

Fuel Loss Detection and Web-Based Management for Petrol Pumps: A Literature Survey

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Abstract: *Small and medium petrol pumps often keep their daily records by hand, and fuel lost through theft, leakage or wrong entries may be noticed only after many days. This paper surveys ten published works related to this problem and groups them into three themes: sensor-based fuel monitoring and theft detection, anomaly detection with Isolation Forest and related methods, and inventory management with web-based systems. The review is based on the abstracts and publication records of the ten papers; full texts were not analyzed. The fuel monitoring studies relied mainly on added hardware such as level, flow, vibration, GPS and GSM modules, and only one of them was aimed at tanks in petrol depots. The anomaly detection studies showed that Isolation Forest is fast, can work without anomalies in the training data, and has been extended and applied to electricity and vehicle fuel data. The inventory studies dealt with web systems and small-business practice but not with fuel loss. According to the abstracts reviewed, none of the ten works describes a low-cost web system that joins daily pump accounts with anomaly alerts and needs no sensor hardware. The paper explains how the planned FuelX system, built with PHP, MySQL and Python, is meant to address this gap, and states that its performance is yet to be tested.*

Keywords: Petrol Pump Management, Fuel Theft Detection, Anomaly Detection, Isolation Forest, Web-Based Inventory Control, Literature Survey.

I. INTRODUCTION

A petrol pump produces a steady flow of records. In every shift the nozzle meter readings, tank dip readings, cash and credit sales, purchases and expenses have to be written down and checked against each other. In small and medium pumps these records are often still kept in registers or spreadsheets, which makes the daily closing slow and lets small mistakes grow into large totals. A difference between the stock shown in the books and the fuel measured in the tank may then remain unexplained for many days, whether it is caused by theft, leakage, evaporation or a wrong entry. Researchers have approached this area from three directions. The first is physical monitoring of fuel level and fuel theft with sensors and alert modules [1]–[3]. The second is anomaly detection, where a model learns the normal pattern of data and flags unusual records, with Isolation Forest as a common choice [4]–[8]. The third is inventory management, including web-based inventory systems, in organizations [9], [10]. Each direction covers a part of the problem, but they are rarely discussed together.

This paper reviews these ten works to support the design of FuelX, a web-based petrol pump management system planned by the authors using PHP, MySQL and a Python module based on Isolation Forest. Section II gives the scope, Section III reviews the papers by theme, Section IV compares them, and Section V states the research gap.



II. SURVEY SCOPE AND METHOD

The authors selected ten published works that relate directly to the planned FuelX system: three on fuel monitoring and theft detection, five on anomaly detection and two on inventory management. No other source is cited in the review. For every paper, the abstract and the publication record were read, and four points were noted: the problem addressed, the method used, the key outcome and the limitation. Within each theme, the papers are discussed in order of publication year.

Two cautions apply. First, full texts were not analysed, so a result, data set or limitation described here as not reported in the abstract may still appear in the full paper. Second, the limitations listed in this survey are observations of the present authors drawn from the abstracts, unless the original authors are named as having stated them.

III. REVIEW OF LITERATURE

A. Fuel Monitoring and Theft Detection Systems

Gupta et al. [1] presented an IoT-based smart petrol pump design in which the fuel level at a station is measured and sent to a central server, where an administrator can change and update the data. The design concentrated on measuring the depth of tanks in petrol depots. The abstract did not report test results, and it did not describe any check for abnormal loss, so the system supports observation of fuel levels rather than detection of unexplained differences.

Prabhu et al. [2] aimed at fuel theft and leakage in vehicles. Their system combined an ultrasonic sensor for fuel level, a flow sensor for leakage, a vibration sensor for theft and a GPS module, all connected to an ESP32 Wi-Fi board. Theft alerts were sent through API-based messaging, a sound alert warned of leakage, and the nearest petrol station was suggested with the Haversine formula when the fuel level reached its minimum. The abstract gave no performance figures and did not describe any analysis of stored records. The design needs several sensors on every vehicle.

Mathi et al. [3] considered fuel theft from vehicles, transport containers and industrial storage, and also abnormal battery behaviour in hybrid and electric vehicles. A resistance-based level sensor was used, so that a sudden change in resistance indicated a sudden change in fuel level, while a voltage sensor watched the battery state of charge. When an abnormality was found, a GPS module recorded the location and a GSM module sent an alert. The authors described the method as accurate and low in cost, but the abstract gave no figures to support this.

Taken together, these three works [1]–[3] depend on sensors and alert hardware installed at the tank or the vehicle. Only [1] was aimed at tanks in petrol depots, while [2] and [3] were aimed mainly at vehicles and containers. None of the three abstracts describes a statistical or learning-based check of recorded stock data.

B. Anomaly Detection Methods

Liu et al. [4] noted that most model-based detectors build a profile of normal data and treat anything that does not fit as an anomaly. They proposed Isolation Forest (iForest), which instead isolates anomalies directly. Because the method works on small random samples, its time cost grows linearly and its memory need is low. Compared with ORCA, LOF and Random Forests, iForest performed favourably in AUC and processing time, especially on large data sets. It also worked when many attributes were irrelevant and when the training data contained no anomalies. The abstract gave no numerical results.

Hariri et al. [5] found that the anomaly scores of the standard method showed artefacts in score maps, caused by the way branches are chosen. Their Extended Isolation Forest offered two remedies: transforming the data randomly before building each tree, or, preferably, cutting the data with hyperplanes of random slope. The second approach removed the artefacts and made the scores more consistent, and the authors reported AUROC and AUPRC on synthetic and real benchmark data. They found no noticeable difference from the standard method in convergence rate or computation time. The evaluation used benchmark data rather than stock or fuel records.

Ruff et al. [6] observed that deep learning had produced many new anomaly detection methods without a common view of their principles. Their review connected classical (shallow) and deep approaches, identified assumptions that many



methods make without stating them, and compared major methods empirically with the help of explainability techniques. Worked examples and practical advice were included, and open challenges were outlined. As a review, it proposed no new detector, and the abstract did not say which challenges were identified.

Wang and Li [7] studied abnormal electricity use, where users with similar consumption patterns are hard to separate. Using Irish smart-meter data, they built features describing the volatility, trend and correlation of consumption and fused them with principal component analysis. A Canopy-Kmeans clustering method improved with weighted density was then combined with Isolation Forest into an unsupervised detection model. The model separated users with different consumption patterns and gave better accuracy, recall and F1 score than other algorithms, although the abstract did not state the values. The study was limited to electricity data.

Turan et al. [8] turned to fuel: they aimed to detect high fuel consumption in heavy-duty vehicles from operating data, motivated by efficiency and CO₂ emissions. Isolation Forest, an autoencoder and a k-NN regressor were combined as an unsupervised ensemble, with the outputs merged by weighted majority voting. The data set had 459 driving records with 14 signals from 187 vehicles, and the Local Outlier Factor was used to validate the ensemble and to find root causes of anomalies. The abstract presented the approach as new for this setting but gave no performance metrics. It used vehicle signals, not station stock.

Isolation Forest is the base of [4], [5], [7] and [8]. Hariri et al. [5] changed its splitting, Wang and Li [7] combined it with clustering, and Turan et al. [8] combined it with other detectors, while Ruff et al. [6] placed such methods in a wider frame. Wang and Li [7] (electricity) and Turan et al. [8] (vehicle fuel) each applied unsupervised detection to consumption data, but none of the five abstracts applied it to stock reconciliation at a petrol station.

C. Inventory Management and Web-Based Systems

Muñoz Macas et al. [9] reviewed inventory management in retail small and medium enterprises (SMEs). They pointed out that studies supporting the adoption of advanced inventory systems are hard to find, and carried out a systematic literature review of the years 2015 to 2019. The outcomes were the leading inventory systems and models, key performance indicators, and the benefits and challenges of adopting an efficient system. Their findings indicated that SMEs rarely invested in sophisticated systems and mostly used a simple ERP package, Excel sheets or manual inventories. The review was limited to retail and did not deal with fuel or with detection of stock loss.

Misahuaman et al. [10] observed that many organizations still count inventory physically, and that web systems for inventory control can raise efficiency in small, medium and large organizations. They collected and reviewed the approaches, methodologies and frameworks used to build such web systems, finding 85 articles and selecting 26 that met the inclusion and exclusion criteria. The abstract links web systems with efficiency and savings in hardware and software costs. It did not describe fuel, stock-loss checks or anomaly detection, and it did not report findings for individual frameworks.

Misahuaman et al. [10] presented web systems as a route to efficiency, while Muñoz Macas et al. [9] showed that small firms still rely mostly on simple tools. Both are general inventory studies; neither examined fuel stock or checked recorded data for abnormal differences.

IV. COMPARISON OF THE REVIEWED WORKS

Table I compares the ten works by authors, year, venue, method and limitation. The limitation column gives the observations of the present authors based on the abstracts, as explained in Section II.

TABLE I: COMPARISON OF THE REVIEWED WORKS

Ref. No.	Authors	Year	Venue	Method	Limitation
[1]	Gupta et al.	2016	PDGC	Tank level sensing at petrol depots; data shown on a central server with admin editing	No loss analysis or results in abstract; sensor-dependent



[2]	Prabhu et al.	2022	ICCCNT	ESP32 with ultrasonic, flow, vibration and GPS sensors; API alerts	Vehicle-focused; hardware-dependent; no results in abstract
[3]	Mathi et al.	2024	ICICT	Resistive level sensor, voltage sensor, GPS and GSM alerts	Vehicle and container focus; hardware-dependent; no figures in abstract
[4]	Liu et al.	2008	ICDM	Isolation Forest (iForest)	No numbers in abstract; score artefacts later reported in [5]
[5]	Hariri et al.	2021	IEEE TKDE	Extended Isolation Forest with random-slope hyperplane splits	Tested on synthetic and benchmark data, not stock data
[6]	Ruff et al.	2021	Proc. IEEE	Review linking shallow and deep anomaly detection	Review only; open challenges not detailed in abstract
[7]	Wang and Li	2024	IEEE Access	Weighted-density Canopy-Kmeans combined with Isolation Forest	Electricity data only; no values in abstract
[8]	Turan et al.	2024	INDIN	Isolation Forest, autoencoder and k-NN ensemble; LOF validation	Vehicle signals, not station stock; no metrics in abstract
[9]	Muñoz Macas et al.	2021	ICI2ST	Systematic review of retail SME inventory management, 2015–2019	Retail focus; no fuel or loss detection
[10]	Misahuaman et al.	2021	SNPD 2021-Fall	Systematic review of web inventory systems (85 found, 26 selected)	No fuel or anomaly detection; findings not detailed in abstract

V. RESEARCH GAP AND POSITION OF FUELX

The abstracts reviewed show four points. First, fuel loss detection was approached mainly by adding sensors and alert modules [1]–[3], with [2] and [3] aimed at vehicles and containers. Second, Isolation Forest and its variants were applied to electricity [7] and vehicle fuel consumption [8] data, but no abstract described their use on petrol-station stock figures. Third, the inventory studies [9], [10] covered inventory systems, methods and small-business practice without considering fuel loss. Fourth, the abstracts of [1]–[3] and [8] reported no detection results, so the accuracy of these approaches for fuel loss cannot be compared.

Within these ten works, no abstract describes a system that brings together three elements: a low-cost web application for the daily accounts of a petrol pump, a comparison of book stock with tank dip stock by unsupervised anomaly detection, and operation without added IoT hardware. This statement is limited to the abstracts reviewed here and is not a claim about the wider literature.

FuelX is planned to cover this combination. It will be a PHP and MySQL web application that records nozzle meter readings, shifts, cash and credit sales, stock, expenses, the cash book and the customer ledger, and gives daily reports. A separate Python script will read the stock and sales data, work out the difference between the expected stock (opening stock plus purchases minus sales as per meter) and the dip stock measured in the tank, and apply Isolation Forest from scikit-learn to flag unusual shifts or days. Flagged records will be saved in an alerts table and shown on the dashboard for the owner to check. Liu et al. [4] reported that Isolation Forest also works when the training data contain no anomalies, which suits a setting where real theft records are hard to obtain. The first version will not connect to



dispensing machines or payment gateways, so it needs no extra sensors.

FuelX has not yet been tested, and its usefulness remains to be shown. Its alerts depend on the accuracy of manually entered meter and dip readings, and sample or simulated loss data may be needed for training and testing. Later work can compare standard Isolation Forest with the extended splits of [5] and the ensemble idea of [8], and can add automatic tank gauges so that readings arrive without manual entry.

VI. CONCLUSION

This survey reviewed ten works in three themes. The fuel monitoring studies [1]–[3] relied on added sensors and alert modules, the anomaly detection studies [4]–[8] showed that Isolation Forest is efficient and adaptable to consumption data, and the inventory studies [9], [10] addressed inventory systems and web-based tools without considering fuel loss. On the basis of the abstracts alone, none of the ten works joins daily pump accounts with anomaly alerts in a low-cost web system without sensor hardware. FuelX is planned to fill this gap, and its performance will be checked on sample and simulated pump data in the next phase.

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