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An Efficient Fuel Management System to Address the Ongoing Fuel Crisis in Sri Lanka

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ABSTRACT

The economic crisis has made huge impacts on people's lives to the extent that certain daily tasks no longer feel normal, like pumping fuel from a fuel station. Mental and health conditions of people are deteriorating due to these types of issues which must immediately be addressed. This paper discusses about a proposed fuel management system to eliminate or at least reduce this unnecessary hassle for the public and fuel stations also illustrating and discussing the available systems for the same. New innovative features have been proposed to this system respective to the system already in use which is believed that it will vastly help in managing fuel more efficiently for both distribution and pumping. We also believe that the data collected through the system will also be very useful in making prediction models for the government as well, to make certain decisions. Another aim of this system is eliminating the black market for fuel which has been created putting more pressure on people and the government by a complaint management feature and tracking fraudulent fuel stations using a formula which has been proposed. Thus, we hope this system will aid both for the government and the public for an efficient fuel management.

Keywords-- Fuel Management, QR Code, Fuel Quota, Fraud Detection, Fuel Crisis

I. INTRODUCTION

People in Sri Lanka are facing a very critical economic crisis which was created by many factors and has affected many fields as well.[1] As a result, inflation in the country increased exponentially. [2]

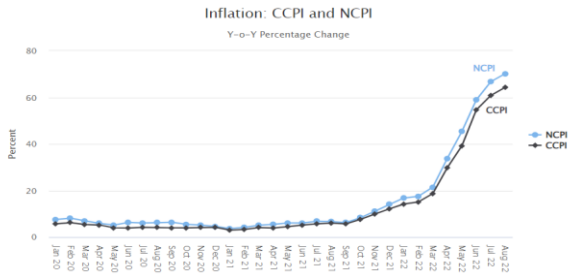

Figure 1: Inflation Graph

Date	Colombo Consumer Price Index (CCPI)		National Consumer Price Index (NCPI)	
	Headline Inflation (Y-o-Y)	Core Inflation (Y-o-Y)	Headline Inflation (Y-o-Y)	Core Inflation (Y-o-Y)
2022				
January	14.20	9.90	16.80	12.90
February	15.10	10.90	17.50	14.10
March	18.70	13.00	21.50	17.30
April	29.80	22.00	33.80	27.90
May	39.10	28.40	45.30	37.70
June	54.60	39.90	58.90	49.30
July	60.80	44.30	66.70	57.30
August	64.30	46.60	70.20	60.50
September	69.80	50.20	73.70	64.10
2021				
January	3.00	2.70	3.70	4.20
February	3.30	2.60	4.20	4.10
March	4.10	3.10	5.10	4.30
April	3.90	3.00	5.50	4.10
May	4.50	3.20	6.10	4.20
June	5.20	3.20	6.10	4.10
July	5.70	3.70	6.80	4.40
August	6.00	4.10	6.70	4.70
September	5.70	5.00	6.20	4.80
October	7.60	6.30	8.30	7.20
November	9.90	7.00	11.10	8.80
December	12.10	8.30	14.00	10.80

Figure 2: Inflation rates as per the CBSL statistics

People are struggling with daily hour-long power cuts and shortages of basic needs such as medicine, food and fuel.

According to the officials, there isn't sufficient fuel in the country to provide key transportations services like buses, trains, and medical vehicles, and there aren't sufficient foreign currencies to import either. As a result, people have been urged to work from home to conserve supplies, and schools have been closed.

Petrol and gasoline prices have risen significantly because of the fuel crisis. For two weeks in late June, the government restricted the selling of gasoline and diesel for non-essential vehicles. Fuel sales are still severely constrained.[3]

Therefore, in this kind of situation an efficient fuel management solution is very important for a country like Sri Lanka due to the prevailing economic crisis. Which has forced the government to set limitations for fuel distribution and consumption. The government must introduce new restrictions as well as people must limit their travels. With those restrictions and limitations, people must face many struggles such as waiting in fuel queues for weeks, not getting enough fuel for daily traveling, frauds in fuel queues and many related problems.

The existing system is only capable of generating a fuel quota weekly and modify the weekly availability with the user consumptions and reallocate the quote at the beginning of a new week. It will provide a solution only for allocating and limiting the fuel consumption, but there is no other specific advantage than a few new modifications when registering multiple vehicles in an organization or a business.

The proposed system is a centralized system which can perform many functionalities related to fuel management. All the functionalities in the existing system are included in the proposed system such as single/multiple vehicle registration, generate QR for users, weekly update and reallocate a quota as well as new functionalities like ordering fuel for a station, track the fuel ordering and fuel distribution records and generate reports, fuel bookings could be done for users, complaint management, user's fuel consumption and booking reports etc. Tracking all the records from one specific system will be helpful to forecast ordering and distribution decisions, get measurements of fuel usage and amounts, ordering and distributing in the most optimal way after considering the past records.

As an example, the government can look for the most demanding districts, cities and allocate the fuel distributions accordingly. And fuel stations can decide how much of liters they should order by looking after their past records which are very important functionalities of the proposed system.

II. LITERATURE REVIEW

Fuel consumption in Sri Lanka has surged respective to the last year [4], that with the economic crisis which has strike after the long covid period, the government has been struggling to provide fuel as for the demand which has created a massive tension among the people who have been forced to spend their valuable time at fuel station queues for days.[5]

The unavailability of fuel for demand has also affected many other sectors, mainly electricity distribution. The government has been forced to limit electricity supply for households as well due to unavailability of the required amount of diesel for continuous power generation, thus people are experiencing daily hour-long power cuts. A situation of people selling fuel at black market prices has also emerged. This tension has also created rage among people in which research from "ACLED's Conflict Change Map" [6] [7], points out that violence in Sri Lanka has increased by 700% during this period. Thus, this has become a massive concern to be addressed.

Initially, a token card system was introduced as a solution [8], but due to the failure of this method, a 'QR system' was introduced as a national pass for fuel [8]. This system has made a good impact reducing queues at a certain extent, although it has failed for the first few days since people faced difficulties registering to the system, which was caused by low system performance.[9]

"NFC Fuel Card Solution" is also a card-based system to provide fuel to consumers, aiming it to be efficient and quick, even though this has not been implemented as a solution for the crisis, it is worth understanding such concepts in creating new systems.[10]

The QR code system has been used also considering security aspects which are well explained by (M. Mary Shanthi Rani, 2016)[11], a high error correction level has been used since user email and user id should get encrypted.

Khan et al proposed 'Smart Fuel Station Controlling System' [12] uses RFID technology for fuel pumping activities, rather than an online system, a GUI on the fuel station itself is used, which may take a longer time to get inputs and start the procedure.

Fraud detection is also required for an overall efficient fuel management, (Sri Sangeetha R)et al. have proposed an IoT based smart fuel meter mainly to track frauds [13], meanwhile our system will use data generated for fuel pumping and fuel provided to fuel stations to identify potential frauds.

Taking the features in the already existing 'QR system' used in Sri Lanka into consideration [8], an approach has been made to add a 'booking system' from which we believe existing queues could be further reduced, thus saving people's valuable time.

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III. METHODOLOGY

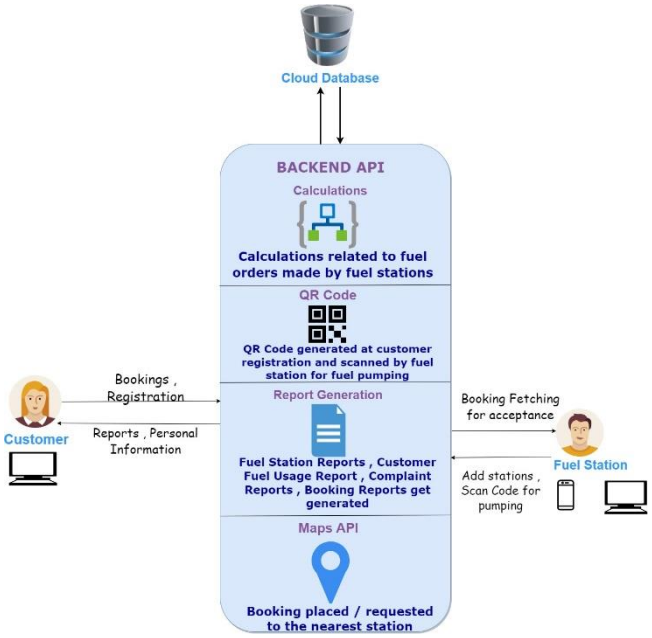

Figure 3: Overall Architecture of the System

A three-tier architecture has been used for the system development implemented using the MERN Stack. The MERN stack is a combination of (Mongo DB, ExpressJs, ReactJS, Node.js), which mainly use JavaScript as their base language. Mongo DB is a cloud-based NO-SQL database in which data is stored in JSON format, many companies use NO SQL databases for their efficiency. ReactJS is used for the presentation layer meanwhile Node and Express are used for the business layer.

The proposed system intends to provide a solution for the current fuel crisis the country is experiencing for better efficiency in fuel management thus limiting fuel consumption. The system will provide services to both customer and fuel station parties.

Availability fault tolerance and security are key attributes that the system should consist, for that it is planned to deploy the solution in a cloud environment such as AWS to also easily scale up when required.

The customer party is provided with a web-based solution for which a PWA solution is planned to be implemented while the fuel station party is given a mobile and web solution, through the mobile solution QR codes (embedded user information) can be scanned when pumping fuel for customers. This data will be sent in real time to the backend of the system from which relevant fuel data will be calculated and adjusted in the cloud database.

Fuel stations are also able to place fuel orders to their fuel stations and when doing so, the relevant amount will be calculated by the backend API, also from which current fuel rates are fetched for the calculation.

For the booking system implemented in the system, customers' eligibility for booking is checked by the backend to ensure enough fuel quota is available which then requires acceptance from the relevant fuel station. Google map API is used to get the nearest fuel station relevant to the customer by real time location.

IV. PROPOSED SYSTEM

A. Customer Management Model & Fraud Detection

The customer management function consists of basic functionalities a customer could use in the system. Below mentioned are the main functions under customer management.

- Login.
- Registration.
- Add Vehicles.
- View/Search Vehicles.
- Edit Profile
- Remove Vehicles
- View Fuel Reports
- Unregister.

Customers can add their personal vehicles providing the relevant information, view and remove them when required.

Customer's personal info can be edited other than the email address which is used for logging in.

The fuel report is a downloadable pdf which consists of 2 tables. One table represents the fuel allocations and the other fuel pumping for the vehicles. This report can be generated by providing a date range.

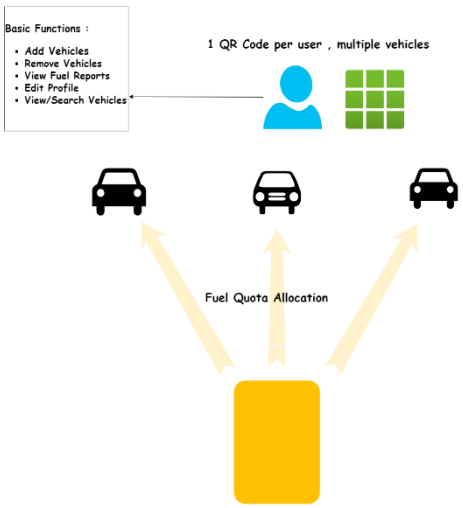

Figure 4: User Management Module

A customer is provided with a QR code upon registration, one QR code is used per customer despite the

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number of vehicles, so that at the fuel station, when this QR code gets scanned, a vehicle list relevant to the customer would appear to be selected.

Customers have a fuel limit for each vehicle and this fuel is allocated by the admin panel (This is planned to be automated) with an expiry date.

A fraud detection mechanism is planned to be implemented based on the generated data. For this, once a month an API runs in the backend which is controlled by a scheduler and will generate a report of all the stations with potential frauds.

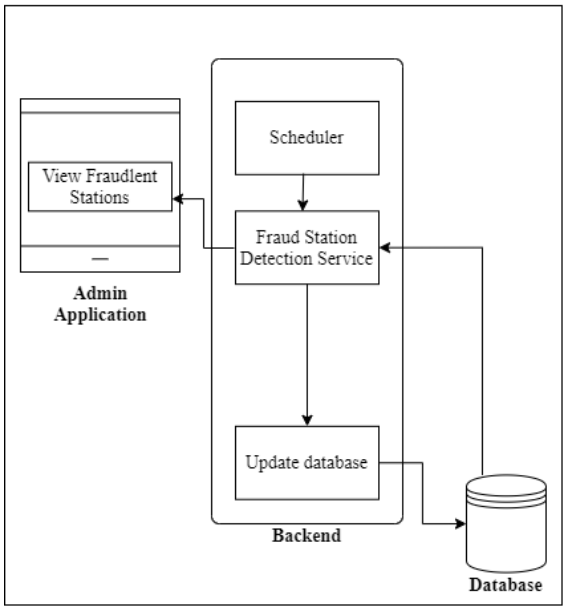

Figure 5: Fraud Detection Mechanism Procedure

$$Tp = Total\ fuel\ pumpings + Remaining\ fuel$$
$$Td = Total\ fuel\ distribution$$
$$Rpd = Pumping\ to\ distribution\ ratio$$
$$Rpd = Tp \div Td$$

Equation 1 Pumping to Distribution Ratio Calculation

$$If\ Rpd < 1 \,||\, Rpd > 1 \Rightarrow Potential\ Fraud$$

According to the above figure, the scheduler will trigger the service as scheduled (once a month), the calculations will be done throughout, also updating the database and creating the view for the admin.

Equation (1) will be applied for all fuel stations registered under the system, potential frauds will get reported for stations which have a Rpd ratio less than 1 or greater than 1.This value being less than 1 means that less pumping has been done relative to the distribution , hence a fraud alert should be marked, the other scenario means that more pumping has been done relative to the distribution, this scenario too can be marked as fraud. The admin will have access to view these reports which will consist of fraudulent fuel stations along the fuel balances data.

B. Booking Management Model and GPS Usage

The booking model has been introduced in this fuel management system mainly aiming to save people's time, reduce queues and provide a more efficient manner to request and receive the fuel for users as well as for fuel stations to efficiently use and track their fuel distribution for the public.

The general flow of the booking model is illustrated in the following diagram.

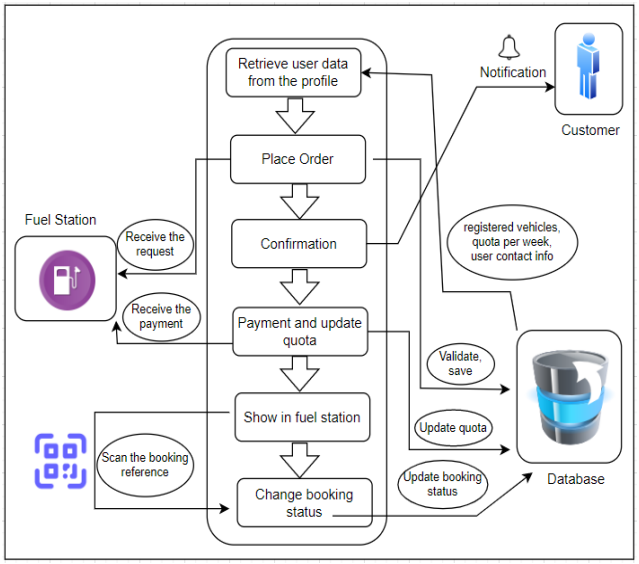

Figure 6: Fuel Booking Model

In the proposed system, we have minimized the manual work as far as possible, therefore when a customer creates a booking, all the customer data such as email, contact no, registered vehicle details, available weekly fuel allocation and available fuel stations will be displayed to the user, and they will only need to select the values instead of entering the data manually. The entering value for the requested liter amount cannot exceed the available weekly quota for a particular vehicle.

Also, when selecting a fuel station, we have given an additional option to select the fuel station via google maps additionally to select a particular fuel station by dropdowns. In general, the fuel station will be automatically selected based on the user's current location. The following image will be elaborated on it.

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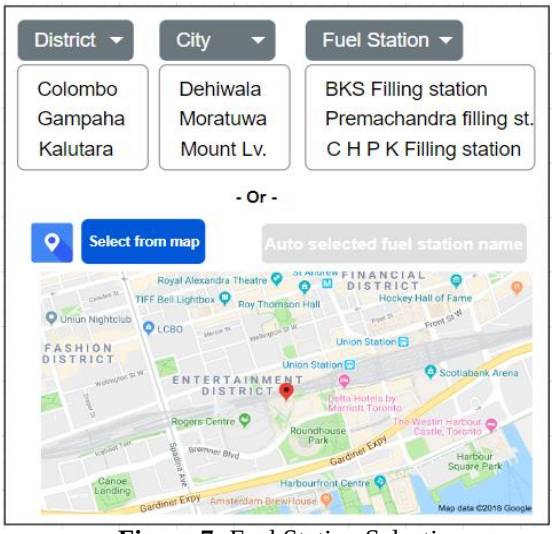

Figure 7: Fuel Station Selection

Once a booking is created, a booking reference will be generated with a scan code which can be simply scanned at the fuel station from which the agent can easily scan and update the status to 'complete' once the fuel is pumped to the user vehicle. The system additionally provides a payment option to the user to make the payment for the booking once the confirmation is received from the fuel station. Otherwise, payment can be done at the fuel station.

In the booking process, several notifications/alerts are generated for the user and fuel station when a customer places a booking, fuel stations providing the confirmation of a booking and when the status is changed as the last step at the fuel station.

If this model gets fully deployed for a country, it would be very convenient to track, collect and make decisions for government, fuel stations and users by viewing their history records, reports and fuel consumptions as well as manage the fuel in a highly efficient manner. Further, the system can forecast for the fuel stations and users how much fuel is required to order or book by checking the past records which will be a very optimal process and cost effective for every user.

C. The Use of QR Codes

Quick Response (QR) code generation is a vital part of the system. A QR code is a simple two-dimensional (2-D) image that contains information in both horizontal and vertical directions [14]. Usually, these codes are scanned using a camera of a smartphone. Most of the smartphones available in the market today are capable of reading QR codes. Since it is a standard method of sharing information, and it is known by most people, QR codes were chosen as the method of customer identification and validation in the system.

When a person registers to the system as a customer, a unique QR code will be generated based on the details provided by that person. In the system that is currently implemented, the customer's user id, email, name and the registration date will be used to generate the QR code. The above-mentioned user id is a 6-digit number generated by the system to uniquely identify a customer. As both user id and email are unique to a customer, the generated QR codes will also be unique. This whole QR code generation process is done by the backend application. Once the QR code is generated, the backend will send a response to the frontend (web client) with the generated QR code.

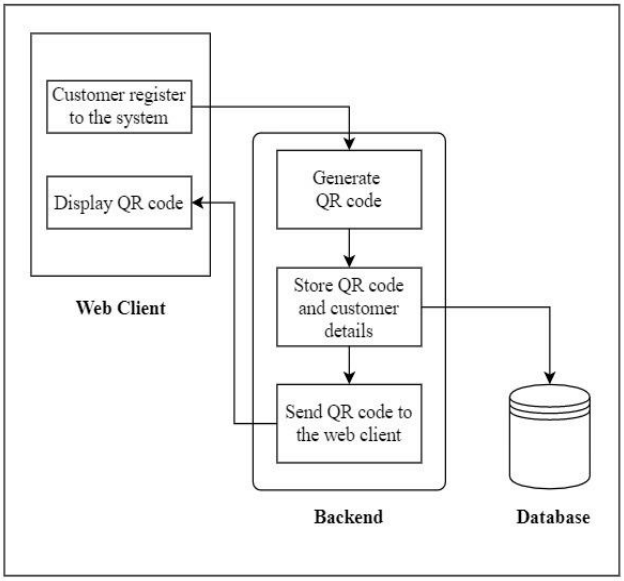

Figure 8: QR Code generation

After receiving the QR code, customers can use it to pump fuel. When a particular customer wants to pump fuel from a fuel station, first a fuel station employee will scan the QR code using a scanner. After scanning, the fuel station employee will check the validity of the QR code by entering decoded customer details to the system. If the QR code is valid, then the customer can proceed to pump fuel. After pumping fuel, the fuel station can enter how much fuel that customer pumped. When the system receives these fuel pumping data, it reduces the amount of fuel pumped from the amount of fuel allocated to that customer. This helps the customers to keep track of how much fuel available from the amount of fuel allocated to them.

In the currently implemented system, fuel stations have to login to the web client to validate customers and enter fuel pumping details. Since this is inconvenient for the fuel stations, it is planned to introduce a mobile application with QR code scanning capability. The purpose of this mobile application is to identify and validate customers by scanning their QR codes when they pump fuel from a fuel station.

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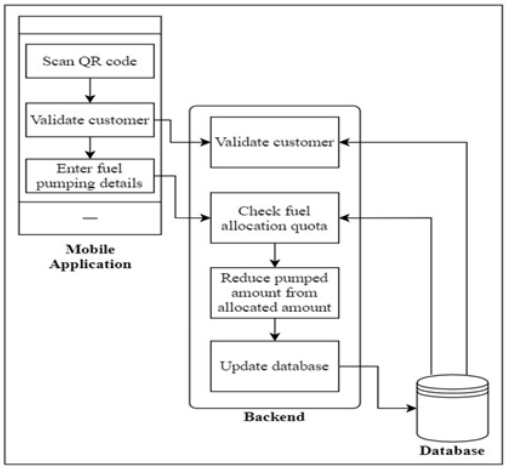

Figure 9: QR code usage process

The mobile application will only be capable of scanning QR codes and entering fuel pumping data to the system. When a QR code is scanned using this application, decoded data will be put into a JavaScript Object Notation (JSON) object and will be sent to the backend for validation. Upon receiving the validation request, the backend will read the user id and email from the received JSON object and will scan the database to find a registered customer with the same details. If a customer record is found, then the backend will proceed to check the amount of fuel allocated to the customer. If the customer has already exceeded the allocated amount or a customer record was not found, the backend will send a response to the mobile application stating that the scanned QR code is invalid. However, if the backend states that the QR code is valid, then the mobile application will allow the fuel station to enter the amount of fuel that customer wants to pump.

As fuel station employees must install this mobile application on their devices, the application should be capable of running on many different devices with different levels of performance. Because of that, it is aimed to make this application as lightweight as possible. And, when validating customers, availability of the backend services will be important. To achieve high availability, the backend will be implemented over multiple different servers. This is done to reduce system downtime and ensure the system is operational even in the event of a failure. It is important for the customer validation process to be always operational.

D. Fuel Order Calculation

It is obvious that the amount of fuel is changing constantly. There should be a proper way to calculate the fuel order without updating the database every time. Hence proposed system provides details of fuel price along with type of the fuel.

Product	Price (Rs. Per Liter)
Petrol (92 Octane)	310
Petrol (95 Octane)	510
Diesel (Auto Diesel)	415
Diesel (Lanka Super Diesel)	510

Table 1: Sample Fuel Price List

As it is required to display the latest prices, those are fetched daily through an API and updated for calculations, since customers would be able to review the usage of fuel history. Otherwise, it may cause many issues. Whenever the user pumps the fuel from the fuel station the calculation API will calculate the fuel price according to the following formula.

$$Payment = No.of\ Litres \times Price\ per\ Litres$$

Equation 2 Payment Calculation

Furthermore, there should be a proper way to estimate the remaining quota of fuel in the fuel station. Proposed system automatically deducts the amount of fuel after the customer pumps the fuel. Hence using our system customers can decide the type of fuel and make a booking from available fuel stations. It will reduce their time as well as the money.

E. Complaint Management Module

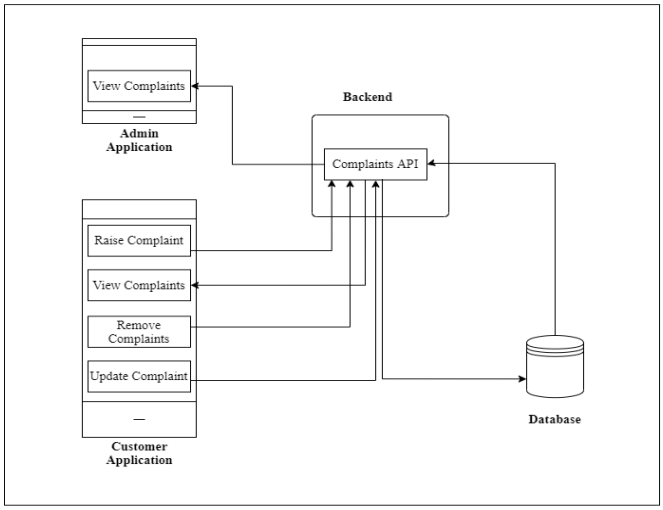

Figure 10: Complaint Module Process

During the crisis, many frauds have had happened especially for fuel, where some people would privately sell fuel at a higher price more than double the normal price. We have identified this as an issue which should be addressed as well, hence this module has been proposed to manage or limit any frauds happening. As in the figure 10, this module is accessible for both admin and customer, in which customers can raise, modify, delete, view their complaints while the admin can view all the complaints made by customers and provide feedback

for each. Admins can also see the complainer's information to further elaborate the issue and raise it to the relevant authorities. Apart from frauds, customers may also raise complaints regarding the app functionality so to enhance the user experience. To further enhance this module, a reward system could be implemented to motivate people to raise complaints to limit frauds.

V. DISCUSSION

Fuel queues became a major problem in the country recently [5]. However, in this study we have identified that none of the existing fuel management systems have introduced a proper approach to manage fuel queues. As a solution to this, in the system we have proposed, the 'Fuel Booking' feature has been introduced. This newly introduced feature allows customers to book a date, time and place to pump fuel and makes it not necessary to wait in long fuel queues. This feature is expected to make a considerable impact on long fuel queues by reducing them vastly. However, we cannot expect each customer to use this feature regularly, thus it is difficult to guarantee that this feature will eliminate fuel queues completely.

In addition to fuel queues, fuel consumption has also become a major concern. With the current situation in the country, demand for the fuel has increased vastly [1], and it has become extremely difficult for the government to manage fuel consumption in the country. The absence of a proper fuel management approach makes this situation even more difficult to handle. The government has introduced fuel allocation and QR code approaches to overcome this problem [5]. However, in the system we have proposed, it is planned to make this fuel allocation process automated with the aim of making it more convenient for the government to allocate fuel quotas to the customers. In addition to that, the proposed mobile application that is aimed to be used for scanning QR codes and entering fuel pumping data, reduces the work that has to be done manually by the fuel stations and the government to keep track of the fuel consumption of customers.

Both mobile and web applications must be tested to find any potential issues before going live and becoming available to the entire public. By using usability testing we can guarantee that menus, buttons, or links to different pages are easily visible and consistent on all the interfaces. Cypress test would be a better solution to decode the data of our tests. Since we developed our application using the MERN stack, the "zxing-js" library can be used to decode the QR code in many formats. When it comes to booking management security testing will play important role as it is must to ensure that APIs like google map are not subject to typical attacks like SQL Injections, Malformed Inputs, and Boundary Violations because APIs frequently provide direct access to the data and logic that make up the core value of the entire system. Furthermore, unit testing, integration testing, system testing and many other general testing methods will be applied to optimize the system along with requirements.

VI. CONCLUSION

In this paper, our proposed fuel management system is discussed as a solution to problems related to fuel shortage in Sri Lanka. Proposed system consists of customizing fuel usage, allocating customers for the nearest fuel station, managing user complaints and how certain calculations for fuel orders would be operated. Not only web based but also mobile solutions are considered to improve human interaction for certain functionalities. Importance of key functionalities and how they are interrelated to the main problem is further discussed. Modern techniques like QR scanning to fuel filling procedure, google API to book fuel stations are utilized for each functionality. In near future this system will be adapted according to the requirements of present and subsequent stakeholders.

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