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Development of an ACTIve Vehicle Air Pollution-Control System (activAPS)

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***Abstract*— Nowadays, in large part of the globe, air pollution due to CO, NOx and HC are the major degradation factor. So in order to reduce pollution and make the environment eco-friendly, an Active Vehicle Air Pollution-control System (activAPS) can prove to be a revolutionary idea to counter affect the negative aspects of the vehicular pollution. The device calculates the percentage of pollutants emitted by *moving* automobiles. This device informs the vehicle owners as well as the concerned authorities via mobile network about the emission levels beyond the threshold limit (set by the concerned authorities). The device alerts the owner, automatically, that it is time to give the vehicle a service within the stipulated amount of time. The authorities concerned can take appropriate steps to curb the problems after the specified time.**

In this paper, the idea of ActivAPS is being presented that collects real-time data on the emission level of vehicle pollutants and stores them in systematic profiles of individual users on an online utility platform.

Keywords: - Emission: Vehicular exhaust gases.
NOx: Oxides of Nitrogen.
CO: Carbon Monoxide.
HC: Hydro Carbons.

I. INTRODUCTION

From times old, pollution has been a source of all major environment related problems. The increased pace of industrialization led to a drastic improvement in the quality of living of man in terms of leisure, comfort etc. in every way possible. In his haste to achieve this comfortable life, man did not see the deteriorating effects which his advancements were causing on the surroundings in which he was living.

This prolonged, callous attitude of man towards Mother Nature has degraded the environment to an alarming state which in turn has made adverse effects on mankind as a whole. Better late than never, man has finally started taking initiatives to solve the problems which he himself created, due to his ignorance.

The 21st century saw a large boom in the automobile industry. In India, specifically, the vehicle population is growing at a rate of over 5% per annum. Today, there are more vehicles than people moving on roads. Though this increase in vehicle population has shortened the distance between people to a great extent but it has also polluted the air that we are breathing to a devastating condition which has given rise to a number of health issues for the people.

Hence, the need of the hour is to device a method to effectively and efficiently keep a check on vehicular pollution- the biggest cause of all environment related problems.

Working on this aspect, activAPS is being developed which will ensure the participation of every individual in the move against pollution and in turn preserving the community health and Mother Nature.

II. SYSTEM STUDY AND ANALYSIS

A. EXISTING SYSTEM

The exponential growth in vehicle population and dominance of old vintage vehicles on Indian roads has made the issue of inspection and maintenance a prime concern in India. In the last decade, several aggressive initiatives to control vehicle pollution have been taken in India, but most of the steps are directed towards new vehicle emission norms and fuel quality improvements. In major cities, there exists a mandatory system for inspection and maintenance but it is now increasingly felt to upgrade the present system to a more effective one in the near future. The existing practice of I&M is described, accordingly:

- Every commercial vehicle in India has to go for a mandatory fitness test.
- The renewal period for fitness certification in general is 2 years for new commercial vehicles and 1-year for old vehicles.
- For private as well as new vehicles, no mandatory periodic fitness check is required in India but there exist a system of re-registration of private vehicles after 15 years of initial registration or 1st registration. Thus, after 15 years a private vehicle has to go for fitness to get re-registered which remains valid for the next five years
- All in-use vehicles are compulsorily required to obtain emission check certificate called PUC. Frequency of this PUC certification system varies from 2 to 4 times a year. This PUC is issued based on conformity to idle emission test for gasoline vehicles and free acceleration smoke test for diesel vehicles.

TABLE:
PETROL/CNG/LPG driven vehicles

Sl.No.	Vehicle Type	CO%	'HC (n-hexane equivalent ppm)
1.	2 & 3 –Wheelers (2/4-stroke) (Vehicles manufactured on and before 31st March, 2000)	4.5	9000
2.	2 & 3 – Wheelers (2 –stroke) (Vehicles manufactured after 31st March, 2000)	3.5	6000
3.	2 & 3 – Wheelers (4 –stroke) (Vehicles manufactured after 31st March, 2000)	3.5	4500
4.	4-Wheelers manufactured as per pre Bharat Stage-II norms	3.0	1500
5.	4-Wheelers manufactured as per Bharat Stage-II or Bharat Stage-III emission norms.	0.5	750

Petrol/CNG/LPG driven vehicles, manufactured as per Bharat Stage –IV norms

Sl No.	Vehicle Type	Idle emission limits		High idle emission limits	
(1)	(2)	(3)		(4)	
		CO%	HC(n hexane equivalent)ppm	CO%	Lamda (RPM-2500+_200)
1.	Compressed natural Gas/LPG driven 4-wheelers manufactured as per Bharat Stage IV norms	0.3%	200ppm	-	-
2.	Petrol driven 4-wheelers manufactured as per Bharat Stage IV norms	0.3%	200ppm	0.2	1+_0.03 or as declared by the vehicle manufacturer

Smoke density for all diesel-driven vehicle shall as follows,

TABLE:
(DIESEL VEHICLES)

Sl No	Method of Test	Maximum Smoke Density	
(1)	(2)	(3)	
		Light Absorption Co-efficient (1/m)	Hatridge Units
1.	Free acceleration for Turbo charged engine and naturally aspirated engine for vehicles manufactured as per pre Bharat Stage IV norms	2.45	65
2.	Free acceleration for Turbo charged engine and naturally aspirated engine for vehicles manufactured as per Bharat Stage IV norms	1.62	50

Table I: Present PUC Limits

PENALTY FOR NON-COMPLIANCE: A vehicle, found to be not in possession of a valid PUC Certificate can be prosecuted under Section 190(2) of the Motor Vehicle Act, 1998. A penalty of Rs.1000/- for first offence and Rs.2000/- for every subsequent offence of violation has been provided. The offence is compoundable with a fine of Rs.900/- for first offence and Rs.1800/- for subsequent offence.

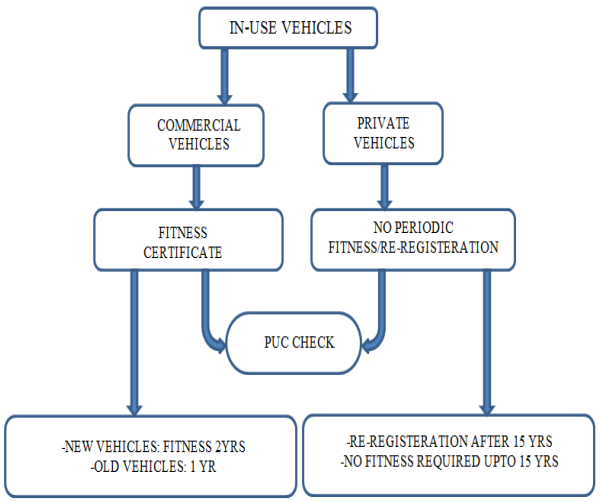

FIG I: EXISTING I&M SYSTEM IN INDIA

Fig. I shows the procedure adopted in the existing PUC system in India to keep pollution at bay. The limits for various genres of vehicles set by GOI (Government of India) are specified in Table I. All moving vehicles in India have to abide by these rules and procedures.

There are obvious gaping loopholes in the existing system for pollution control. The drawbacks in the current system have created drastic problems in the environment and has led India's air to become one of the most polluted in the globe.

Thus, owing to these drawbacks, a need was felt for a new system that could change the entire perspective of pollution control using simple means and practices.

B. PROPOSED SYSTEM

The proposed system, namely, activAPS ensures that the pollution levels of all ***mobile*** vehicles remain under check individually because it does not measure the emissions of a traffic population as a whole instead it measures the pollution levels of vehicles individually and sends the recorded data to a single database system instantly which can be accessed in real time via web. The spontaneous storing of data ensures the transparency of the entire system and hence reduces the probability of any bypass to a great extent.

III. COMPARITIVE ANALYSIS

Some of the gaps of the existing PUC system covered by the proposed system are as under:

- The test procedures currently used do not represent typical driving conditions, and hence the emissions levels measurement cannot be used to generate an emission profile of in-use vehicles, whereas, activAPS, making use of a portable device, will give a ***real time*** measurement of the vehicular emissions.
- PUC center operators are not sufficiently trained but activAPS being a smart system will itself send an alert to the user as soon as his/her vehicular emissions exceed the set limit.

- In existing system, no auditing and quality assurance is carried out at the test centers and as a result the measurements are not reproducible from center to center but in the proposed system, the above problem is overruled because activAPS will be continuously connected to the database system which shall ensure the transparency of the system.
- The existing system being inefficient and inclined more towards visual checks encourages false passes and corruptions but in activAPS logical hardware reduces the probability of false reports and chances of corruption.
- Fitness is more a practice in paper than in reality. This gives scope for corruption, which exist in the system in India but since the proposed system, activAPS is automated hence the scope of human errors and faults are reduced to almost null.

Henceforth, it can be seen that the proposed system, when implemented, will be able to monitor the vehicular pollution far more effectively and efficiently than the existing system and hence play an active role in saving the environment.

IV . SYSTEM DESCRIPTION

We first describe the portable device being used which will be fit in the vehicle (hardware) and then the database system to be used to allow the user easy access to the system.

A. Hardware Specifications

Hardware used in activAPS consumes low power, so there shouldn't be any problem for vehicle manufacturers to install it with the existing technology.

The hardware components are highly sensitive to vehicular exhaust and hence they will respond instantaneously.

Most of the components used are to be set in such a manner that it doesn't allow corrosion or rust to attack; hence the sensor has a long life.

activAPS can be fitted in the vehicle machinery in the in-line with the tailpipe.

Since the idea of the activAPS is to obtain continuous run time data using the sensor, so the hardware is embedded with the software and hence will display the run-time data instantaneously and continuously on the device as well. activAPS will transmit the calculated output to the corresponding database system at regular intervals of time.

Our aim is to construct a low-cost, portable, monitoring device by combining sensor units, central processing unit, power unit, GSM unit, and RF unit. The sensor unit will measure the air quality, the central processing unit for data acquisition and processing, the GPS unit to track the position of the RF-sensor in real time and the RF unit for the wireless transmission and reception of the data.

Fig. II shows the block diagram of the unit where various sensors (NO_2, CO, and PM sensors), GPS and wireless transceiver circuits are included. For the device to be power efficient, we could be using MiCS 4514 pollution sensors to detect pollutants in exhaust of the vehicle. These also could be coupled with MiCS 4514 voltage trimmer so as to ensure a constant flow of power. CO sensor measures the Carbon monoxide content (CO value) which is a major pollutant, along with the NOx level measurement. The information from the sensor units is collected from the RF receiver and relayed to the control system. As can be seen in the figure below, the sensor unit includes MCU, power circuits, and RF transceiver circuits for wireless communication.

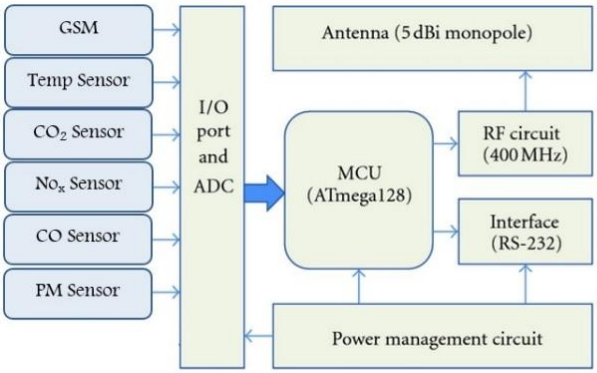

FIG II: DEVICE DESCRIPTION

For the proper functionality of the sensor, we choose the low-cost portable sensors to apply to the air pollution measurements. PM, CO and NO_2 gas sensors and dust sensors are chosen because these are the most common air pollutants. The goal is to devise a portable device so as to achieve real time measurement. RF technology is used to conveniently collect the measured data.

- Sensors (CO, PM, NO etc.): We choose low-cost, portable sensors to apply to the air pollution measurements. The choice of PM, CO, NO_2 gas sensors and dust sensors was obvious because these are the most common air pollutants.
- GPS: The installed GPS provided us with the current location information in real time while the sensors detect various contamination elements.
- RF circuit: RF technology was used to conveniently collect the measured data and send it to the database for proper storage for future use.
- Analog to Digital Converter (ADC): An analog-to-digital converter is a device that converts a continuous quantity to a discrete digital number. Typically, an ADC is an electronic device that converts an input analog voltage (or current) to a digital number proportional to the magnitude of the voltage or current.
- Microcontroller unit (MCU): Manipulates the air quality information, the data will be stored in memory and transmitted to base station, received data is also stored into the memory. It performs important manipulations which reduces power and time.

To monitor various kinds of air pollution we installed the corresponding sensors in the unit. These various sensors will have their own I/O ports to transfer the measured data to MCU. MCU has internal 12 bit ADC to convert the sensor output values to the digital values.

The final processed information is transferred to the RF transceiver for data transmission. iSENSE receiver with a RJ 45 jack shall be used for easy retrieval of signals and reduce

retransmission requirements to a Remotely located central server which will collect these data and use them for further processes.
As we will be using small-size RF chips in our RF sensor system, the size of the system becomes remarkably smaller than the system used in the moving vehicle test stations. Each activAPS device will be enabled with a serial number that will be associated with a particular vehicle that will be used to associate the device and the vehicle to a particular profile on the online database.

B.Software Specifications

Our system follows a systematic, sequential approach to software development that begins at system level and progresses through analysis, design, coding, testing and support. Software works within operable and acceptable speed and can work efficiently even if the database grows rapidly.
We will be using MySQL to create the database at initial stages and coupling it with PHP to create a dynamic environment. Basic markup languages such as HTML and CSS shall be used to create the front end. JavaScript and other dynamic languages shall be used at later stages to make the front end more interactive and user-friendly.
The vehicle's info (owner's name and contact no. etc.) is required at the initial stage so as to make the system work with the database in a synchronized manner.

DATABASE HANDLING- Database required needs to be developed (i.e. defined, constructed and stored) initially and also the manipulation and updating process needs to be done frequently as per the status of the vehicles.
activAPS will calculate the emission level of the vehicle, while it is in motion, continuously with the help of corresponding sensor software and display the calculated reading on the dashboard/display meter of the vehicle.
The data transmitted by activAPS will be stored in the database in a well-organized and effective manner so that the records of every activAPS user can be checked regularly.
A portal known as THE GREEN PAGE shall be created where the entire database will be made available for viewing purpose for the benefit of the users so that even they can keep track of their current emission levels and act likewise.
Special benefits will be provided to the users who will be successful in keeping their pollution emissions under check regularly over long periods of time which will add a can-do spirit in everyone associated with activAPS.
The specifications for the database to be created are discussed below:
CORRESPONDING SRS SHEET:
The database consists of the following entities:
1. Users
2. Vehicles
3. Emission Profile
4. Authorities

a. USER: will consist of the following attributes:
Name, contact number, mailing address, vehicle (make and model), registration number(s), points awarded and pending penalties.
b. VEHICLES: will consist of the following attributes:
Vehicle Reg.No. , Vehicle type, make and model
c. EMISSION PROFILE: will consist of:
- Highest emission level, lowest emission level, average emission level, current emission level, status of the vehicle.

d. AUTHORITIES: will consist of:
- Name, contact number, mailing address, vehicle (make and model), registration number(s), jurisdiction area.

The Entity-Relationship diagram in Fig. III further clears the picture:

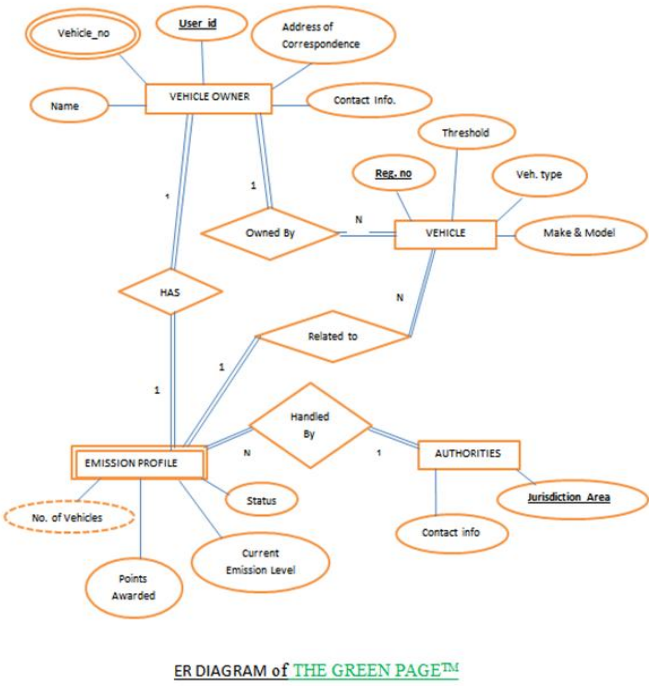

FIG. III: ER DIAGRAM OF THE ONLINE PORTAL

V. SYSTEM CONSTRUCTION

The main parts of the construction include the interfaces, the power, the MCU, and the sensors part. The base of the device containing all the circuitry will be approximately, 170x120 mm^2. The MCU could be of type AT mega 128.Various MiCS sensors could be installed in the sensors part, and the extension of this part to include more sensors could be done very easily. The entire circuit shall work on a DC power source and our portable system shall detect and analyze the exhaust moving in the tail pipe of the vehicle. Additional LEDs will be installed in the dashboard of the vehicle which can be used to alert the driver when his/her emission levels exceed the threshold value. The overall working of the hardware is explained through Fig. IV

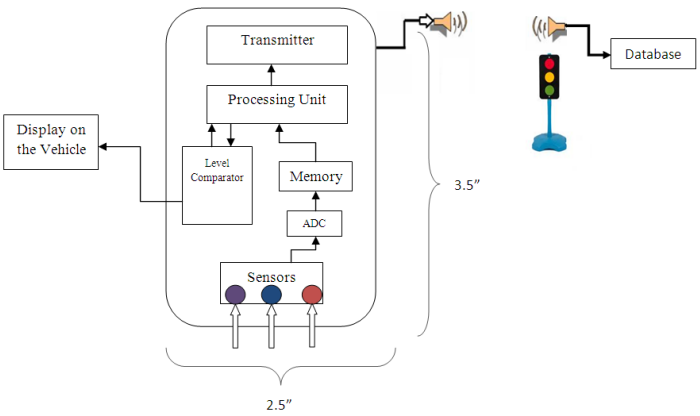

Fig IV: Approximate Diagram Of Fabricated Activaps System

Power consuming factors in a wireless sensor network is one of the biggest challenges, because the sensor has limited source of power which is also hard to replace or recharge. Wasteful power consumption is mainly due to:

- Idle listening to channel "waiting for possible traffic".
- Retransmitting because of collision "e.g. two packets arrived at the same time at the same sensor".
- Overhearing i.e. "when a sensor receives a packet doesn't belong to it".
- Generating and handling control packets.
- Over emitting "when a sensor received a packet while it is not ready".

Since our system uses the wireless communication for data transmission hence the same factors can affect the efficiency of our system as well.

Conventional Solutions to the stated problems:

- Reducing power consumption starts from the selection of Microcontroller unit (MCU), low power consumption MCU should be considered at first.
- Choosing chip with low standby current and steady transceiving current for Radio frequency module.
- Power source with low output voltage and low consumption power itself.
- Reducing system operating frequency can lower current consumption effectively.
- Lowering system operating voltage influences system power consumption. So under the premise of system credibility, make sure that system is in lower operating voltage.
- Use interrupts to make the processor into deep sleep as shown. As we all know, sleep and power down mode will lower operating current greatly.
- Dynamic Power Management. When there is nothing interesting happened around, some modules are idle, switching to low energy consumption state (sleeping mode).
- Dynamic Voltage Scaling. When calculated load is low, reduce working voltage and frequency of MCU and thereby reduce processing capacity, can reduce power consumption of MCU.

Apart from the above mentioned traditional approaches, we formulated a simple algorithm that can be implemented to save power and keep the retransmission probabilities to a minimum. This is shown in Fig. V:

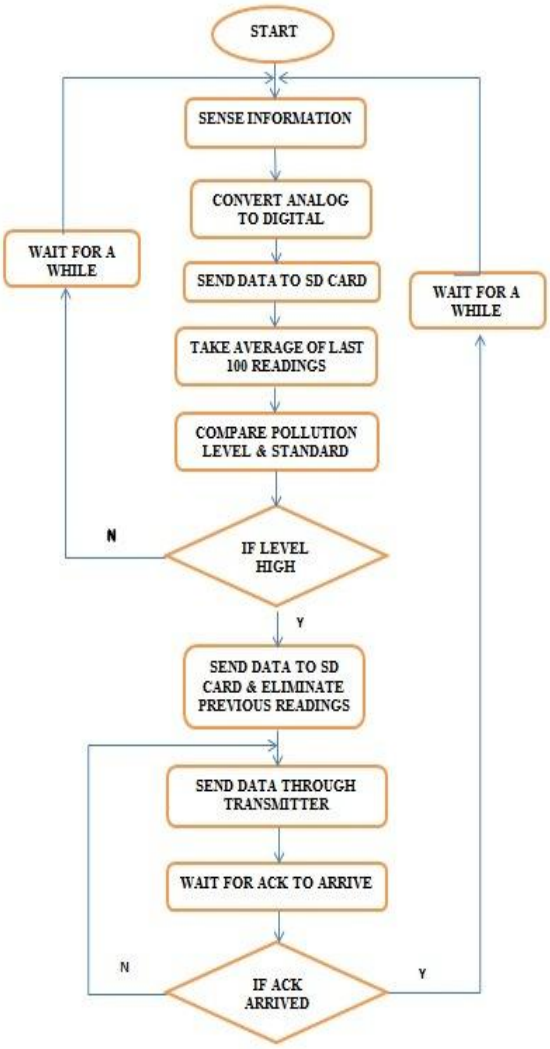

FIG. V: Proposed transmission cycle

WORKFLOW DIAGRAM

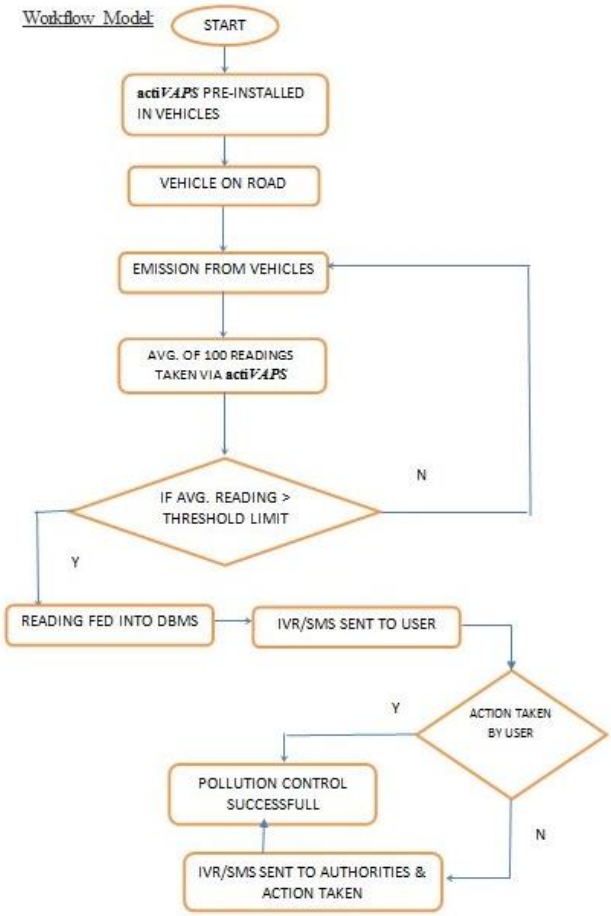

Fig. Vi: Workflow Model Of Activaps

The workflow model showcases the method in which the device can detect the emission from the exhaust of the vehicle.

The device becomes active once the vehicle gets on the road and starts detecting the emission levels. It takes the average value and compares to the threshold value and if the value is high, the value is sent to the user. The user is given a generous time period in which he/she must get his vehicle a makeover. If the user fails to do so then an IVR can be sent to local authorities so that the vehicle owner can be penalized using appropriate measures such as challans, etc.

VI FUTURE ENHANCEMENTS

activAPS is a system that not only helps in controlling the environment pollution but also helps in increasing the life cycle of an automobile. The system, if applied effectively, to the machinery of an automobile will act as a supporting system for its health and at the same time act as a safeguard against pollutant emissions. The system being one-of-a-kind shall unravel new kinds of areas in the automobile industry that are yet to be explored.

Since, activAPS is a new implementation; hence, wide arrays of future enhancements are possible. There can be unlimited number of metrics derived to improve the quality of the device; it is evident that the enhancements possible to the device are immense, such as:

- GSM tracking to avoid theft,
- Fuel quality check,
- Mileage indicator,
- A speed controller for public means of transportations, etc.

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