Proposal

For

Low - Cost Camera Based Adaptive Intelligent Traffic Control System

Kerala Development and Innovation Strategic Council

(K-DISC)

K-DISC
Kerala Development and Innovation Strategic Council

Contents

List of Tables & Figures

1 Organization/Company Profile

Kerala Development and Innovation Strategic Council (K-DISC) is a strategic think-tank and advisory body constituted by the Government of Kerala. It aims at bringing out path-breaking strategic plans that reflect new directions in technology, product and process innovations, social shaping of technology, and creating a healthy and conducive ecosystem for fostering innovations in the State. In the sphere of development, K- DISC is promoting and initiating new projects in Emerging Technologies such as Blockchain, Internet of Things, Machine Learning, Artificial Intelligence, Robotics, and soon that would enable transparent and cognitive advances in various departments of the state Government and deliver the ultimate benefit to the citizens. K-DISC would facilitate with different government departments that may need any of these technological advances to solve their critical problems and to arrive at the proof of concepts stage with adequate technical and financial resources to promote innovation. Also, K-DISC will ease the implementation by overseeing the same.

Citizen Service-One Department One Idea 2021 (CS-ODOI) is an initiative from K-DISC which is an exclusive platform for the employees of Government Departments and Agencies under the Government of Kerala, to submit Innovative Ideas. The objective of this program is to encourage the unreserved participation of all Government staff to improve the process or product innovations in the respective departments or any Government departments that they interact with. The Idea "Sensor Camera Based Adaptive Intelligent Traffic Signal Control System" submitted by Mr. Dilip Kumar K G (Motor Vehicle Inspector, Motor Vehicle Department) through the CS-ODOI initiative was shortlisted as one of the top 12 ideas and is being considered for pilot implementation.

2 Introduction

Traffic is the main source of the city life because it is the backbone of, logistics, information, and various activities which plays an important role in social stability, development, and improvement of community. Without an appropriate traffic control system, the possibility of traffic congestion will be very high and hinder people's life. Most of traffic control systems are still using stand-alone system, where each traffic light intersection has been determined by an officer. This causes the traffic signal unable to adapt to the traffic density, which often leads to the accumulation of vehicles and traffic congestion. Traffic congestion causes various negative impacts, including loss of productive time and manpower, waste of fuel, late delivery of goods, the pollution, and so on. A possible solution to reduce traffic congestion is by implementing an adaptive traffic control system.

2.1 Need of the Project

The motivation for this project was the trend towards vehicle actuated control in many parts of the world and the development of a large number of different approaches towards it. These trends and developments prove the high interest in this research area as well as the potential for improvements arising from this type of control.

Currently fixed-time signals are used which follow a predetermined sequence of signal operation, always providing the same amount of time to each traffic movement, whether traffic is present or not. The disadvantage of the present timer-based Automatic junction signaling system is the improper balancing of traffic. The green signal will continually glow even if there is no vehicle in the stretch. At present traffic police handle this manually during traffic congestion.

When site study was conducted at 3 junctions (Neeramankara, Kaimanam & Pappanamcode) it was noticed that the unused green signal time from the approach roads was maximum at the Neeramankara junction (Refer figure:1). Due to the unused green signal time at the approach roads, the vehicles in the main arterial road are unnecessarily idling. Moreover, the drivers of the idling vehicles, seeing no traffic from the side lanes, have a provocation to commit traffic violation.

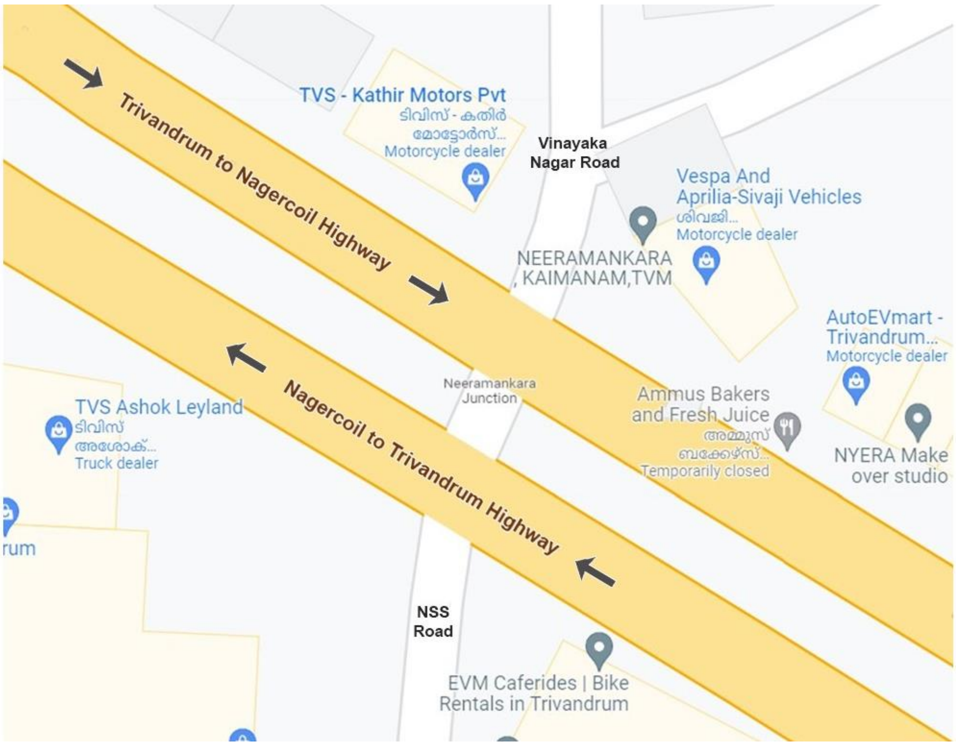

Figure 1: Neeramankara Junction

Neeramankara Junction - Side-Line traffic signal Idle time (04:30 PM to 05:30 PM)

	Vinayaka Nagar Road	NSS Road	
Available Green Signal (Sec)	13	13	
Available Red signal (Sec)	105	105	
Available Amber signal (Sec)	3	3	
Cycle	**Wastage Time (sec) in Vinayaka Road**	**Wastage Time (sec) in NSS Road**	**Minimum Wastage Time (sec) from Vinayaka Road & NSS Road**
cycle 1	10	3	3
cycle 2	13	12	12
cycle 3	7	6	6
cycle 4	4	13	4
cycle 5	1	10	1
cycle 6	13	13	13
cycle 7	9	2	2
cycle 8	13	0	0
cycle 9	5	13	5
cycle 10	10	8	8
cycle 11	9	13	9
cycle 12	13	6	6
cycle 13	6	13	6
cycle 14	3	13	3
cycle 15	8	0	0
cycle 16	13	10	10
cycle 17	8	12	8
cycle 18	1	6	1
cycle 19	13	0	0
cycle 20	8	6	6
cycle 21	3	2	2
cycle 22	8	6	6
cycle 23	6	9	6
cycle 24	13	13	13
cycle 25	2	0	0
cycle 26	5	12	5
cycle 27	8	0	0
cycle 28	7	11	7
cycle 29	13	3	3
cycle 30	5	6	5
Average wastage time in a cycle (Sec)			**5**

Time for a complete Cycle (Sec)	121
No of complete cycle in an hour	30
Time Wastage in a Cycle (Sec)	5
Time Wastage in an Hour (Minutes)	**2.5**

Table 1: Site Study at Neeramankara Junction (04:30 PM to 05:30 PM)

As shown in Table 1, the cycle time at Neeramankara junction is 121sec. The wastage time in Vinayaka Nagar Road and NSS College Road due to fixed time allocation for traffic are monitored for a period of one hour. If we consider the minimum time wasted in each cycle, the average time wasted in a cycle is 5sec. The no. of completed cycles in an hour being 30, the time wasted in an hour is computed as 2.5 minutes.

Neeramankara Junction (Study conducted during 4.30 pm to 5.30 PM) -Fuel Wastage	
Unutilized green signal time in an hour (Minutes)	2.5
Time wastage percentage in an hour (%)	4.13
Total Working Hours of the Signal (hours)	13.00
Total time wastage if signal works for 13 hrs (Minutes)	32.23
Total time wastage if signal works for 13 hrs (hours)	0.54
Total number of Vehicles in Waiting	20
Total vehicle hours wastage (considering 20 vehicles in the main corridor waiting)	10.744
Idle Fuel consumption of a vehicle for an hour(litres)	1.89
Fuel consumption of vehicles for 20 vehicle hours(litres)	20.31
fuel price(petrol) in Rs	₹ 106.6
Total cost of wastage fuel a day(in Rs)	₹ 2164.60
Total cost of wastage fuel for a Month(In Rs)	₹ 64937.90
Total cost for the project (In Rs)	₹ 750000
Return on Investment (In Months)	≈ 12 Months

Table 2: Fuel Wastage calculation at Neeramankara Junction

In Table 2, it is shown that considering the traffic control system functioning for 13hrs a day and the no. of vehicles waiting for the signal is 20, the wastage time in a day is 10.74 vehicle hrs. A considerable amount of fuel wastage is caused due to this. The cost of fuel wasted in a month is computed as Rs.65,000/- approximately.

Neeramankara Junction (Study conducted during 4.30 PM to 5.30 PM)- CO2 Emission	
Fuel consumption of vehicles for 20 vehicle hours (@ 2.5 Minutes Unutilized green signal time in an hour)	20.31 L
carbon dioxide emission from 1 liter petrol	2.31 Kg
Daily total carbon dioxide emission	46.91 Kg

Table 3: Co2 Emission calculation at Neeramankara Junction

Additionally, the vehicle idle time will lead to pollution. Table 3 shows that the daily carbon emission caused with an average wastage time of 2.5 minutes per hour and assuming 20 vehicles are waiting at the roads is 46.91Kg. The forced waiting at the roads due to the fixed-time traffic control system may cause the public to lose patience and attempt violation of traffic rules.

Vehicle actuated traffic control system was adopted in many parts of the world to overcome the difficulties posed by the manual system. Initially, the approach was to use induction loop-based detectors to detect the vehicle's presence. Despite the high detection accuracy of loop based sensors, the installation of these requires road cutting and further civil infrastructure management. Road cutting needs approval from different departments and is time consuming. Besides, proper maintenance of the loop detectors is another major challenge. Next development was vehicle detection using AI-cameras. Adaptive Traffic Control System using AI camera is implemented at various intersections across the state, however those high-end cameras employed are costly, since they are imported, and upkeep is also challenging.

Video based camera system is more sophisticated and powerful because the information from the successive and interconnected video image can be used for vehicle detection, tracking, and classification. There are several adaptive traffic control systems that have been developed in several countries, which uses devices that are quite large, expensive, and difficult to be installed. The heterogenous nature of traffic in Indian conditions poses more challenges to accurate detection and classification of vehicles.

The proposed adaptive traffic signal system using the low-cost camera will be a break through as it becomes affordable for large scale deployment. The lack of clarity of the images from low-cost cameras, of course, is a limitation but it can be mitigated by employing innovative technologies like AI and DL/ML and intensive image processing techniques.

2.2 Summary of the Proposal

The project "Low-cost camera Based Adaptive Intelligent Traffic Control System" proposes an innovative method to control the traffic signal system timing automatically according to the traffic density cost effectively employing low-cost cameras. The existing traffic signaling system is based on fixed timings. A tremendous amount of time and power is wasted due to a green traffic signal with no cars passing on its lane. This leads to an increase in excessive time delays of the traffic. Sometimes high traffic congestion at one side of a lane needs a longer green signal as compared to the existing system.

To optimize this problem, it is proposed to design an Adaptive Traffic Control System. This can be achieved by using low-cost vehicle detection camera which detects the density of the vehicle in each arm of the junction. The cameras which are installed at each arm of the junction will detect the presence of vehicle passing that arm and send the information to LPU (Local Processing unit) and then to the controller. Based on the collected information the traffic controller will decide which arm should get additional time and which arm’s time should be deducted. An adaptive traffic signal control system's target is to adapt traffic signal settings to the current traffic scenario by utilizing low-cost cameras, cutting-edge technologies like AI and DL/ML, and sophisticated image processing techniques.

3 Project Objectives

The project “Low cost camera Based Adaptive Intelligent Traffic Control System” aims to reduce the unutilized signal time for side roads and provide maximum green time for the main arterial road by the installation of a vehicle-actuated traffic signal control system which uses low-cost cameras for vehicle detection.

4 Scope of the Project

We intend to pilot the project at Neeramankara 4 arm Junction in Thiruvananthapuram district.

The scope of the pilot project is to develop a new vehicle actuated signal control strategy that can operate efficiently in a city with IP cameras by installation of 4 Vehicle detection cameras, one camera in each lane of the junction and installation of four channel LPU for video analytics to detect vehicle density and pass the vehicle information to the Controller to terminate or extend green signal time based on traffic flow. Existing fixed time traffic Controller has to be replaced with Vehicle Actuated Adaptive Traffic Signal controller and hardware shall be powered through Solar panel and Battery Assembly.

5 Overall Architecture

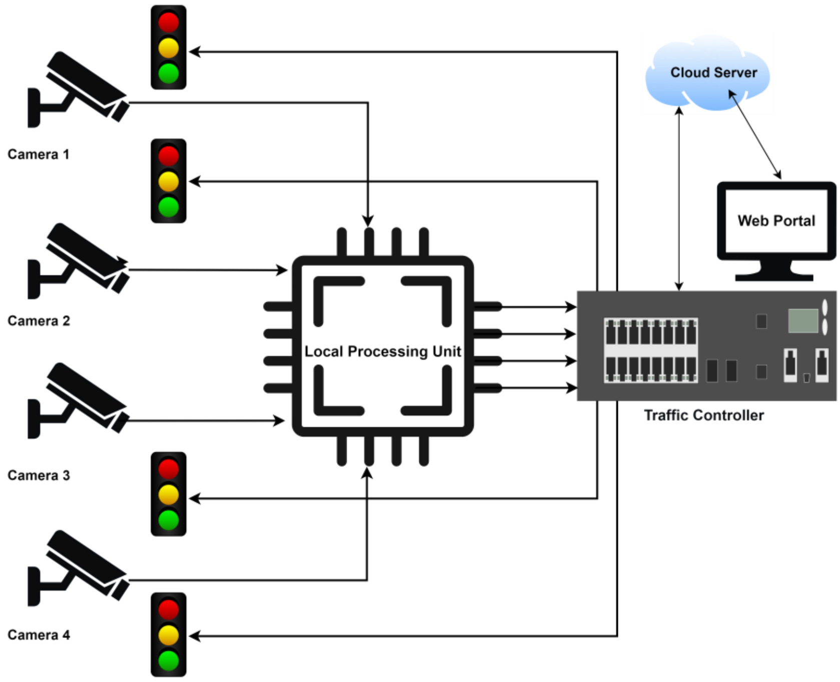

Figure 2: System Architecture

When camera detects a vehicle in the lane, vehicle presence is indicated and the corresponding output of the LPU goes ON. In the case of no vehicle the output should be OFF. The outputs of the LPU are continuously sampled by the Traffic Controller and when vehicle presence is detected in a lane, the Green light is switched ON limited to the maximum period allowed for that lane. When the output corresponding to the lane goes low, Controller switches to the next input.

5.1 System Components

5.1.1 Camera

Low-cost Cameras are used for vehicle sensing. Cameras are located on the mast arms or signal poles that look down to the roadway surface to the video detection zone. Cameras are installed at the 4 arms of the junction. They should have IP 65 rated enclosure, night vision included with 50 m range and waterproof connectors. Cameras should be all season compatible and configured in such a way for optimum vehicle detection.

5.1.2 Local Processing Unit (LPU)

Vehicle detection is performed using intensive image processing techniques and AI algorithms which resides in LPU. The LPU is capable to perform real time image processing to classify the vehicles and extracts the Passenger Car Unit (PCU), road capacity and other information related to vehicles present and passes the information to Controller to switch signal timing accordingly.

Detection of moving objects including vehicle, people and others in the video can be achieved by three main approaches.

In the temporal differences approach, moving object can be detected from the successive and interconnected video image. However, this approach has several limitations such as the homogeneity of the image and level of effectiveness that depends on the speed of movement of objects in the video image.

Optical flow approach aims to obtain modification of an effective background; this method is based on detecting differences in light intensity. However, the changes of light due to weather or sunlight can decrease the effectiveness of this method.

In the background extraction method, background can be static, where the initial background was specified earlier and used on the entire process, or can be dynamic, where the initial background change dynamically based on external changes that occur, such as weather. Ordinary static background is not effective in many applications so that many methods use dynamic background extraction.

Suitable approach will be used during the project execution.

The spatial and temporal features are extracted using a series of image processing algorithms and DL/ML to differentiate vehicles from roadway or background pixels in day and night in the proposed approach for heterogenous traffic model.

5.1.3 Traffic Controller

The Traffic Controller is a fully adaptive traffic control system that use data from vehicle detectors and optimize traffic signal settings in an area to reduce vehicle delays and stops.

There are three important components or parameters in the traffic lights signal control:

1. Cycle times: Period of one traffic light cycle, to determine the length of each period of red, yellow, and green light.

2. Green split: The length of green light period on each road at the intersection.

The task of the Controller is to receive data from the LPU and based on the data compute optimum timing for the signals. After receiving data from the LPU, the Controller has to give signal of red light or green light at each lane and give the lighting time for each light at the same time. Finally, it allows phases to be skipped if there is no call for service, thereby allowing the controller to reallocate the unused time to a subsequent phase.

3. The traffic controllers should be connected to the server through network, thus traffic monitoring over a junction can be made possible .The system facilitates storing of traffic data of junction over a period, including traffic patterns during peak hours, which enables an opportunity to view and analyze the same via web portal.

6 Technical Approach

Vehicle detection system helps to optimize traffic flow and ease gridlock by adjusting red and green light durations according to actual road conditions in heterogenous traffic model. Camera based vehicle density detection system detects moving and stationary vehicles at signalized intersections. The lack of clarity in the photos produced by inexpensive cameras may be overcome by using cutting-edge technology like AI, DL/ML, and intense image processing methods in the LPU. Controller will receive the vehicle-related data from LPU and use appropriate algorithms to alter signal time based on traffic needs to create an adaptive traffic control system.

The controller provides facilities for a number of phases. Phase is the sequence of conditions applied to one or more streams of vehicular or pedestrian traffic, which always receive identical signal light indications.

Each phase provide control for one of the following:

- Vehicular movements: The Vehicle phase contains three signal aspects, viz. Red, Amber and Green. The termination of vehicle phase is always with leaving amber.
- Pedestrian movements: The Pedestrian phase contains two signal aspects, viz. Red and Green. The termination of pedestrian phase can be either red flash or green flash.
- Filter green: The Filter Green provides signal for the right turning traffic. When linked with a vehicle phase the termination of filter green is blackout; otherwise it flash for few seconds before termination.
- Indicative green: The Indicative Green is a continuously flashing signal, which provides signal for the left turning traffic. The termination of indicative green is always blackout.

The below figure depicts the site layout of the proposed system– “Low-cost Camera Based Adaptive Intelligent Traffic Control System”.

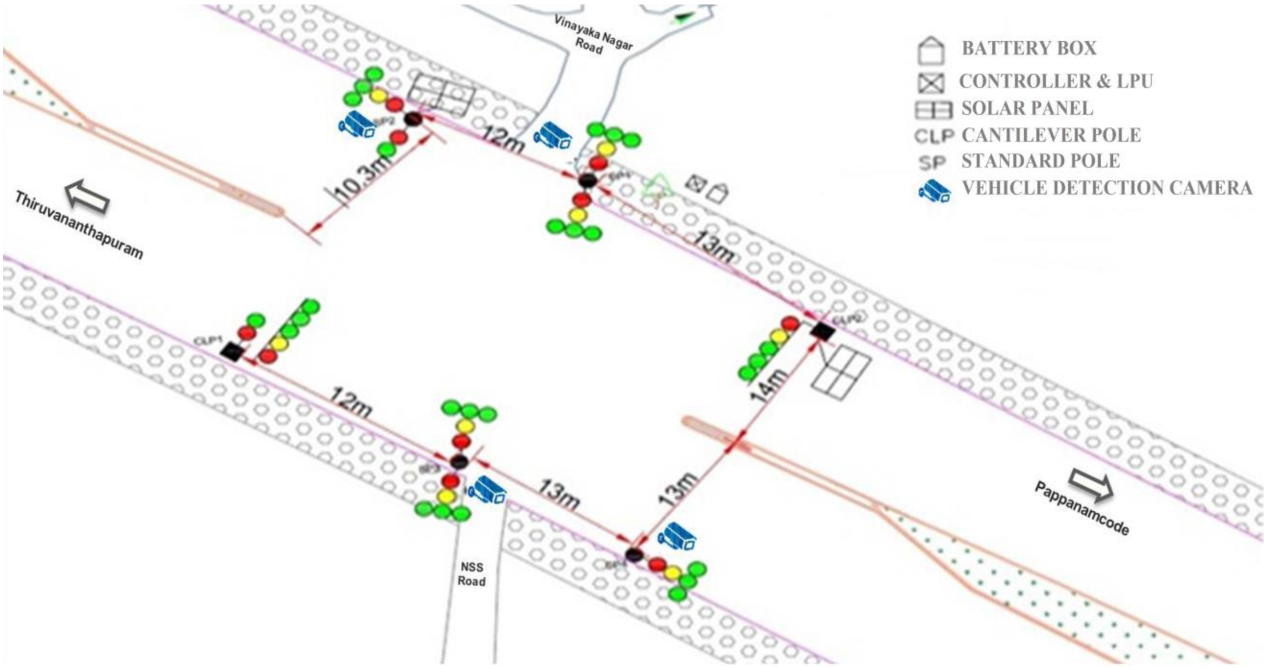

Figure 3: Proposed site Layout at Neeramankara Junction

Below figure 4 depicts the vehicle detection using camera.

Figure 4: Vehicle detection using camera

There are different modes of operation for the Controller.

Traffic Controller can be operated either in Area Traffic Control System mode or Standalone mode of operation. In Area Traffic Control Mode, controllers are networked to a central computer. The central computer (server) is capable of controlling the overall performance of all individual controllers by evaluating the real-time demand. The same

Controller can function in the Standalone mode. If the junction is upgraded for ATCS, the same controller can be used.

In Standalone Mode the signal plans will be executed from the local timetable. Standalone mode is used when controller is used at isolated intersections.

The following modes of operations are available under Standalone Mode:

- Fixed Time Mode (FTM) Input signals from the vehicle detection system are ignored in this mode. The controller will operate within fixed time periods from the timetable.
- Manual Control Mode (MCM) Manual operation of the traffic signal stage sequence is required to cater for situations such as abnormal congestion, accidents, breakdowns and other special occasions. In MC mode, the stages appear in the order specified in the timetable with time periods defined by the person manning the junction. A stage is a group of non-conflicting phases which move at the same time
- Vehicle Actuated Mode (VAM): The Vehicle Actuated strategy uses a technique to determine the allocation of green running time to a running phase, within the constraints of a fixed minimum and maximum green time setting for the phase, according to the demand. With fully actuated control, all signal phases are actuated and all signalized movements require detection.
- Flash Mode (FLM) In the Flash mode, selected lamps are made to flash. The lamps can be amber, red or the combination of both. This mode can be selected either through timetable or by control switch.

5.3 Implementation Strategy

The project is to be piloted at at Neeramankara 4 arm Junction in Thiruvananthapuram district. Four cameras will be deployed at each lane with a LPU unit. Existing fixed time traffic Controller may have to be replaced with Vehicle Actuated Adaptive Traffic Signal controller and hardware shall be powered through Solar panel and Battery Assembly.

5.4 Deliverables

The following will be delivered as a part of the project: -

- Vehicle-actuated Traffic control system comprising of
    - 4 IP 65 protected Cameras deployed at each lane
    - Local Processing Unit (LPU)
    - Controller
    - Web platform with all necessary dashboards and Analytics related to Traffic Control System

7 Key Benefits to be achieved

Following are the key benefits expected to be achieved: -

1. Real-time Dashboard for traffic information management
2. Easy to install and can be mounted on existing infrastructure
3. Low-cost camera and potential for large scale deployment
4. Reduce traffic delays
5. Increase efficacy of traffic signal timings
6. Reduced number of stops in corridor resulting in saving fuel cost & ROI will be within 12 months
7. Reduce congestion through smooth traffic flow
8. Reduce environmental pollution. Daily CO_2 emission of 46.91 Kg can be reduced if Adaptive Traffic Control System is in place.

8 Conclusion

To address the highly heterogeneous traffic conditions, Adaptive Traffic Control System will continuously assess real time traffic demand from vehicle detecting cameras deployed at the locations. Adaptive Traffic Control System is aiming to reduce traffic congestion, to minimize the negative effects of traffic towards the environment and people. We envision a smart road system where the total trip time is minimum due to minimizing the average waiting time at traffic junction. A low-cost camera-based traffic control system that can be easily replicated is envisaged to be built with this project.