

QUALITY MANAGEMENT FOR A MAJOR AUTOMATED PAVEMENT SURFACE ASSESSMENT SYSTEM

INTRODUCTION

Houston, TX, the fourth largest city in the United States, has the daunting job of managing and maintaining 16,000 lane miles of pavement. This job has challenged Houston and many cities like Houston for years. Not only is figuring out where to spend the always limited budget to improve roads and repair problems a challenge. But furthermore, the current methods of rating the quality of pavement were subjective and prone to debate where road improvements became a political event more than a factual need.

Houston decided to take this challenge in hand in 2009 to develop a methodology where not only can they analyze all the pavement in the city for quality, but also do so in a quantifiable manner allowing city leaders and commissioners to better make factual decisions on where to spend road improvement budget. Additionally, by having a quantifiable and automated system, Houston would be able to gain additional federal budget to improve their city's road network even further.

To accomplish this task, Houston engaged Idea, now called Astadia, to develop a solution that is automated, quantifiable, expansive enough to cover the city, and owned and operated by the City of Houston. Idea rose to this challenge and developed what is now called the SSAV Project, or Street Surface Assessment Vehicle Project.

Idea worked with hardware vendors to create a best of breed solution for the City of Houston to own and operate. The solution has both a hardware aspect with a van loaded with equipment and a software aspect that automatically translates the output from the van into analyzed data for decision makers to use in determined street repair schedules and maintenance projects.

This system has now completed two full analyses of the City's road network and will be completing a third pass in 2014.

Astadia is a global business consulting, marketing and technology services company with locations in North America, Europe and Asia

Astadia uses creativity and technology to architect and implement meaningful business solutions that provide measureable results for organizations, their employees and their customers.

THE CHALLENGE

What do you do if roads that you ran an assessment on last year improved in their rating without any work being done to fix the condition? Or if a road lowers in its rating more than 20%? More than 30%? More than 60%? How

about if you ran the same road within a week of another run and the variance in the results was greater than 8%? What if a segment had just received a new overlay and then been resurveyed resulting in a rating with a low score? These are questions that the City and Astadia found themselves needing to answer as the system entered into the second city-wide assessment run. While each of these was an outlier from normal results, these results called into question all results and therefore either needed to be understood, or fixed.

Put simply, if the data is suspect, no result that the SSAV project produces will be trusted.

In collecting and analyzing terabytes of data. Quality assurance was a challenge. With multiple factors that impact the quality of the data collected, and large amounts of processing to be completed, the City and Astadia have had to develop several methods to control quality and make sure that the data is correctly guiding the City in their decision making.

THE SOLUTION

Automated Scoring is for:

- Speeding the assessment process
- Meeting GASB 34 standards
- Removing subjectivity
- Removing human factors
- Standardizing the scoring and assessment so that a score of 80 means exactly the same thing on every road.

The first action that was needed in the quality assurance plan was to identify what was the purpose, or the expected outcome, of the plan. The following were identified as the primary goals of the plan.

- Ensure quality is planned in all stages of the program
- Define how quality will be managed
- Define quality assurance activities
- Define quality control activities
- Define acceptable quality standards
- Collect and check quality standards

By accomplishing these factors the City will have assurance that the system is functioning properly and collecting data that the City can have confidence in. However, in order to be successful, this program must meet its quality objectives by

utilizing an integrated quality approach to define quality standards, measure quality and continuously improve quality. There are three primary areas that must be tracked and improved to meet the quality standards.

- i. Human Process Control
- ii. Equipment and Data Quality Control
- iii. Verification of Quality Results

Each of these must be identified and tracked throughout all stages of the SSAV workflow to make sure quality standards are adhered to from beginning of the process to the end of the analysis.

QUALITY DEFINED

The first thing that was needed was a definition for what quality meant for the SSAV program. There are a multitude of variables and metrics that could be tracked to define quality, so to make it feasible a simple definition is required. However that simple definition must impact all of the critical aspects of the program to confirm that

quality data and decisions are coming out of the program. This is critical to enable management to make well informed decisions.

It was decided that quality for the SSAV program would be defined by the accurate and consistent scoring of pavement distress. The focus is on the data quality of the program and that the standards and criteria being used will ensure the data meets established quality standards and customer satisfaction.

The process quality standards and requirements were initially determined by the City's outside consultant with input from Street & Drainage Division officials. Many of these items were based on standards relating to proper equipment calibration and data collection techniques. Some current quality management processes, as well as possible future enhancements, are the result of analyzing unexpected score variances and determining solutions for the variances.

QUALITY IS PART OF THE PROCESS – NOT AN AFTERTHOUGHT

Before establishing the quality program for SSAV, quality checks were done on an as needed basis. This as needed basis was determined by the SSAV team, other members of the City's Public Works & Engineering Department, the City's outside consultant, the Mayor & City Council, various City boards and commissions, as well as input from the public. While being able to confirm quality when a person asks is an important task, to actually control the quality of the deliverable the quality checks must happen during the workflow. So while the results of quality can be checked at any time, those quality checks must happen during the workflow to make sure quality happens each and every data run.

Regularly publishing the SSAV's product (PCR scores) will continue to allow input from various sources regarding the scores. This includes accepting input from the internal end users of the scores for potential review as well as what unknown factors may have artificially inflated or decreased a particular PCR score. A focus of this plan is to have internal product quality measures in place to limit the need for end-user/public requests for score reviews.

WORKFLOW BREAKDOWN

The workflow for collecting and analyzing the data is complex, and therefore it is broken down into three stages of discrete effort to more easily handle each stage's quality needs. Process quality is ensured through tracking the continual implementation of the required steps needed for proper pre-collection preparations, in-progress collection activities, and processing of the data collected.

The three primary stages that require quality assurance are as follows:

1. Pre-data Collection – This stage confirms that all equipment and personnel are prepared to collect data.
2. Data Collection – This is the actual data collection phase where the van is on the road.
3. Post Run Data Processing – This is the processing of the data once it is uploaded off of the van and into the Houston data structures.

The quality programs for each stage are focused to solve the specific needs of that stage. The following sections detail the quality approach for each stage and the impact of that program. This document details the current status and some of the planned future enhancements of the quality assurance program. This is a continual process where we are constantly finding new and better ways to effectively collect and measure surface conditions of the road in Houston.

PRE-DATA COLLECTION

Before the van drives out of the garage several quality checks occur to confirm data will be gathered in an accurate manner. Additionally, training and procedures are put into place to assist in making sure that the personnel are collecting the data in a uniform manner. These procedures involve preparations per the technical specifications provided by the City's contractor along with certain management expectations for employees working on the SSAV team. There are three categories of preparatory steps that have been identified for this stage of the process.

INITIAL PREPARATION

This involves ensuring the personnel and equipment is prepared to gather data. The first aspect of this is training and certification of the personnel driving and navigating the SSAV van. This sets the parameters of what speeds can be driving, how to drive the lanes, impact of weather and what to do when the weather changes, etc. This also has a maintenance aspect for the van itself. Prior to any runs, a maintenance checklist is completed to make sure the van is in good working order and all equipment is working to make the data gathering a success.

Finally a critical factor in data quality is planning the routes. Without the planning, streets are missed, other streets driven multiple times and time and money is wasted redoing work that could have been done correctly in the first place. So the final preparatory work is to plan the routes that will be driven over the next several days.

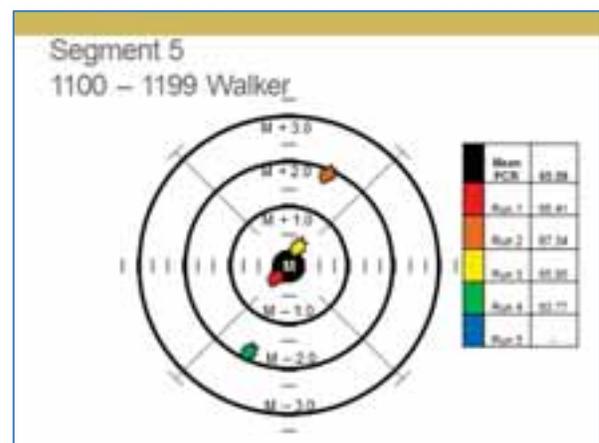
DAILY STARTUP PROCEDURES

The City and Astadia have also implemented a daily startup procedure, much like the pre-flight checklist that a pilot does, to make sure that the vehicle is ready and able to perform the data gathering correctly. There are two primary factors covered with this startup procedure. The first is a vehicle safety check, making sure nothing changed or happened to the vehicle that would create an unsafe run. The second is the computer systems startup and check. This makes sure the computer system is up, running and ready to collect data.

PERIODIC CALIBRATIONS

The final pre-data collection quality assurance step is calibration of the equipment. The van is made to on all road surface conditions including rough roads and to spend hours and hours driving the streets of Houston. This constant vibration and bumps from heavy use can affect the calibration of the instruments and could potentially result in erroneous data if the systems are not periodically checked and recalibrated. Astadia and the City have implemented a calibration program to confirm the equipment is aligned and working properly. There are three primary components to the calibrations.

1. Calibrations of the Technical Components – This is the direct testing and, if needed, adjustment of either physical settings or computer electronic calibrations for each measuring instrument
2. Bounce Testing – This tests the functionality of the equipment that picks up roughness and rutting of the road



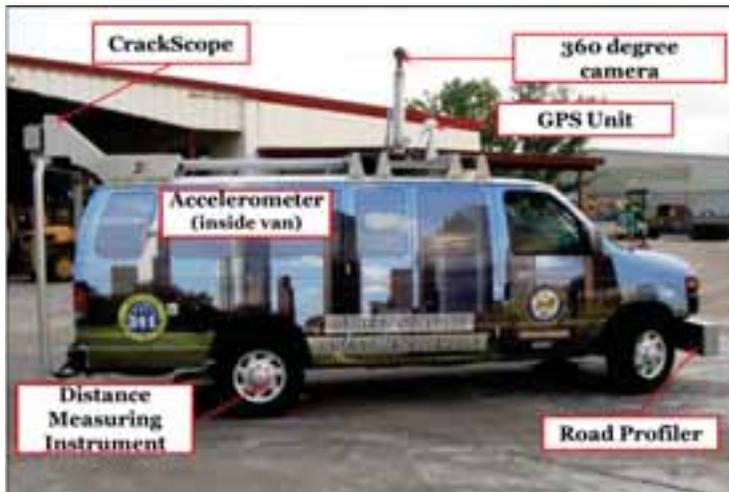
3. Control Runs – This final test is to run roads that have already been scored and confirm the new score is within similar metrics of the original scores. The controlled runs are run over the exact same section of roads and it is driven three to five times to assure repeatable results. The diagram shows an example of the results of these control runs.

Once all of these various checks and procedures are complete, this provides the basis for starting the actual field data collection.

FIELD DATA COLLECTION

In the morning before leaving the garage and en route to collect data the SSAV team must go through several steps prior to actually recording data. These steps are designed to properly collect and record the data and confirm the information gathered from multiple sources is being done correctly.

RUN PREPARATION



There are three steps to preparing for the run. These steps are taken to ensure that the equipment is turned on and is working as it should prior to recording data. The first step is on-board instrument power-on and power-check to make sure everything is on. Then the run software is configured to make sure it is aligned and ready to collect data. Finally verify that all SSAV components (Crackscope, accelerometer, etc.) are detected and working.

With these steps the final assurances that the system is working are complete and the data collection is ready. While many of these steps seem like a simple event,

each one of these have happened causing loss of data or quality of data for a daily run. It is critical to confirm even the smallest event to make sure the SSAV is gathering quality data immediately.

DATA COLLECTION

The data collection quality assurance is broken into a procedural checklist to make sure all is turned on and setup. These steps ensure the vehicle is ready to collect the field data required to calculate the Pavement Condition Rating (PCR) score. The checklist for the beginning of the run is as follows.

1. Power on data/video equipment – turn on and raise the camera
2. Re-power the laser
3. Turn on data collection
4. Record the run-specific data parameters. This is a step the navigator does to make sure the parameters are lynched to the data when uploaded to the home office.

5. Monitor on-board systems to confirm continuous running. This again is what the navigator does while the driver follows the route.
6. Driver follows correct driving procedure through all data collection. Maintaining proper speeds, road positioning and braking procedures is critical to data quality.

At the point that the data is being collected, most of the pro-active data quality assurance efforts should be done. However, following the proper procedure in collecting the data is also required to make sure all is as it should be. Every single step is important to create a quality product for the City.

END OF RUN

The final step of the data collection process to follow the proper procedure to make sure that the data is collected and uploaded without loss of integrity. The first step is to end the data collection in the system. This will allow the in vehicle software to close the files, lock them down and get them prepared for upload into the analysis and post-processing system. The second step is to then turn off all the video recording components. The next step is to export the collected data into the off-vehicle or home base servers for processing. After this is done, the data gathering programs and equipment need to be shutdown and the data storage devices are removed.

These steps are necessary to properly capture data for processing once it has been established that the personnel and equipment meet operational requirements. These steps may need to be repeated if more than one data collection run will take place in a day prior to complete system shutdown.

POST-RUN DATA PROCESSING PROCEDURE

The final steps of quality happen after the data is collected and secured within the City's infrastructure. A large part of the process that creates the PCR score is the post-processing, where systems run large algorithms for analysis and compression of the data, preparing if to view and analysis by the City.

This is where the GPS data is combined into the output from the various collection devices to create a map of the results that can be viewed through the user portals as shown to the right. Esri technology is used to combine this data and Bing Maps used to visualize in the interface. There are possible changes to Esri or Open Street Maps from Bing in the future.



DATA PROCESSING

Once the data is collected and the systems in the vehicle are shutdown, the first step is data processing. This is the process that gets the data prepared for viewing and analysis, and finally gets the PCR score created. The first stage of this process is to begin preliminary run log procedures. This step is to prepare the basic information around a run and make sure all data is logged and tracked for the run. The second step is to process the data from the various sources. These sources include the CrackScope, Surface Profiler, DMI, the GPS, etc. This process takes all these sources and aggregates the data together giving a score for the overall results. The final step in this process is to associate the video to the data gathered and link that directly to the GPS locations within the data.

Creating this data package allows the analysis to be accurately tracked to the proper location. The PCR score is set for city-wide analysis, and video attached to allow review of the score and conditions from the run. This data is then published to all user portals and reports required for viewing and analysis purposes.

VARIANCE AND CONTROL RUN CHECKS

This is where we take the results from the run and confirm that they were indeed successful. The City and Astadia worked together to find checks that give strong assurance that the data collected and the analysis run were accurate and correct. The following checks are performed to confirm that something didn't go wrong.

1. Compare Run-to-Run Variance Reports to identify outliers that show a plus or minute ten point differential from one run to the next on the PCR score.
2. Examine the new overlay variance report to show roads with an overlay performed within the last twelve months to identify those areas with a PCR score of less than 80.
3. Compare PCR score for a set of control runs, much like the pre-data collection checks, and verify a differential of less than 5 points.

Finally, after the results of these checks are complete, the City performs any necessary recalibrations, if needed, and reruns, if needed, of areas as a result of these checks.

NEW STEPS TO INTEGRATE THE USER

Not only has the City and Astadia gone through a workflow overhaul to make sure that the data is accurate, but they have also included input from the user and public. New steps that are being taken to make sure that scores and data are matching what is in the real world. The following steps show some of these initiatives.

1. Accepting and reviewing 311 requests for re-evaluation of PCR scores in an area.
2. Accepting and reviewing requests for PCR re-evaluation from stakeholders and City users.
3. Track these requests and confirm that they do not result in a larger than 10 point difference from the original score

With the checks the city then addresses any quality control problem and reruns the results for the area in question. These items will ensure that the data received is correctly processed and represents an accurate snapshot of the street conditions in a given area at the time the data was collected. The intent is to be able to review the quality of the data internally prior to it being published. This will allow for confidence in the integrity of both the PCR scores gathered as well as the operational decisions made using this data.

CONCLUSION

The City took on a large challenge, to bring about consistent and automatic scoring of their pavement to improve the overall quality of roads in Houston. While the solution provided a significant cost savings to the alternatives, there is still a cost to assure quality; quality isn't free. Much effort goes into making sure the system is functioning and it continually needs to be monitored to give accurate results. Through the lessons learned, two actions stand out.

1. Consistent adherence to process makes for consistent data and consistent results
2. Quality management must be implemented from the beginning to the end of the process to ensure data quality throughout.

The SSAV project has been a huge success for the City and Astadia. Now with a strong quality program, it will continue to serve the City for years to come.