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Review Article

Investigation of Tanks Inventory at Fuel Terminals Based on Data Quality Dimensions

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Abstract: A recurring challenge in the global oil and gas industry is the issue of reduced volume of petroleum products when loaded into petroleum trucks. Incorrect measurement of product volumes during custody transfer operations can lead to discrepancies in actual quantities, which can have significant financial implications for the parties involved. For these reasons, data collected from hydrometers and thermometers for determining the density at 15°C must be reliable to avoid discrepancies in volume delivered and received. The present study estimates the reliability of super and gasoil temperature and density measurements by applying data quality dimensions. It was also found that the data for quantifying volumes of petroleum products operations was approximately 13.8% erroneous. The most common errors found in the specific condition monitoring data were caused by outlier data. The most likely cause for the outlier data is the quality of work performance at ABC company fuel terminals. The economic impacts resulting from these small measurement errors prompt companies in the sector to focus on continuous improvement of their measurement systems.

Keywords: Industrial data, Data quality dimensions, Oil & Gas industries, Storage systems.

INTRODUCTION

Fuel terminals are used for the purpose of transferring, transporting, and storing petroleum products from refinery plants via bulk vessels and distributing them to retailers by road tankers. The volumes of petroleum products at fuel terminals are measured in tanks and must be corrected to equivalent volumes at a standard temperature of 15°C. Tank gauging is a critical process in determining the physical quantity of petroleum products. This is particularly evident during the volume calculation of transferred petroleum products at fuel terminals, as the results directly impact financial transactions (Sulaiman *et al.*, 2011); (Muthukumaran *et al.*, 2018).

Due to their volatile and temperature-sensitive nature, petroleum products are susceptible to significant losses during storage and transit. Such losses can be attributed to fluctuations in temperature, which can lead to contractions or expansions in volume. Inaccurate volume measurements at fuel terminals can have a significant impact on the income of distributors involved. Failure to consider the impact of temperature on tank calibration or tank gauging can result in inaccurate measurements, particularly when determining actual product loss or gain. This is a particular issue when measuring the loss or gain of products in storage (Meškuotienė *et al.*, 2022).

It is therefore crucial to ensure the utmost accuracy during tank gauging, as the volumes will be used to quantify a custody transfer movement and consequently result in financial transactions. Moreover, the measured volume is used for inventory control and/or stock accounting of fuel. It is necessary to use a standard temperature for the measurement of the volume of petroleum products for the purposes of marketing and to enable the comparison of the amount of products at the time of receipt and delivery from or to another terminal. The standard temperature is employed for the conversion of density and volume correction factor (VCF).

It is the responsibility of the fuel terminal staff to perform tank dipping, temperature reading, and density tests on samples before and after the transfer of products. This is done to determine the product level and volume transferred into the tank. The density and temperature readings are essential for calculating the actual volume of liquid transferred to a tank. The accuracy of the density measurement is contingent upon the quality of the equipment utilized, the precision of the tester, and adherence to the prescribed test procedures. Inaccurate measurements and recording can result in poor data quality, which can have a negative impact on the business.

Small independent retailers are particularly vulnerable to inaccuracies in the volumes of petroleum products loaded into their tanks, as there is no quality control after loading to ensure that they receive the quantity they have paid for (Tamnyuy, 2022). The inaccuracies in the quantification of volume and mass of petroleum products are, to some extent, attributable to the quality of the data used. Inadequate data quality has been demonstrated to diminish customer satisfaction and impede efficient decision-making processes. However, there are clear benefits to be gained from investing in data quality improvement. These include increased customer satisfaction and greater confidence in analytical systems (de Meyer *et al.*, 2021).

Despite the increase in research related to data reliability over the past few years, there has been limited research conducted on the accuracy of the system for measuring and controlling the volume and mass of petroleum products during their transfer into tanks in the Cameroon petroleum industry. This study aims to address the existing knowledge gap by estimating the isolated reliability of density and temperature data for density at standard temperature of 150°C conversion through the application of multiple data analytics techniques.

RESEARCH METHOD

Measurement of Observed Density and Temperature

The data to be used in evaluating the final output volume during petroleum products transfer includes laboratory data of temperature and density measurements and ASTM 53B, 54B tables. The data was collected by sampling petroleum trucks. After loading, the samples were measured and recorded for density and temperature every 15 minutes over a two-day period. Samples of Super and Gasoil were collected and taken to the laboratory for testing. The density and temperature values for the samples were measured using the appropriate hydrometer and thermometer, based on the density range of the product.

Currently, the hydrometer and pycnometer methods are the primary methods for measuring the density of petroleum products (Zhou *et al.*, 2023). Density is a common physical index of petroleum products and is widely measured by the hydrometer method. Figure 1 illustrates the various types of hydrometers available to measure density.

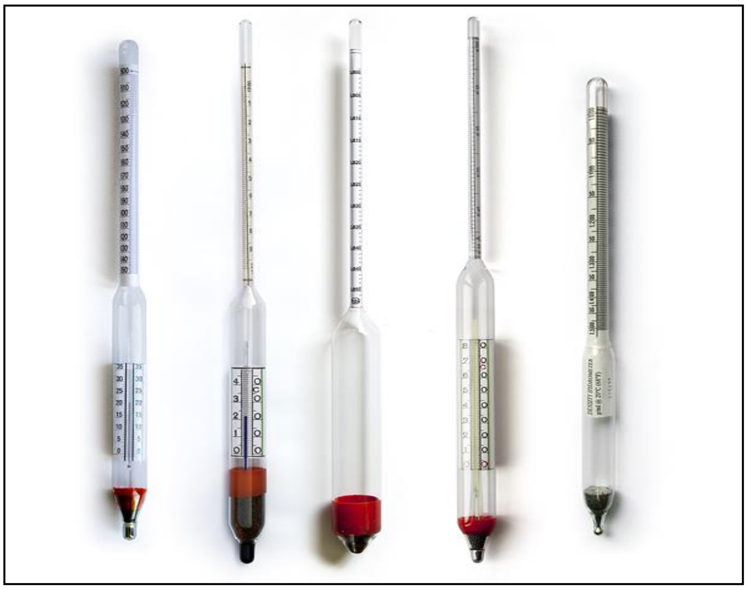

Figure 1: Hydrometers

The hydrometer and thermometer were simultaneously inserted into the measuring cylinder containing the sample. After 30 seconds, the thermometer was removed first, and the observed temperature was recorded. The hydrometer was then removed and its corresponding density recorded (Tamnyuy, 2022). The following figure depicts the experiment conducted in the laboratory.

Figure 2: Testing equipment and sample

Data Integrity Analysis
The isolated reliability of each data point was calculated using the methodology described below (Figure 3).

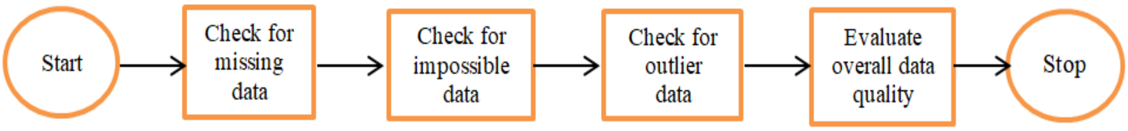

Figure 3: Data analysis process flow chart

- Impossible data points are those that are not possible within the context of the data stream. These impossible values can be used to identify misreading of the hydrometer and/or thermometer values.
- Outlier data are data points that fall within the expected range for the component, yet do not align with the typical profile of the data. They can be used to identify potential issues with data reading, measurement, and/or transmission processes.
- In the event that a data point is identified as being unreliable by any of the data checks, it is to be considered as such from the perspective of isolated reliability (de Meyer *et al.*, 2021).

A variety of metrics were employed to assess each data quality dimension, as illustrated in Figure 3. These metrics were defined by Gosen (2019). The missing data was measured using the missing metric, impossible data was measured using the static metric, and the abrupt errors were measured using the outlier metric.

Missing Data Metric
Given that the densities and temperatures were recorded at 15-minute intervals, the number of missing data points was evaluated using Equation 1.

$$T_{Missing} = \frac{N_{Available}}{N_{Expected}} \ldots\ldots\ldots\ldots\ldots (1)$$

Where:
$T_{Missing}$ = Metric score for the Missing metric
$N_{Available}$ = Number of data points in the date range from the database
$N_{Expected}$= Expected number of data points in the date range from the database

Impossible Data Metric
It calculates the number of data points in sensor data that exceed the limits. Equation 2 was used to calculate the ratio between the data points that exceed set limits and the data points that does not.

$$T_{ExceedsLimits} = \frac{N_{ExceedsLimits}}{N_{Analysed}} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:
$T_{ExceedsLimits}$ = Exceeds Limits metric

$N_{ExceedsLimits}$ = Number of data points that exceeds limits
$N_{Analysed}$= Number of data points analyzed

Outlier Data Metric

Once the outliers in a data set have been identified, the metric defined in Equation 3 was used to determine the ratio between the number of outlier data points and the non-outlier data points.

$$T_{Outlier} = \frac{N_{Outlier}}{N_{Analysed}} \ldots\ldots\ldots\ldots\ldots\ldots \text{(3)}$$

Where:
$T_{Outlier}$ = Outlier metric
$N_{Outlier}$ = Number of outlier data points
$N_{Analysed}$= Number of data points analyzed

Overall Data Quality

Once the data points had been analyzed, the overall data quality score was determined. The overall score for the data was determined using Equation 4.

$$T_{Overall} = \frac{N_{Correct}}{N_{Expected}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

Where:
$T_{Overall}$ = Overall score
$N_{Correct}$ = Number of correct data points
$N_{Expected}$= Expected number of data points analyzed

Results and Discussions

Figures 4 and 5 illustrate the measurement results over a two-day period of the temperature and density of two typical types of petroleum product. These results are consistent with the previous section and are utilized for the evaluation of data quality needed in evaluating quantities of petroleum products during super and gasoil transferred to road tankers.

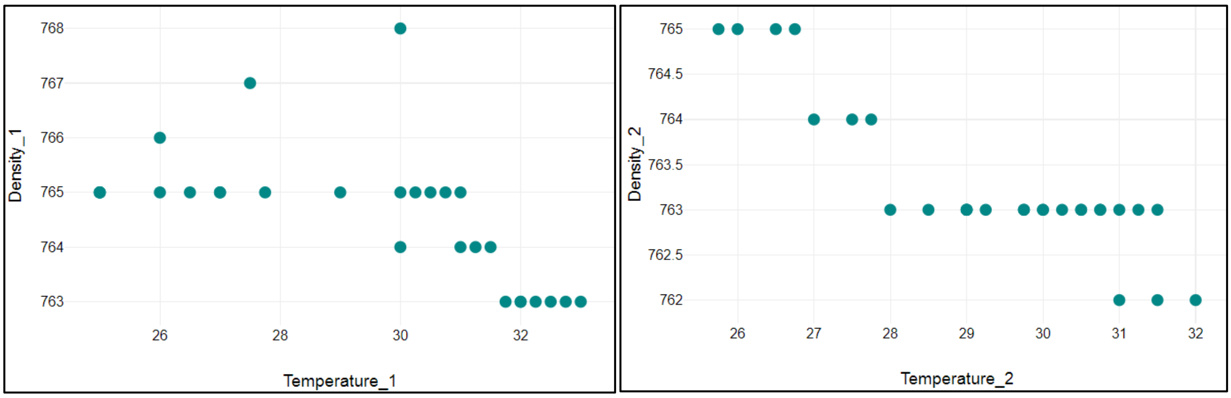

Figure 4: Graph of density values against temperature for super

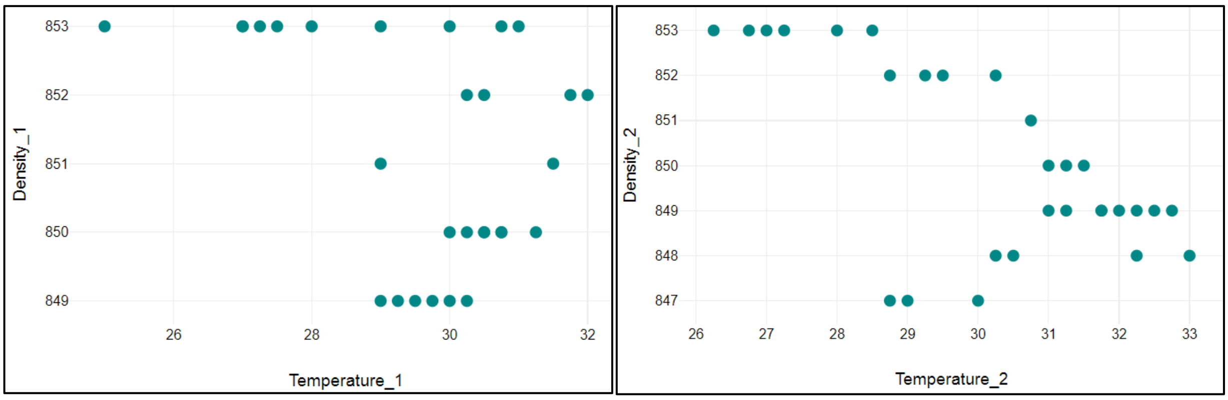

Figure 5: Graph of density versus temperature for gasoil

Figures 6, 7, and 8 present box plots that illustrate the variability in temperature and density measurements. In these figures, the variables "density_1," "density_2," "temperature_1," and "temperature_2" correspond to the 28 measurements of density and temperature used to evaluate the volume of petroleum products over the two-day investigation period. The interquartile range is a useful measure of the variation in the data, as illustrated in these figures. Any data point that is more than 1.5 box lengths from the box is considered an outlier. The two outliers for the super density in Figure 6, with values of 768 kg/m³ and 767 kg/m³, were obtained from measurements at 8:00 a.m. and 8:30 a.m., corresponding to the first and third measurements. The outliers for the gasoil temperature with a value of 31.75°C in Figure 7 were obtained on the first day of measurement.

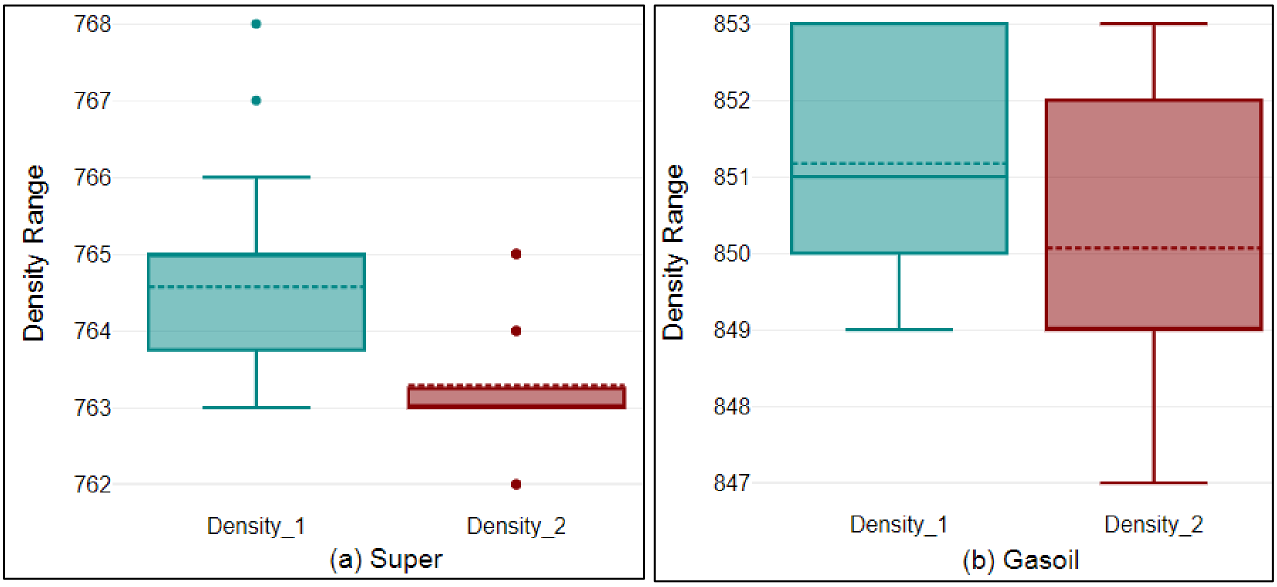

Figure 6: Box plot for observed Density: (a) super; (b) Gasoil

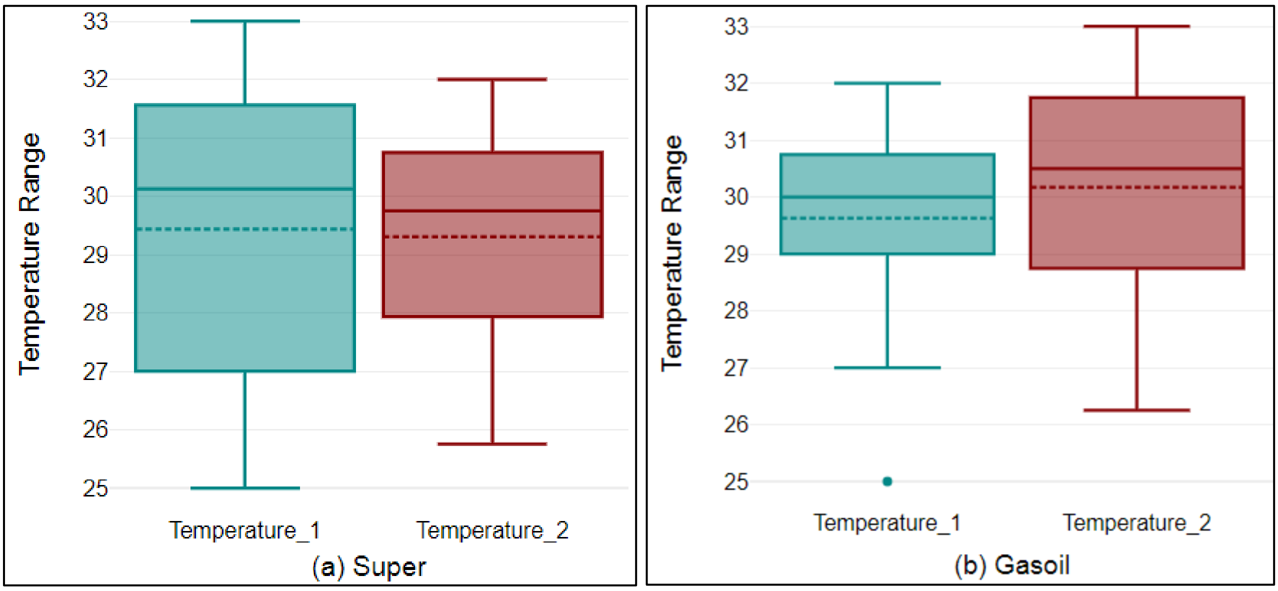

Figure 7: Box plot for observed Temperature: (a) super; (b) Gasoil

Table 1: Results for each data quality dimension

Metrics	Number of faulty data points	Number of data points expected	Overall score (%)
Missing data	0	29	100
Impossible data	3	29	89.7
Outlier	4	29	86.2
Overall data quality	25	29	86.2

The outliers for the super density at 15oC in Figure 8, shown by one circle, correspond to values of 781 kg/m³, while the outliers for the density of the gasoil, presented by three circles, correspond to three data points of density values

862.0 kg/m³, 862.2 kg/m³, and 862.7 kg/m³. The metrics associated with the aforementioned data quality dimension were evaluated. Table 1 provides a summary of the outcomes for each data quality metric. These results were used to verify that the staff responsible for measuring and reporting observed temperature and density data had done so correctly. The total number of erroneous data points was calculated by summing the number of erroneous points generated for a quality metric.

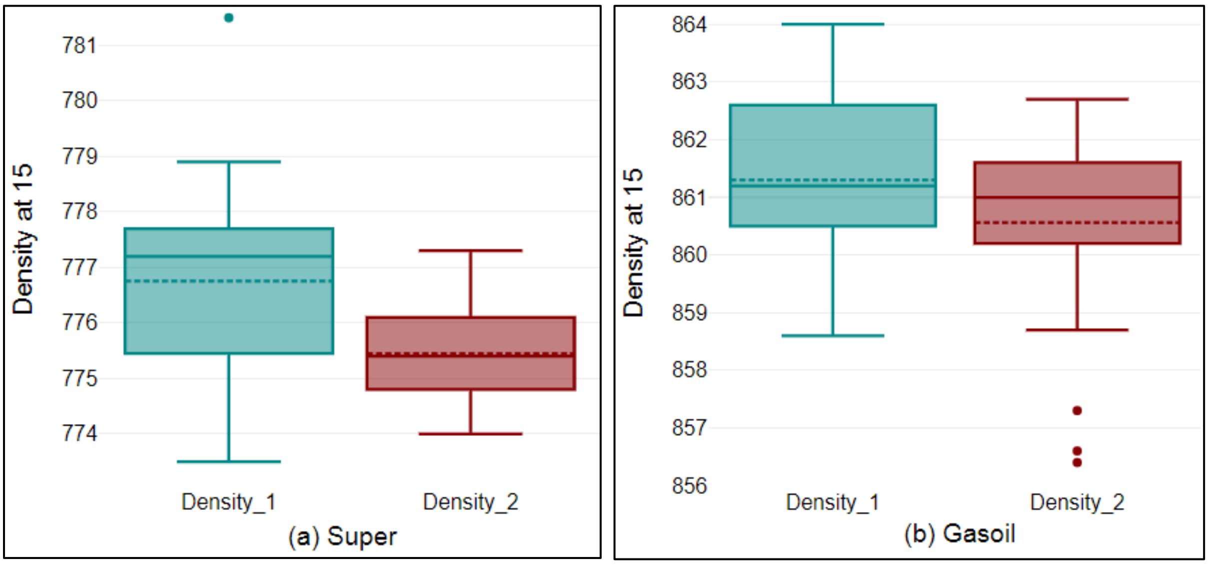

Figure 8: Box plot for Density at 15^{0}C: (a) Super; (b) Gasoil

Table 1 provides an overview of the overall data quality for the density at 15°C. The data quality metrics indicate that approximately 13.8% of the data is erroneous, with 10.3% of this being impossible data. As illustrated in Table 1, it is evident that the outlier data metric is of low quality. The primary causes of suboptimal measurements can be attributed to human factors, such as fatigue among terminal staff that are overwhelmed by the demands of their work. However, in the oil and gas industry, it is of the utmost importance to guarantee the reliability of measurements to prevent potential conflicts in business relationships that could result in significant financial losses for all parties involved (Orsay, Medeiros, & de Oliveira, 2023).

The manual measurement of the temperature and density of petroleum products is a time-consuming and labor-intensive process. Inaccuracy in the measurement and recording of measurements could occur due to various factors, resulting in false records of the quantity of petroleum products transferred at the fuel terminal. Other authors have reported that typical manual tank gauging uncertainties range from 0.6% to 2.5% of the transferred product amount (Shunashu & Casmir, 2020). Previous studies have demonstrated the advantages of automatic tank gauging, which has the potential to enhance the accuracy of level measurement (Endress & Hauser, 2015); (Okperigho, Nwozor, & Geteloma, 2024) in comparison to manual gauging utilized by the company.

Conclusions

An investigation into the data quality required for the transfer of petroleum products at fuel terminals revealed that some of the data was erroneous. This has resulted in a reduction in the income of the distributors involved. To ensure better and fairer trade, ABC Company should implement good measurement and conversion practice for density conversion to density at 15°C in order to get the maximum benefit from ASTM Tables. The results of such an analysis can be used to improve the accuracy of volume and mass measurement, reduce tank gauging uncertainties, and facilitate fairer trade. A smart automatic tank gauging temperature and density monitoring system with suitable sensors made with the latest technologies has demonstrated its ability to minimize errors related to human factors, thus improving accuracy and efficiency. It is therefore recommended that such a system be implemented.

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