Vehicle Flow Analysis and Traffic Coordination System of the King Fahd Causeway

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Introduction

Project Inspiration

The inspiration for our project emerged from a comprehensive understanding of The King Fahd Causeway Authority's (KFCA) challenges, needs, constraints, and specifications. The primary issues that KFCA faces include traffic congestion especially the unexpected ones, delayed root cause analysis, and slow responses to traffic issues.

Problem statement

The project aims to revolutionize the operational center in the King Fahd Causeway through an AI-based vehicle tracking and flow analysis system. The project enhances traffic flow, improve traffic coordination, and facilitate communication among stakeholders.

Constraints

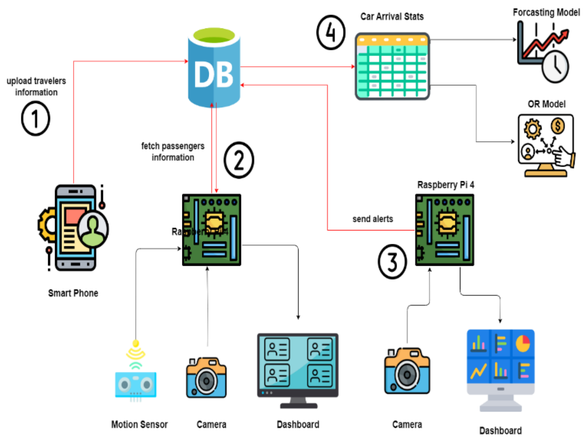
1. Target Time in Procedure Areas
2. Manpower
3. Weather
4. Server Network and Power
5. Camera Clarity

Target specification list

- Waiting time
- Maintenance Time
- Material cost
- Service Time
- Energy efficiency
- # of cabins
- Manpower
- Encryption
- # of steps
- Traffic Jam
- System Lifetime

System Design

The Design consists of 4 integrated subsystems as shown in the below figure :



1- Travelers' user interface

- Uploading travelers' information to the database. the user here registers the needed information (License, Serial Number, ID, Date of Birth, etc.) ,and expected arrival time then click on submit to send it to the database.

2- Plate Recognition Subsystem

- The AI camera will read the plate of the car then it fetch the passengers' info that is related with the car plate, then it will display it in the screen.
- Use to record the arrival rate of cars.

3- Causeway Surveillance Subsystem

- AI cameras on the causeway detect traffic issues like accidents and jams, sending instant alerts to the dashboard.

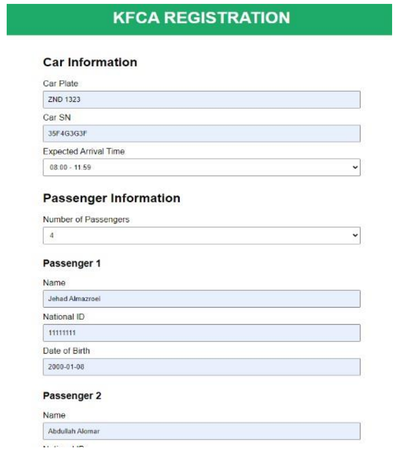
4- OR and Forecasting models

Car arrival rates from the DB utilized for:

- The OR model prevents sudden jams by monitoring fluctuations and suggesting the optimal number of cabins to be opened.
- An annual forecasting model provides KFCA with a tool to anticipate and prepare for upcoming jams.

Prototype Design

Travelers' user interface



OR Decision screen

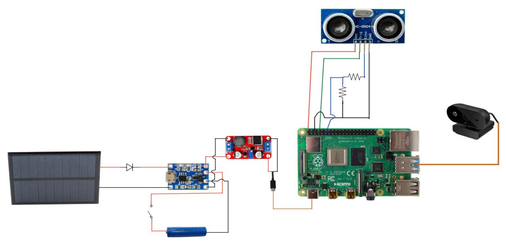
The Optimal Number of Cabins from KSA to BHR

Entity	Number of Cabins
Saudi's Departure Customs	8
Saudi's Departure Immigration	12
Security Point	4
Bharanin Arrival Immigration	7
Insurance Company	10

The Optimal Number of Cabins from BHR to KSA

Entity	Number of Cabins
Bharanin Departure Customs	6
Bharanin Departure Immigration	5
Saudi's Arrival Immigration	8

Plate Recognition Subsystem



Causeway Surveillance Subsystem

Before detection — After detection

Mathematical model

Objective Function

$$\text{Min} \quad z = \sum_k \sum_e C_{ke} \cdot x_{ke} + \sum_k M\delta_k$$

Subject to

1) $\frac{\lambda_{ke}}{X_{ke} \cdot \mu_{ke}} < 1 \qquad \forall\ ke$

2) $\sum_e W^*_{ke} - T_{max,k} \le M\delta_k \qquad \forall\ k$

3) $X_{ke} \le NC_{ke} \qquad \forall\ ke$

4) $W^*_{ke} = WQ_{ke} \cdot CF_{ke} + \frac{CF_{ke}}{\lambda_{ke}} \qquad \forall\ k,e$

5) $P_{0,ke} = \left\{\left[\sum_{n=0}^{X_{ke}-1} \frac{(X_{ke}\cdot\rho_{ke})^n}{n!}\right] + \left[(X_{ke}\cdot\rho_{ke})^{X_{ke}} \left(\frac{1}{X_{ke}!}\right)\left(\frac{1}{1-\rho_{ke}}\right)\right]\right\}^{-1} \forall\ k,e$

6) $L_{ke} = X_{ke} \cdot \rho_{ke} + \frac{P_{0,ke} \cdot (X_{ke}\cdot\rho_{ke})^{X_{ke}+1}}{x_{ke}\,(x_{ke}!)(1-\rho_{ke})^2} \qquad \forall\ k,e$

7) $WQ_{ke} = \frac{L_{ke}}{\lambda_{ke}} - \frac{1}{\lambda_{ke}} \qquad \forall\ k,e$

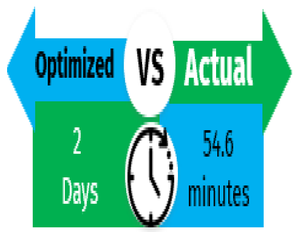
Design Result & Validation

❖ **Positive Impact of the OR model on the Time in the procedure area:**

From KSA to BHR: Improvements by the Model: 22%

From BHR to KSA: Improvements by the Model: 9.8%

❖ **Solar panel calculations**



Conclusion

Our project revolutionizes the causeway's operational center with an AI-driven system, optimizing traffic management, reducing congestion, and improving coordination. Estimated implementation cost of the project in the causeway ranges from 10,000,000 SAR to 15,000,000 SAR.