Ten Years of Pavement Distress Independent Verification & Validation (IV&V) in Virginia

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Word Count

Abstract:	226
Text:	2045
Figures (10x250):	2500
Tables (0x250):	0
Total:	4771

Submitted date: 12/08/2014

ABSTRACT
High quality data is essential in a pavement management process for achieving the objective of accurately reporting the existing network conditions, recommending maintenance and rehabilitation activities, developing performance models, and predicting the future network condition. The Virginia Department of Transportation (VDOT) has required an independent verification and validation (IV&V) of the automated distress data collection process since the early 2000s. The IV&V process includes both quality control and quality assurance activities.

The process of IV&V has been effective in identifying systematic errors, correcting those, and in taking steps to prevent further recurrence of such errors. At the same time, it insures that random errors are kept to a minimum. At this time the process has been applied to 10 data collection cycles using pavement monitoring information collected by a single vendor using automated data collection equipment and a semi-automated rating process. Results of this process are presented in this paper. Two pavement distress indices used by VDOT, the Load Distress Rating and the Non-Load Distress Rating have been closely controlled for each data collection cycle. As shown in the paper, there is an indication of data quality enhancement over time as well as a stabilization of the variability in the data from one year to the next. The paper also includes a summary of several significant issues that should be considered in any data quality effort.

INTRODUCTION

The Virginia Department of Transportation (VDOT) has utilized the same vendor to collect, analyze, and deliver automated pavement distress data since 2005. In 2005 the vendor collected and reported pavement condition data on the Interstate Pavements and associated ramps and loops. Since 2006, the vendor has collected and reported distress data for the Interstate Routes and the Primary Routes annually. In addition, they have collected data for approximately 20% of the Secondary Routes annually.

Over this period the pavement imaging system has remained basically the same, although the forward image collection system was upgraded to a single high definition camera in 2009 for the Interstate Routes and 2010 for the Primary and Secondary Routes. A semi-automated process has been used to report the pavement distress from the images. A computer program identifies the location and width of cracks, which leads to crack classification. A manual review of the images is then completed to identify non-cracking distresses such as patching and bleeding.

For the collection of condition data of the pavement network in Virginia, a comprehensive process of quality monitoring is established. This includes pre-data collection quality procedures, ongoing equipment/procedure checks, quality control checks during data collection, data processing checks, and independent verification and validation (IV&V) checks of the automated distress data collection process. Quality Engineering Solutions, Inc. (QES) has been providing these IV&V services for the past decade. The IV&V process includes both quality control and quality assurance activities. At the start of the data collection, an initial set of defined Quality Control/Quality Assurance (QC/QA) steps were identified. These steps helped not only in the identification of the factors affecting the data quality but also resulted in improvement in the data quality assurance process over time. The results of the IV&V process for the past decade (10 years on the Interstate Routes and nine years on the Primary Routes) are presented in this paper. It should be noted that the data on interstate and primary pavements are collected on 100% of the network annually. Therefore, the error associated with the sampling process is not present in the results discussed. This process of IV&V is conducted after the collection of data for the network, and is conducted in batches.

LITERATURE REVIEW

The reliability and usefulness of summaries and reports generated from a Pavement Management System needs a database with data of acceptable quality. Depending on the length of time for which the data is collected and accumulated in the database, the pavement condition data could constitute the largest portion of a pavement management database. The IV&V process helps in monitoring the quality levels of pavement condition data over time with potential improvements in the quality. According to a FHWA report *(1)*, the foundation of a quality management plan is the definition of methods, standards, and protocols to be used in collecting pavement condition data. Some common techniques used for Quality Control of pavement condition data collection, as mentioned in the report are: equipment calibration and method acceptance, personnel training, control site testing, distress rating checks, and data reduction and processing checks. This report also provides examples and case studies of pavement condition data quality requirements specified by some agencies that include: British Columbia, Alabama, Virginia, Pennsylvania, Colorado, Nebraska, Louisiana, and Oklahoma.

NCHRP Synthesis 401 *(2)* describes quality management principles and techniques followed by transportation agencies for pavement data collection. In this report, the details from 55 agencies that include 46 states and nine Canadian provinces are provided. The report states that the quality control includes actions and considerations necessary to assess and adjust production processes to obtain the desired level of quality of pavement condition data. Sources of variability in data processing generally involve distress identification and classification as well as assigning distress severity levels. The expanding use of data has resulted in a greater focus on the quality of data *(3)*, and the quality of data encompasses 11 factors, e.g., relevance, accuracy, precision, timeliness, cost, etc. Another study provides a quantitative assessment of the impact of error magnitude and type in pavement condition data on the accuracy of PMS outputs (*4*).

PROCESS

The development of this IV&V process has been described in other research reports (*5,6*). The impact of a complete and comprehensive quality monitoring plan which includes quality control, quality assurance, and independent verification and validation on PMS decisions and output are presented in a previous study (*6*). That study showed that the implementation of a quality monitoring plan has increased the accuracy in reporting deficient pavements by as much as 30%, and a cost correction of over 18 million dollars for the interstate pavement maintenance recommendations. It also concludes that without a comprehensive and active quality monitoring plan, one which includes an IV&V review, maintenance and rehabilitation needs may be underestimated or overestimated by 25% or more.

The process utilized to control the asphalt distress consists of a 5% random sampling of each District Deliverable. An independent distress rating is completed on these samples and compared to the vendor delivered data. Two index values are used for the comparison, the Load Related Index (LDR) and the Non-Load Related Index (NDR). It was previously determined that each index value reported by the vendor should fall within 10 points of the independently verified index value at least 95% of the time. A typical LDR index comparison chart, as produced from each Division's samples is shown in Figure 1. The value on the vertical index is the LDR derived from the independent rating minus the LDR delivered by the client. The closer these values are to zero, the less variability is evident in the process. When the values exceed 10 points, the data is flagged for further checking. Illustrated in Figure 1 are three samples that exceed the expected range of variability.

For this paper, we have evaluated how this variability between the independently rated index value and the vendor delivered index value has changed over the years. By the process of IV&V both the systematic errors and random errors are detected, and the production data is corrected by the data collection vendor for these errors. Examples of systematic errors that were identified and corrected over the years include: lack of separation of alligator cracking in the wheel path and longitudinal cracks of various severities in the non-wheel path, improper classification of severities of various types of cracking (alligator and transverse), detection of less quantities of cracking on rough-textured surfaces such as chip seal, improper classification of severities of cluster cracking, and improper identification of joint seal damage. These systematic errors were identified and corrected by proper training of personnel or by adjusting the settings of the distress identification software. On the other hand, identified random errors were corrected on specific sections provided the entire batch of data satisfied the criteria set for acceptance.

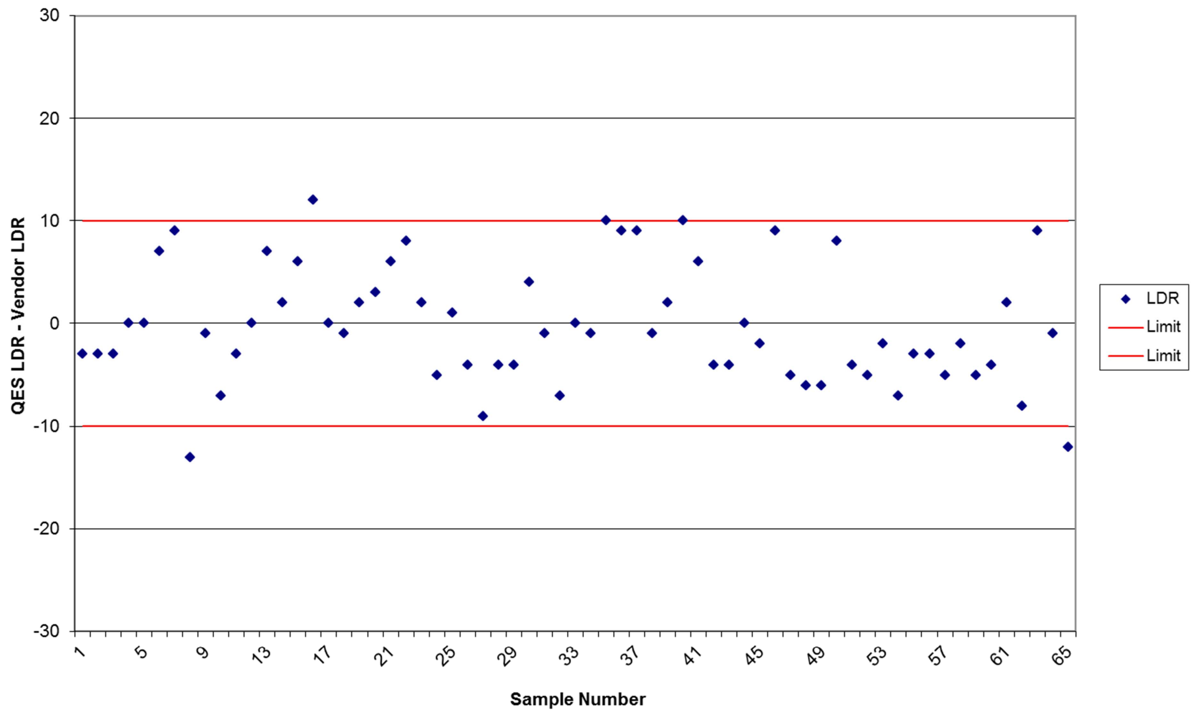

FIGURE 1 Example of LDR Comparison Chart for 65 random samples from Primary Routes in District 3.

RESULTS

Figures 2 and 3 illustrate the average LDR and NDR difference for the Interstate Routes and each Primary District samples over the 9 or 10 years of data collection. This data was then averaged over the entire data set to develop Figures 4 through 10.

FIGURE 2 Average LDR difference by District over the years.

FIGURE 3 Average NDR difference by District over the years.

As illustrated in Figure 4, the average difference in the index values (QES-Vendor) is a low value generally between + or – 4 points. The trend is random, with positive values or negative values in different years. A value of zero would be indicative of no variation between the independent rating and the vendor rating.

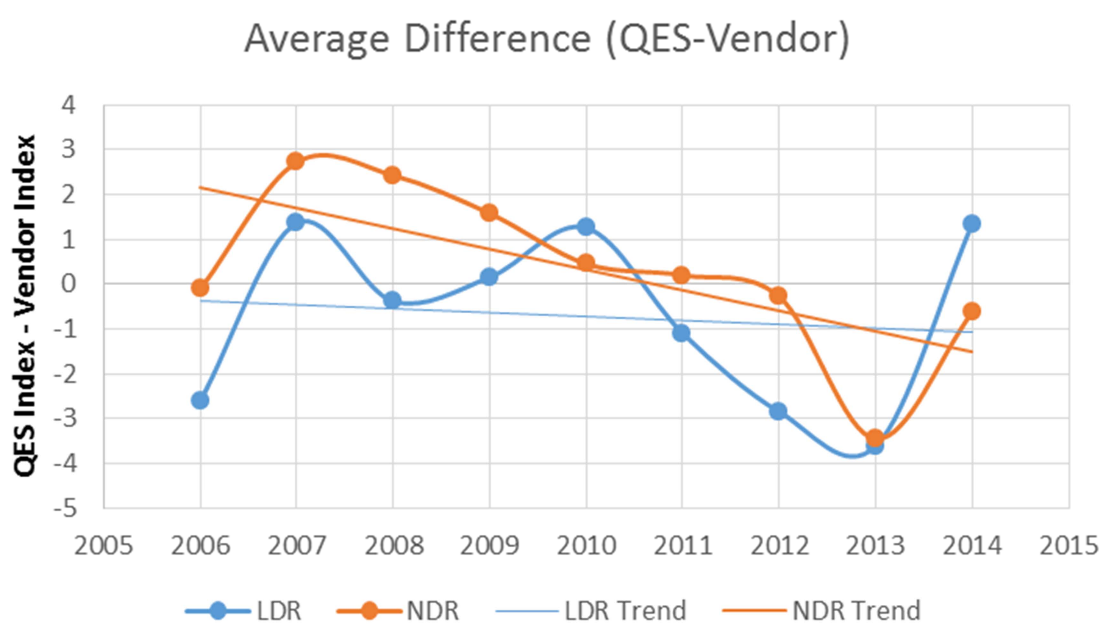

FIGURE 4 Average difference in index values for each year.

The maximum range of difference between index values was considered next. For example, in 2014 on the Interstate Routes, the maximum negative difference between NDR values was -12 and the maximum positive difference was +8, resulting in a maximum range of 20 points. These values were averaged for each District and are presented in Figure 5. The average range shows a decreasing trend over the years, which means the observations from the IV&V and the production data are in better agreement, i.e., the production data progressively is of higher quality over the years.

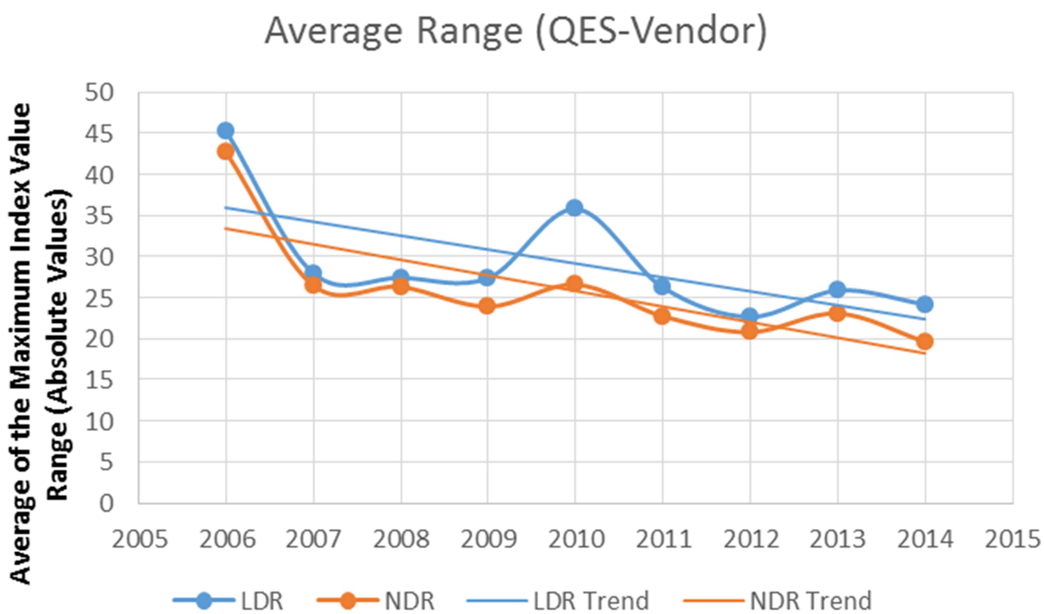

FIGURE 5 Average of the maximum range of index value difference per year.

The average magnitude of the maximum difference between the ratings is shown in Figure 6. The absolute value was used to recognize the maximum difference between the IV&V ratings and the production ratings. There has been a slight decrease in this difference for NDR ratings over the nine year period, while the LDR difference has remained the same.

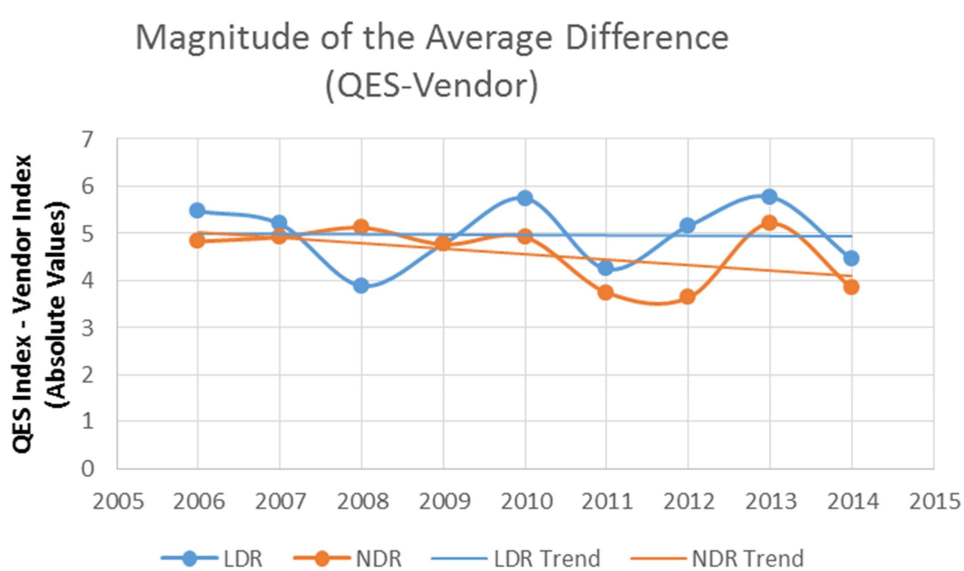

FIGURE 6 Overall magnitude of the average differences.

Figures 7, 8, and 9 illustrate the root mean square error (RMSE), the root mean square percent error (RMSPE), and coefficient of variance (CV) values, respectively. In each case, these show decreasing values over time, which again are additional indicators of enhanced quality of production data over the years. One LDR outlier in the data significantly skews the 2010 data, particularly for the RMSPE.

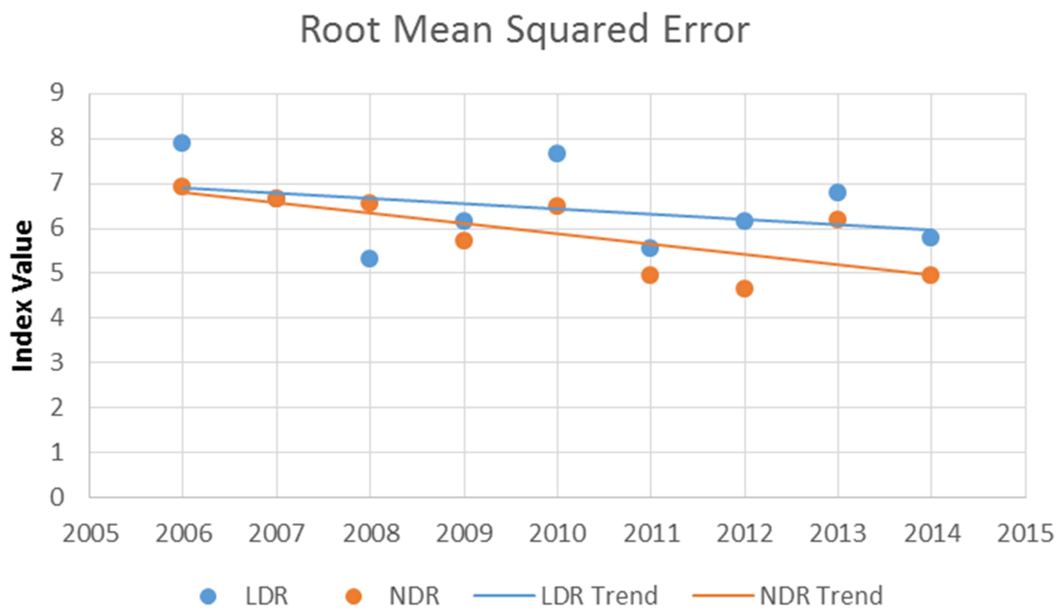

FIGURE 7 Root Mean Squared Error (RMSE) over time.

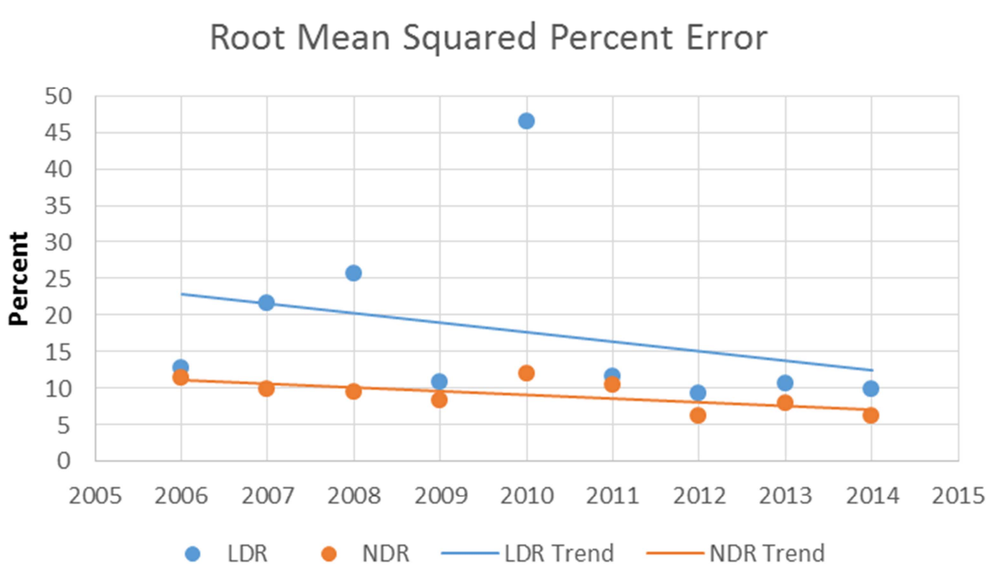

FIGURE 8 Root Mean Squared Percent Error (RMSPE) over time.

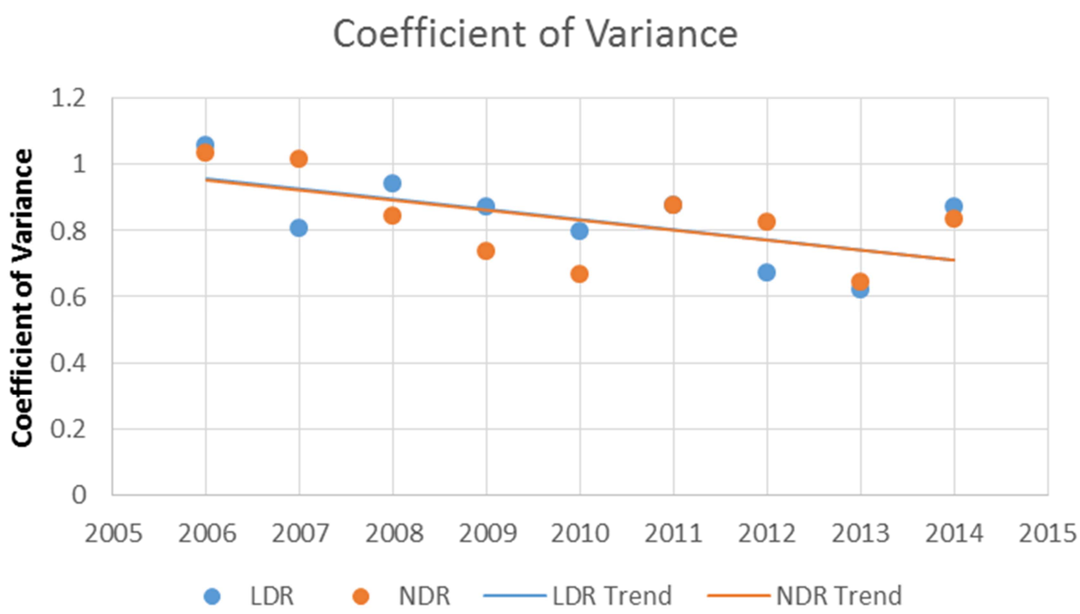

FIGURE 9 Coefficient of Variance (CV) over time.

Positive values of covariance, as illustrated in Figure 10, illustrate that the data from the IV&V and the production either increase or decrease together.

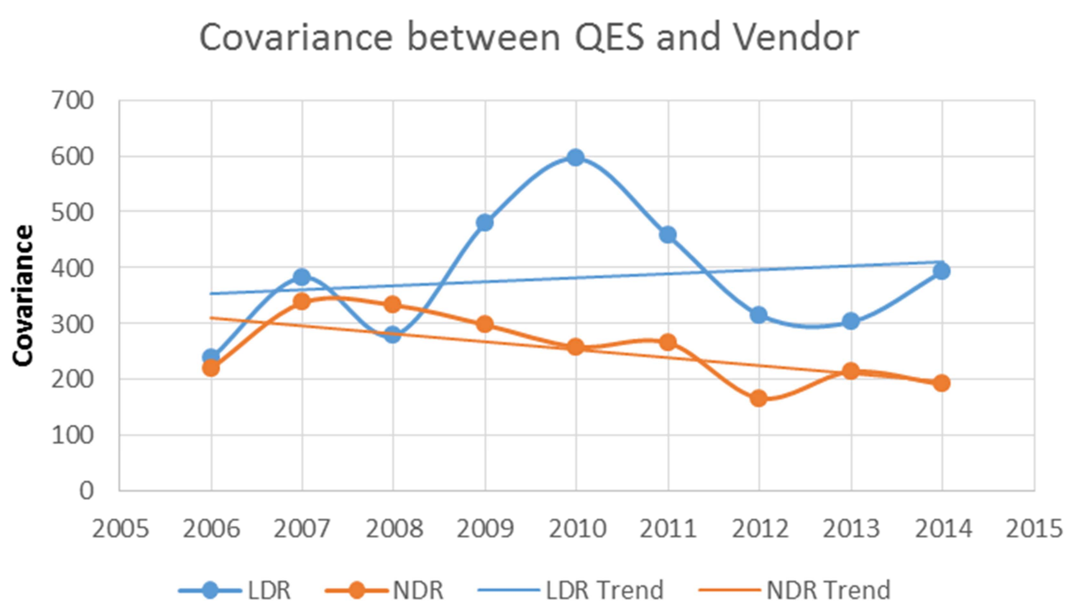

FIGURE 10 Covariance of the index values over time.

SUMMARY AND CONCLUSIONS

As evidenced in the early years of the reported data, it is important to have a quality monitoring process. The variability experienced in the early years is much greater than recent years. A comprehensive data quality effort must include several key elements, such as:

- Pre-data collection quality procedures
    - Identification of the key data elements to be controlled
    - Determine the criticality of each element and expected variability
    - Establish control data
    - Develop tolerance limits and variability measures
- Production level quality checks
    - Equipment and procedural checks
    - Verify data collection measures and associated QC
    - Develop control measures for data processing and associated QC
    - Develop reporting process and associated QC
    - Data reporting and delivery
- Independent Verification and Validation
    - Control key data elements
    - Independent distress evaluations
    - High level data range checks
    - Year-to-Year consistency checks

In this paper, the process of IV&V conducted for the network data collected over a period of 10 years has been presented. Results from the checks for the last 10 years showed that the IV&V has been critical in improving the quality of the collected data. Also demonstrated is the fact that the quality monitoring process corrects the errors that could extend beyond a particular batch of delivered data. Such detected errors are corrected and these errors do not propagate to other data batches. Different ways of evaluation of the effectiveness of the IV&V results shows that the quality of the data has progressively improved, and has remained within the specified limits for data acceptance. The improvement in the data quality over time is further evidence of the effectiveness of the quality process in producing reliable data to support PMS decisions.

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