description of the activities performed. These activities were guided by the Study Advisory Committee that consisted of the following INDOT individuals:

Barry Partridge (Research)	Becky Gross (Seymour)
Joe Lewien (Crawfordsville)	Krystal Cornett (Greenfield)
Larry Goode (Central Office)	Phil Springer (CO)
Bob Allman (CO)	Terry George (Greenfield)
Todd Johnson (Fort Wayne)	Todd Shields (CO)

Eight SAC (study advisory committee) meetings (through January 2012) have been held, with an additional one for project closeout. The SAC members were involved and directed the following project activities:

1. The SAC subject matter experts were used to establish and approve the following:
 - a. Inspection items and their corresponding criteria.
 - b. Operation activities – their defects and corresponding level of effort assignment
 - c. For each inspection category determine the OPI score range values
 - d. Determine the weight values or priorities of the inspection categories
 - e. For each operation activity establish productivity values, equipment and material needs, and unit costs.
2. Review and describe the MQS and MQA (maintenance quality assurance) inspection programs used by other state agencies.

3. Work with the Research Division to approve the random sampling program.
4. Work with the GIS Section, to ensure all enhancements to the MQS Inspection procedures are attainable. These include:
 - a. Field inspection procedures; for input on the collection application requirements. Identify the user interface requirements for collection changes and any hardware changes required. Review current collection and scoring documents; provide final copy of LOS Inspection Manual.
 - b. Data collection techniques: Discuss changes to the collection parameters with GIS to incorporate into current ArcGIS collection program, on inspectors' laptops and GPS receivers. Define the sampling program, confidence level goal, number of samples and segment length.
 - c. A comprehensive LOS program will replace the MQS inspection program, so determine the required level of effort for the LOS Collectors' inspection logistics plan.
5. Training program. Design, develop, test, and implement a training program that will train LOS Collectors on modified inspection procedures. This consisted of field training.
6. Determine the level of effort, time, and required resources (manpower, equipment, money, etc.) to operate the LOS program.

4.1 MQS Inspection Program

INDOT developed an inspection or survey program named Maintenance Quality Survey (MQS). MQS was used to rate the condition of INDOT's assets in nine Roadway Services categories and three traffic categories. The inspections created various reports used to direct and guide the work program. MQS is a visual inspection of all six districts' assets and was performed from a moving vehicle using two teams of two inspectors. All roads in the state were on a 2 year cycle for MQS inspections.

The MQS approach provides a complete evaluation in these asset areas requiring two years of resources. While it takes two years to complete it is not a complete evaluation of today's features (e.g. edge drains require stopping, getting out of vehicle, and a visual inspection). A survey of other state agencies reveals that most other states are using a random sampling approach to collect the same information. This approach inspects randomly selected segments that represent the overall population at a certain level of confidence. Most of these inspection programs are attempting to achieve between 90–95% confidence in the results. If properly performed, this approach can deliver similar inspection results as the MQS program at lower costs. Table 4.1 provides a summary description of agencies inspection program.

4.2 Maintenance Inspection Programs Summary

See Table 4.1 for a summary of the maintenance inspections programs. A more detailed description of these programs is found in Appendix A.

4.3 LOS Inspection Program

4.3.1 Random Sample Program

Table 4.1 summarizes state inspection programs. All the states except for Ohio use a random sample segment inspection approach. Segment lengths vary, with the 0.1 mile segment length the most common. Based on other state inspection programs the SAC committee approved a randomly selected 0.1 mile segment as the basis for LOS inspection. This represents a different approach from the current MQS program of visually inspecting 100% of the routes every two years.

With any random inspection program a sample size that is representative of the overall population and meets a certain confidence level is desired. Looking at other state agency programs the sample size was arrived at by using statistical calculations. For example Mississippi DOT published their methodology and it is shown in the below equation.

The following equation may be used to determine the minimum sample size necessary to achieve the desired confidence and precision for LOS measures:

$$n = \frac{(z^2)(p)(1-p)}{e^2 + \frac{(z^2)(p)(1-p)}{N}}$$

where:

n = sample size (for example, number of 0.1-mile increments).

N = population size (for example, total number of 0.1-mile increments).

z = standard normal deviate (that is, number of standard deviations for desired level of confidence). See Table 4.2.

p = proportion of the population that meets a specified criteria (for example, pass/fail – expressed as a decimal value from 0.0 to 1.0).

$1 - p$ = remaining proportion of the population.

e = allowable sampling error (or precision), expressed as a decimal.

For condition assessments, a confidence level of 95 percent is generally considered sufficient ($z = 1.96$). The value for p was assumed to be 80% for Interstate and U.S. highways and 70% and for other highways. To keep the number of samples at an achievable level and, at the same time, achieve an acceptable level of precision, +/- 7 percent was selected ($e = 0.07$). After some initial data collection in the districts, the value of p can be reviewed and "fine-tuned", if necessary, but these values have worked well in other states.

4.3.2 Sample Sizes

For each district and road class, the number of centerline miles was used to determine the number of required samples. It is recommended that sample sizes should be developed for each road class: interstate and divided, and two lane routes. Using this approach and obtaining centerline miles by sub-district, sample sizes

TABLE 4.1
State Agency Inspection Programs

Agency	Inspection Segment Length	Inspection Scope	Sample Size	Inspection Type	Frequency
Arizona	0.5 mile	R/W to R/W	Approx. 200	Random samples	Annually
California	1.0 mile	R/W to R/W	12% of road miles in each district; statewide 1572 samples	Random samples	Annually
Florida	0.1 mile	R/W to R/W		Random samples	Annually
Kansas	0.1 mile		3360 samples, 112 subareas, 26 areas, 6 districts	Random samples	Annually
Kentucky	0.1 mile			Random samples	Annually
Louisiana	0.1 mile		2423 samples at 95% confidence level; 16,698 road miles	Random samples	Semi-annually
Maryland	0.5 mile	Shoulder Drainage Traffic Control and Safety	30% of each units centerline miles	Random samples	Annually
Michigan	0.1 mile	R/W to R/W		Random samples	Annually
Missouri	0.1 mile		1500 segments statewide	Random samples by road class	Annually
Mississippi	0.1 mile	R/W to R/W	95% confidence level for 13,052 road miles; no. of samples = 2340; requiring 198 crew days	Random samples	Annually
North Carolina	0.1 mile	R/W to R/W		Random samples	Annually
Ohio	Statewide network	from vehicle		Whole network	¼ of network every 3 months
South Carolina	0.2 mile	(1) Pavement, (2) shoulders/ditches, (3) drainage structures, (4) roadside, (5) signs, (6) pavement markings, and (7) guardrail	1443 segments; represent 1% of the total network	Random samples	Annually
Tennessee	0.1 mile	(1) Traveled pavement, (2) shoulder, (3) roadside, (4) drainage, and (5) traffic services	4000 1-mile sections were evaluated from the inventory of 79,897 roadway miles	Random samples	Monthly
Texas	1 mile			Random samples	
Virginia	0.1 mile		2200 samples taken from a network that has 7700 centerline miles	Random samples	
Washington	0.1 mile			Random samples	Annually
Wyoming	0.2 mile			Random samples	Annually

calculated to be from 150 to 160 inclusive of all road types.

See Appendix B for sample size calculations by sub-district. Based on these calculations, the Research Division statisticians determined the sample size to be 160 per sub-district.

TABLE 4.2
Values of z for Frequently Used Levels of Confidence

Confidence Percentage	z
68.3	1.000
90.0	1.645
95.0	1.960
95.5	2.000
98.0	2.326
99.7	3.000

The GIS map will have 160 points per sub-district. They will be identified by latitude and longitude and reference posts. A request was made to add a bridge layer. The GIS section added a bridge layer and it was revealed that 7% of the bridges will be inspected. This was presented to Research for approval and granted.

4.3.3 Inspection Software

Each two-member team is provided a laptop and a field inspection card. The laptop is equipped with the ArcPad program for capturing data, as shown in Figure 4.1. The reusable field card shown in Figure 4.2 provides a temporary form for recording inspection and eliminates paper forms. This card can be carried by the inspector to record the evaluation over the 1/10th mile segment. As failures are discovered, the inspector marks it on the card with a grease pencil. Each single click

failure is either pass or fail. For example, if one or more bridge bearings are deemed deficient, the category is marked deficient. “Special Markings” falls under the category of multi-click failure.

Upon completion of segment inspection, the inspector will enter the data from the field card into the ArcPad program. Check that the route and travel direction are correct. If a single click failure is marked on the card, the corresponding program button is selected. “Special Marking” falls under the multi-click failure category. On the inspection card, each marking will be marked either deficient or OK. For example, there are seven marks under “OK” and four marks under “Deficient” on the card. That means there were a total of eleven special markings in the segment. The button “Special Marking OK” should be selected seven times and the button “Special Marking Def.” should be selected four times. Once all the data from the card is entered, select “New Segment,” wipe the field card clean, and proceed to the next location.

By using the field card, the need to carry the laptop during the inspection is eliminated, removing the potential for damage due to inclement weather or dropping. Paper waste is eliminated because the card is reusable. Also, because the card must be cleared before reuse, it requires data to be entered into the program immediately after obtaining it and eliminates the possibility of misplacing the data (as could be the case using multiple sheets) or entering the data at a later time.

4.3.4 Inspection Changes

All guardrail deficiencies/descriptions were consolidated to one guardrail category. Mile marker and sign deficiencies/descriptions were consolidated to one sign category. The items cable barrier, and shoulders cracking were added.

Some deficiency descriptions were modified and others were eliminated, such as pavement deterioration: rutting; pavement failure: non flush manhole. Some deficiencies were moved from one category to another. Examples: potholes: pavement deterioration → pavement failure; rigid pavement: pavement failure → pavement deterioration.

Training

Appendix C contains the LOS Inspection Manual which contains information on inspection criteria and is a training resource for field inspectors.

On August 9, 2011, field training for LOS inspection was performed in the Crawfordsville District. The two inspection teams tested the new software program and field procedures. Some recommendations were generated for the inspection program which was relayed to the GIS section resulting in modifications to the inspection software. The user interface screen is shown in Figure 4.1.

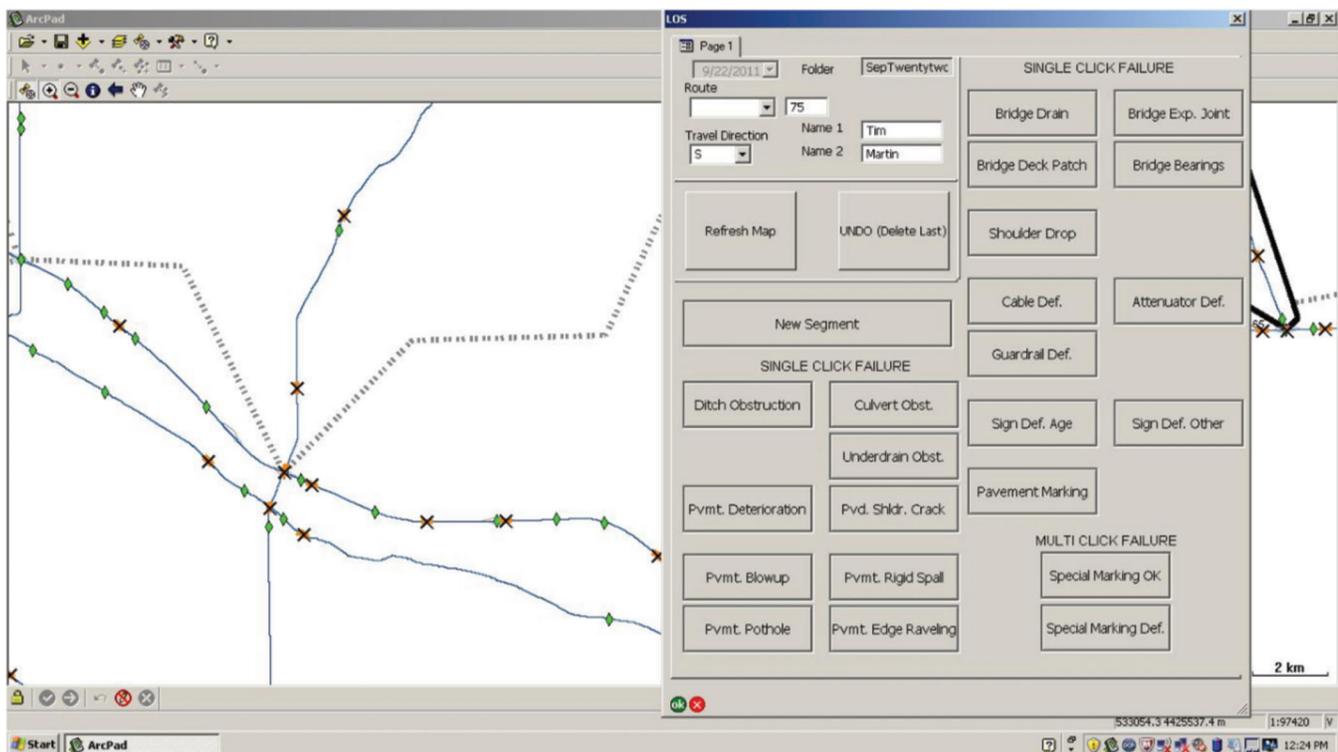


Figure 4.1 Field inspection form.

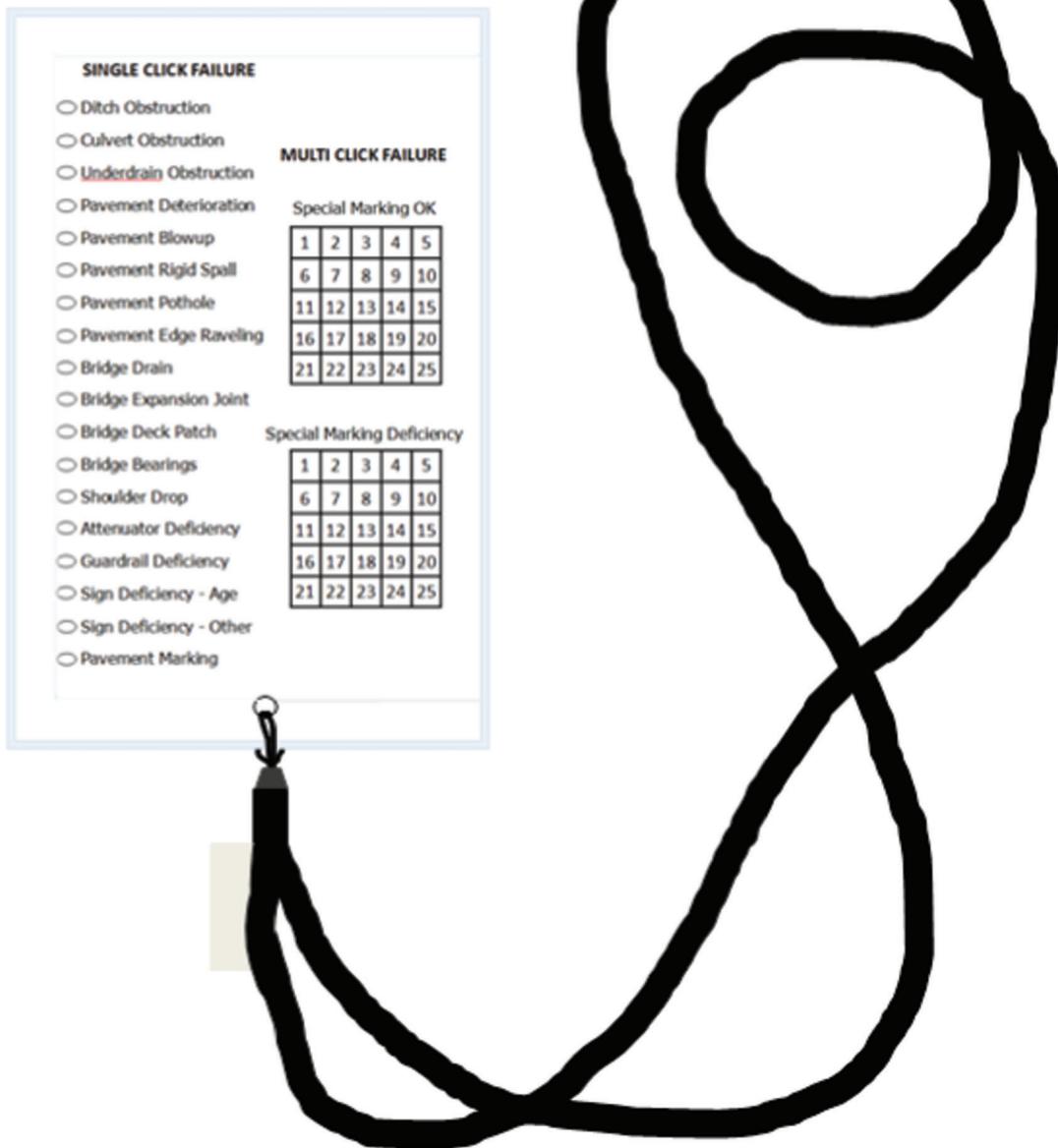


Figure 4.2 Field inspection card.

4.4 WMS LOS Data Needs

WMS has LOS functions that must be populated with INDOT data. The SAC identified four tables to develop which contain the necessary LOS data. These four tables are:

1. Deficiency score index
2. Activity defect assignment
3. Asset deficiency weight scale
4. QG table

Each of these tables is described next.

4.4.1 Deficiency Score Index

This table lists all the LOS inspection categories, the Organizational Performance Index (OPI) Scores and their associated percent deficient ranges.

For each category, an OPI score will be generated based on the percentage of that item found to be deficient in the sub-district. OPI scores range from 1 to 6, where 1 represents the highest range of percent deficiencies and 6 represents the lowest range of percent deficiencies. Six is the highest OPI score and one is the lowest. For example, when an item is found to be

deficient 50% to 100% of the time in a sub-district, an OPI score of 1 is assigned. On the other end of the score scale, when an item is found to be deficient 0% to 4.99% of the time in a sub-district, an OPI score of 6 is assigned. The complete table is found in Appendix D.

4.4.2 Activity Defect Assignment

This table assigns the defect types with a maintenance activity and if multiple defects are associated then their corresponding weight values in percent affecting the activity.

For example, activity 2010 – shallow patching, is performed to repair pothole, spalling, and edge raveling. A weight value is assigned to each defect type for the purpose of establishing a level of effort. The weight values should equal 1.0 for an activity. For 2010, pothole repair is assigned a value of 0.8, spalling a value of 0.1, and edge raveling a value of 0.10, which says that 80 percent of the time activity 2010 is used to repair pothole issues and 10% each for repairing spalling and edge raveling.

Appendix E is the complete table.

4.4.3 Asset Deficiency Weight Scale

A copy of this table is found in Appendix F. This table lists all the inspection categories and their corresponding ranking in terms of perceived importance. The highest ranked defect is pothole which means it comes first in repair and making resources available. The lowest ranked is traffic, which means it is last in repair importance and dedicating resources.

The columns Match Column and Groovy Script ID are WMS information. The best and worst columns are the OPI score range. The MMS Util Function states that in WMS if the OPI score is above 4 then use 6 as the OPI value.

4.4.4 QG Table

The QG Table was previously developed by INDOT and directed by Pavement Preservation Engineer. It plays an important role in the WMS LOS module. It contains a couple hundred activities described by the following:

- Activity description
- Daily production values
- Unit costs
- Crew size and info
- Equipment info
- Material codes
- Material amounts associated with each activity

The table is too large to include in the report and it resides with INDOT Operations.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 GIS Section

The GIS section modified the MQS inspection software program and produced the LOS inspection

program. Figure 4.1 shows the Field Inspection form. This form has been tweaked, tested, and is being used to collect field data. One component of this program yet to be defined is the report needs. This will be determined during the implementation phase that will occur in spring 2012.

The GIS section developed the revised Inspection program and MIS services will be needed in the future on a random basis to develop yet to be defined reports and perform expected revisions to the inspection program.

5.2 Field Inspection

The LOS inspection program is operational with the two inspection teams. The LOS inspection program requires 160 segments per sub-district. With 31 sub-districts the total number of inspection segments at INDOT will be 4,960. Based on daily productivity results, 80 inspections for both teams, the estimated time to complete the inspections is 13 weeks, which will be called 4 months. The previous MQS inspection program took approximately 8 months to complete. The LOS inspection program is potentially saving 4 months of time.

Assuming annual four month time savings for the inspection teams a cost saving can be calculated. INDOT's Finance section estimates the hourly rate for a Highway technician to be \$31 an hour. Each team is comprised of two technicians so the total time saved is: 4 technicians x 37.5 hours/week x 4 months x 4 weeks/month = 2400 hours. The potential personnel cost savings is 2400 hours x \$31/hour = \$74,400. This savings will be realized in time and not costs. It will provide the inspection teams time to perform other inspections for QA and High Mast Lighting.

Travel and per diem costs will be less too and are calculated with these assumptions. Four months' time savings is equivalent to 16 weeks. Lodging cost is \$80/day and per diem travel cost is \$26/day. Estimated travel cost savings is:

- Lodging = 4 nights/week x 4 rooms x \$80 x 16 weeks = \$20,480
- Per diem = 5 days x 16 weeks x 4 (inspectors) x \$26/day = \$8,320
- Total estimated travel cost savings = \$28,800

This does not include vehicle costs because it is assumed the vehicles will be used in other inspection activities.

Total potential savings (personnel + travel) = \$74,400 + \$28,800 = \$103,200

5.3 WMS LOS

Four tables were developed by the SAC that will be used to populate the WMS LOS data requirements. The four tables: activity defect assignment, deficiency score index, asset deficiency weight scale, and QG data were previously described. INDOT MIS will be responsible for populating WMS with these data. This may require Agile Assets involvement to update the WMS database

and if this is needed there may be an implementation expense. Maintaining LOS data in WMS will be an ongoing requirement for MIS and the Division of Technical Services.

5.4 LOS SAC

The SAC played an important role in the project by providing direction and participating in the development of the inspection program and the LOS data.

The WMS LOS is to be used as a budget and planning tool. Generated reports will provide Operation managers the ability to assess feature condition and compare with budget allocations. LOS projections can be used to populate the WMS Annual Work Plans. Multiple constraint projections can be run to analyze “what if” scenarios and then the optimum projection can be used

APPENDIX A: STATE INSPECTION PROGRAMS

<http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=1&article=2973&context=jtrp&type=additional>

APPENDIX B: SUB-DISTRICT SAMPLE SIZES

<http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=2&article=2973&context=jtrp&type=additional>

APPENDIX C: LOS INSPECTION MANUAL

<http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=3&article=2973&context=jtrp&type=additional>

as a base work plan. Comparing condition ratings with expenditures gives INDOT the ability to allocate budgets that produce more uniform conditions or meet the higher priority features.

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2. McCullough, B. G. *Maintenance Quality Assurance Program*. Publication FHWA/IN/JTRP-2003/18. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2003. doi: [10.5703/1288284313265](https://doi.org/10.5703/1288284313265).

APPENDIX D: DEFICIENCY SCORE INDEX

<http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=4&article=2973&context=jtrp&type=additional>

APPENDIX E: ACTIVITY DEFECT ASSIGNMENT

<http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=5&article=2973&context=jtrp&type=additional>

APPENDIX F: ASSET DEFICIENCY WEIGHT SCALE

<http://docs.lib.purdue.edu/cgi/viewcontent.cgi?filename=6&article=2973&context=jtrp&type=additional>