SIT225 DATA CAPTURE TECHNOLOGIES

TASK 9.1P

OVERCROWDING DETECTION IN BUSES

RESEARCH REPORT:

ABSTRACT:

In many overcrowded cities, such as specific cities in India, buses are one of the most common daily travel methods for people every day. However, in busy times such as mornings and evenings buses usually get overcrowded at times, and people waiting to board often crowd around the door. This may cause pushing and discomfort or even cause injury. [1][2] To advance the idea of reducing overcrowding on buses, I also want to design a smart solution that can report on the bus's level of capacity (especially by the door) and report this information back to the passengers as well as the bus staff.

The system works with simple and inexpensive sensors like ultrasonic or infrared sensors [3][4][8], placed a few inches from the doors, that can tell when too many people are standing close to them. When this occurs, the system emits a beep, displays a warning on a dashboard, and can even prevent the door from opening automatically. [5][8] The information is collected via an Arduino board and sent to the cloud live via MQTT protocol, but it can also be backed up on an SD card.

This project was selected considering the accident risk and discomfort associated with an overcrowded public transport safety and comfort issue. [1][2] The goal is to provide notifications to both passengers and bus drivers to raise awareness and mitigate collisions in public transportation. This system is intended for low cost, user-friendly and usefulness for real, live buses. In the future, I hope to improve the capabilities by implementing SMS notifications, a mobile app, and machine learning for more advanced analytics. [17][18]

INTRODUCTION:

In various large and bustling cities in India, buses serve as one of the most common means for people to commute each day. People commute from their home to schools and workplaces and back through buses. During peak commuting hours, such as mornings and evenings, you inevitably find people standing patiently at bus stops. As the bus arrives, it is common to see many people rushing to enter this bus. [1] This rush can lead to shoving, unbalancing, or sometimes even falling off-bus [2]. Such

experiences are not just discomforting; they can cause minor injuries and serious issues, particularly for older adults, children, or those with bags.

One fundamental issue is that there is no control over the number of people who go into the bus. Consequently, drivers and conductors normally would not know how many people are already on the bus and this leads to overcrowding. [1][2] There were difficulties of free movement, breathing and travelling safely in an overcrowded bus.

To help address this issue, I am proposing to build a smart system that can account for how many people are on the bus and measure overcrowding on the bus. [3][4] By deploying very inexpensive and uncomplicated sensors, we can strategically place sensors near the bus doors to learn about the overcrowding of passengers. If those sensors determine that there are too many people, especially near the door areas, the system will beep to communicate overcrowding to passengers and the bus driver [4][5]. Additionally, the system will be able to prohibit doors from either opening or closing until it is safe. This will support more appropriate behaviour so no one is pushing or getting hurt while entering or exiting the bus. [8]

The system will be mounted on an Arduino board, which is a small data-reading processing device that will read the sensor data and relay it to the Internet. The sensor data will be sent live to a dashboard cloud-management application so bus staff can check the status of the bus to discover if it is overcrowded at any given time. Overall, the system is meant to use technology to make bus transit safer, more organized, and more comfortable for several passengers; it will provide more self-awareness to become more aware of overcrowding and appropriate behaviour.

LITERATURE REVIEW:

Many researchers and engineers have tried in past, to tackle the problem of overcrowding on public transport. [1][2] They have used various categories of technology to help ensure that buses are a safe and comfortable experience for the rider (or user). This section will summarize some of the more common techniques presently in place as well as some of the benefits and disadvantages they have experienced.

One of the most popular techniques is the use of either CCTV or smart cameras placed inside buses. [9][10][11] Using various image processing or artificial intelligence, cameras can keep track of how many people are on a given bus, and can also aid in the determination of unusual acts or behaviour. [9][19] But, the use of cameras presents numerous challenges. First, the cost to buy and install is a significant barrier. Second, cameras require a great deal of memory, or cloud storage, if video is to be saved. Third, cameras, especially if a person would want video recorded, cannot be relied upon after dark or other situations of low ambient light [10][11]. This is additionally complicated if

a bus has low light, or if there is bad weather. Lastly, privacy is always a concern when using cameras, as cameras are always able to view the faces and actions of individuals.

Infrared (IR) sensors are another method used by some buses. [3][8] IR sensors are usually mounted around the doors and count the people who enter and exit. The IR sensor sends a signal if a person passes through the door, then the system adds or subtracts from the count. Generated in mass production, IR sensors are typically less expensive than cameras; however, they commonly miscount [3]. If two people walk into or out of the bus at the same time, the IR sensor may just count one person or may get confused. Additionally, if a person stands too close to the door, the sensor may think the person entered or exited when in reality they did not.

Some buses have weight sensors located under the bus floor. [4] These sensors measure the total weight of the bus and can thus assume the number of people in the bus. For example, if the weight of the entire bus exceeds a certain weight the system assumes the bus is full. Whereas, weight sensors can give the bus driver an estimate of the total people in the bus, this method is very limited. This method does not show where the people are located in the bus or give insight into how safe a passenger may be when near the door. [4] Additionally, it cannot remotely detect if unsafe overcrowding, or passengers squeezed into unsafe areas occurred.

There is another idea involving mobile apps that allow passengers to press a button to alert whether the bus is too crowded. Although a good idea, this is problematic. One problem is that not everyone has the app, and not everyone will press the button if they do! Others might forget, or just ignore! So, it is too reliant on human action and cannot be too reliable. [14][15][16]

When reviewing the aforementioned possible solutions, each had a form of issues. Some were expensive; some were not that accurate; and some were too reliant on the behaviour of individuals. For this project, the idea to create a simple, yet smarter solution to avoid all these different issues.

I wanted to utilize ultrasonic (or pressure) sensors, which will be inexpensive and very easy to use. The ultrasonic sensors will be positioned next to where people enter the bus, to detect "excessive" standing passengers. [12][14] Once the standing area has been exceeded, the system must provide an alert in order to notify the driver to refrain from stopping because the bus has exceeded its standing limit! The system must also record the event in the cloud. This solution, I believe, is very affordable; requires little battery power; little memory; and provides a safety measure to keep the passengers safe from injury as the doors could be opening. [4][5]

I feel my process has a better combination of cost, safety, usability, and accuracy, based on recent studies and solutions. It is still a work in progress, but I believe it could function quite well in busy public transport services.

LITERATURE REVIEW TABLE:

REFERENCE NO	TECHNOLOGY/METHODS	PURPOSE	FINDINGS	LIMITATIONS
[1]	Survey of public transport	Estimate patron satisfaction level	85% said public transport is insufficient, burden of overcrowding	Survey method; does not provide technical solutions
[2]	Legal perspective	Point out hazards of overcrowding	Court cites overcrowding as the basis for an imminent disaster	Opinion-based; no technical approach
[3]	IR sensors with NodeMCU	Estimating passengers on a bus	Useful for real time counting	Missed when simultaneous entry occurs
[4]	Ultrasonic sensors	Measure distance for estimating crowd	Accurate within 10-20cm	Can only be utilized at entry points
[5]	Ultrasonic sensors with LoRaWAN	Length estimations of passenger queues	Possible to derive real time queue estimation	Requires engineering and infrastructure build
[6]	3D sensors	Automatic passenger counting	Real-time high accuracy	Expensive, complicated installation
[7]	3D stereoscopic sensors	Counting passengers that board buses	Accurate counts assist in planning	May not capture standing passengers
[8]	Infrared sensors	Counts passengers entering or exiting	Reliable counts; real-time data	Installation may be considered intrusive
[9]	AI with cameras	Automatic passenger counting	98% accuracy, respects privacy	Dependent on camera quality

[10]	AI surveillance cameras	Monitor crowds in transport hubs	Provides real-time monitoring; enhances safety	Privacy concerns; expensive.
[11]	Video-based counting	Measure ridership on buses	Good counts; great for planning;	Changes required by lighting conditions.
[12]	Review of sensing technology	Film all crowd management technology	Provides all the taxonomy	Provides an overview of technology; no case studies.
[13]	Seat occupancy sensors	Count occupancy on seats	Support Ahmer revenue needs	Ignore if it is standing room.
[14]	Mobile apps	Provide information of passenger counts for passengers	Increase comfort level of not getting on crowded buses	Dependent on User input for data; data can be old.
[15]	Onboard app	Provides data, count for passengers counts,	Provides ability to get other data without sensors	Dependent on accuracy and honesty of the (bus) operator.
[16]	Real time tracking app	Let's user see bus capacity;	Can assist riders with planning their trips	Requires consistent updating.
[17]	Transit app integration	Provides information about bus crowding to users	Update are very helps with trip planning	Updating is important for trip planning.
[18]	AI ML in transit	Make transport safer and more efficient	Implementing AI ML will make transport safer and has potential to lower safety risk	There's going to be challenges implementing AI ML technology in transit agencies.

[19]	AI surveillance	Monitor what is transpiring in the transport vehicle	Detects unusual behavior; enhances safety	Privacy and ethical concern.
[20]	Motion sensors	Count passengers anonymously	Affordable and simple	Less accurate in dense crowds

METHODS:

To fix bus overcrowding and injury near bus doors, I have constructed a smart system using sensors and cloud technology. This is the step-by-step process of the system: [3][4][5]

(A) DATA SOURCES AND DESTINATIONS:

The data will be gathered from either an ultrasonic sensor or an IR sensor placed near the bus door, which will be able to sense how many people standing by the door and how close they actually are.[5] The data will flow to the microcontroller (such as or Arduino board) which will process the data from the sensors, and send it to the Arduino Cloud. [4][5][8]

(B) DATA TYPES:

The sensor will record distance or presence data such as how close people are. This will produce raw data in the form of numbers (e.g., distance in centimeters). [4]

(C) DATA CAPTURE PROTOCOL:

As soon as the sensor reads the data, it needs to send it to the cloud so that it can be displayed and recorded there. Once again, this process is achieved by using MQTT (Message Queuing Telemetry Transport) functionality that the Arduino board offers.

MQTT is a lightweight, quick, and easy way to get small pieces of information sent fast from a device (i.e. from a sensor) to a piece of software (i.e. cloud-based platform). MQTT is a good protocol for low-power devices, making it a great communication protocol for IoT (Internet of Things) projects, such as this project.

So, each time the sensor sends a new value, the Arduino collects the data and publishes it using MQTT to the Arduino Cloud so it can be displayed live. [5]

(D) DATA LOGGING & STORAGE:

The system saves all data it gathers onto the cloud using the Arduino IoT Cloud. This means that even if the data was not displayed live, it can be retrieved to analyze at a

later date. For example, if a person wanted to know how busy the bus was at 8 AM, they would view the previous data saved.

Additionally, I will have an SD card module connected to the Arduino as a back-up. This module enables the Arduino to save data locally onto a memory card, so if there is no WiFi, it is still functional, and data will be saved for download later at any time. [5][15]

(E) STORAGE TYPE:

For data storage, I am planning on utilizing two storage methods: cloud storage and local storage. Cloud storage means the data will be stored online, using the Arduino IoT Cloud. Cloud storage has the advantage of being accessible from anywhere, even if I am not near the bus with the data. Local storage, however, would mean storing the data on a small memory card, such as an SD card, inside the system. [5]

Local storage is beneficial to have in case one does not have internet and the system still has to work and cannot lose data. Utilizing both cloud and local storage will create better dependability of the system; the cloud and local storage distinguish their failures, and at least one of the storage methods will still have the data.

(F) DATA DASHBOARD:

I will create a basic dashboard utilizing Arduino Cloud. A dashboard is a screen that displays live updates from the sensors [5]. On the screen, the numbers or levels will represent how crowded the bus is, especially near the exits. If there are too many people standing near the doors, the dashboard will display a warning. This will allow a bus operator, or any other person observing the dashboard, to quickly see a crowding issue. The dashboard will help provide an ongoing live monitoring tool, leading to better passenger safety.

(G) DATA ANALYTICS & ALERTS:

The system can also send alerts when there is overcrowding. There are three ways that this occurs:

- **Buzzer Beep Sound:** The system connects to a small buzzer connected to the Arduino that will beep loudly if there are too many people by the door. The sound will warn the passengers to move back or stop trying to enter. [4][5]
- **Warning on Dashboard:** The dash board would show the simple warning "Too crowded - Please wait" so all bus staff or other viewers can take the necessary steps.
- **Door Control (optional):** If the Arduino is connected to an automated door, the Arduino could control whether the door opened. If the crowd is too high, the Arduino would deny the entrance until the crowd level had improved. [5]

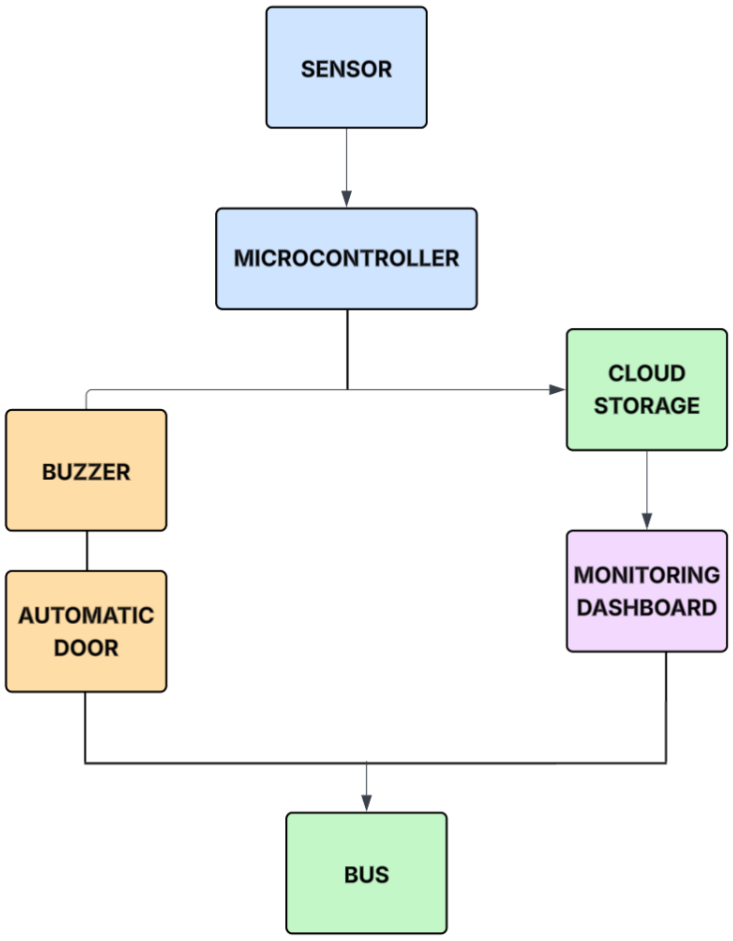
These alerts would be simple yet highly effective in reducing the chance of injury and improve safety.

(H) EXTRA FEATURES:

In the future, I look forward to adding more features to make the system even smarter and more useful. Some ideas for additional features might include:

- **More sensors:** If we place a few more sensors located in different areas of the bus, we can determine if the entire bus is packed or just the front rows.
- **Driver's screen connection:** The dashboard could also be wired to a small display near the driver seat so that they may view the crowd status immediately for any quick decision. [15][16]
- **SMS alerts:** If the bus becomes too crowded, the system can send an SMS, or at the very least, a message to an administrator, or possibly a transport officer. This alerts them to possibly take action quickly, or check the stop the bus is just leaving, and when they see the bus stop the crowd management. [5]

BLOCK DIAGRAM:



BUDGET & PLANNING:

To build my smart crowd detection system for buses, I will need both **hardware** and **software**. I will also make a plan of how much time I need to finish each step.

❖ HARDWARE REQUIREMENTS:

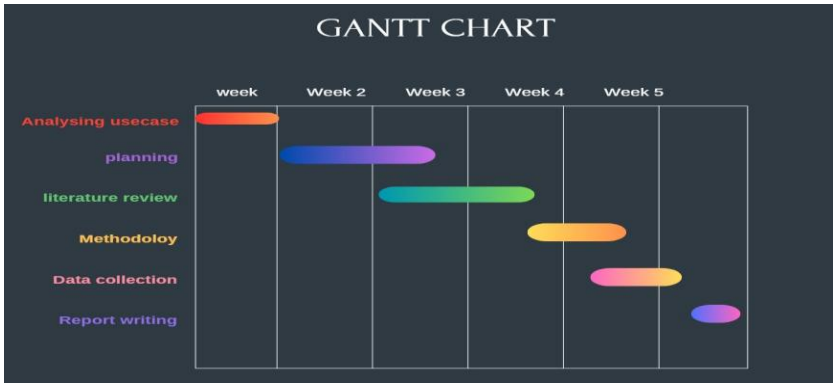
ITEM	DESCRIPTION	ESTIMATED COST	VENDOR
Arduino UNO	Microcontroller to control the system	₹600	Amazon
Ultrasonic Sensor (HC-SR04)	To detect how many people are close to the door	₹100	Amazon
Buzzer	To make beep sound when crowd is too much	₹30	Local electronics shop
SD Card Module + SD Card	For local data storage	₹250	Amazon
Wi-Fi Module (ESP8266)	To send data to Arduino Cloud	₹200	Amazon
Wires and Breadboard	For connections	₹100	Amazon
Power Supply (Battery)	To power the setup	₹150	Amazon

Total Cost Approx = **₹1,430**

❖ SOFTWARE REQUIREMENTS:

SOFTWARE	PURPOSE	COST
Arduino IDE	Writing code for Arduino board	Free
Arduino IoT Cloud	For data dashboard and cloud storage	Free
Python (Optional)	For future backend processing or analysis	Free

❖ GANTT CHART:



ETHICAL CONSIDERATIONS:

When developing a system that gauges information in public settings like buses, it is important to consider ethics, as doing something ethically means doing for the sake of doing right by everyone safely. [12]

My project does not collect any personally identifiable information in the form of people's names, faces, and/or voices [9][10]. The project only collects information through sensors that will tell how many people are near the door or how close, with the intention of preserving people's anonymity. [4][5]

Although I am not collecting personal information, the data must still be saved in a secure manner. For this, I will use the Arduino IoT Cloud, which uses secure HTTPS, to ensure the data is not stolen, hacked or viewed by anyone else [5] . Access to the dashboard will be regulated, so only trusted individuals such as bus employees or administrators of the system will have access. I will utilize strong passwords to protect my system and keep login information private while also routinely changing them to protect my system [5][12]. I will only collect the data necessary to measure crowding and never use the data to measure other things like for marketing/advertising or to track patrons.

Additionally, I will not store the data indefinitely, unless I need it for improvement of the system. To ensure all elements continue to work well, I will conduct regular checks and updates like taking sensor readings and identifying issues or bugs. If there are any issues, I will have the system fixed quickly to avoid issues. [5][15] I will use an SD card to save data locally when the internet is not working and I will ensure that local data is backed up and not shared anywhere unless necessary.

In addition to the privacy aspect, I will ensure that the system is locally secure. For example, the buzzer will be soft and will not hurt the ears of those within hearing range [5]. There will also be a safety feature on any automatic doors to ensure they stop closing if someone is still a barrier. Even if this is a student project, I will behave as if it is not, and ensure basic data protection rules are followed and the system is fair and clearly honest in use. If the system gets tested in real buses in future, I will seek to ensure the system also meets transport laws and data privacy legislation. [12][18]

RESULTS:

At this time in the project, I have not built and ran the system on a real bus, therefore, I do not have realistic results or real-time data to present [5]. However, given the design, planning, and testing of components separately, such as the sensors and cloud connections, I believe the system will function as intended. When a single person or a group stands too close to the bus doors, the sensors will determine their presence through a measure of distance or through detection of objects nearby.

This information will be sent to the Arduino microcontroller, then to the Arduino Cloud, to be presented on a live dashboard [5]. If the level of crowding becomes too high near the doors, a bus will activate a soft buzzer sound alerting all nearby that the crowding is too high and unsafe. With the buzzer alert, the system can also send an alert to the dashboard for the bus operator to see.

In future versions, they may even stop the door from opening on its own if it's too crowded [5][8]. The goal of all of these features is to prevent people from pushing or rushing onto the bus, leading to injury when people lose their balance and fall.

While I currently do not have any real-world data, the technology I have used sensors, cloud storage, and alert systems have all been shown to work in other projects. I have every confidence, and look forward to, fully installing it on a bus to test it for myself as I think it will work well and slow crowd-related injuries, which can help make bus travel safer for all passengers. [5][17][18]

DISCUSSION:

The problem this project addresses is one that many passengers on a bus confront, especially in India where the norm is usually overcrowding [1][2]. At peak hours, buses could get so crowded that people are being pushed back and forth to the point where they may stumble and fall due to some minor injury [4][5]. Typically, it happens when everyone tries to get on and off the bus at the same time, especially when the bus door is opened in a crowded and sometimes dangerous condition. The goal of my project will be to develop a very simple and inexpensive idea that will challenge this rather typical problem. A system would be designed to use sensors, whether ultrasonic or infrared sensors that will allow the system to detect the oncoming crowd at the door of the bus.

Once the system can identify the crowd about to enter the bus, it will warn the passengers through a buzzer sound as well as a message to the bus operator reflected on a dashboard. The bus operator can then take action in order to keep passengers safe, whether that means delaying the door to open, or even the discharge of passenger when they see fit.

A key strength of this solution is that it is inexpensive and easy to administer compared to other solutions on the market. [9][10][11] For example, some buses have used CCTV cameras, or smart cameras, which can incur risk, are expensive, are too technical to install, or may not provide useful data in low-light situations. Instead, this solution uses very basic, inexpensive sensors which can provide real-time data. The sensors can identify the presence and distance of riders at acceptable costs, while also being non-invasive which is critical for many types of buses. [5] The solution can also easily scale to multiple buses, providing a way for public transport authorities to monitor crowding on a more expansive level.

While there are advantages above, there also are challenges to consider. For example, if a crowd of people are close together by the door, the sensors might have a harder time giving an accurate measure of the crowd [4][5]. Passengers also may ignore the buzzer alert, particularly if they are in a hurry or unaware of the functions of the system. This is why testing the system in the real world is key to optimizing reliability and minimizing these challenges. However, with adequate adjustments and real-world feedback, the system may be even more reliable and safer for passengers.

In general, the system provides a low-cost and straightforward remedy to a frequent safety concern [5][8]. If used effectively, the system can reduce the number of injuries resulting from overcrowding on buses, and improve the safety and comfort of public transportation.

FUTURE WORK:

In the future, there will be a variety of innovative ways to enhance and broaden the platform. [15][16] One key direction I would like to experiment with is merging the platform with a mobile app allowing the bus drivers or transit operator to view the real-time crowding data directly on their phone. This could make it much easier for an operator to adapt to overcrowding in real-time at busy times when they could be managing multiple buses at once.

Another improvement I could make could be applying machine learning or smart algorithms to improve peak times and crowded times predictability [18]. By looking at historical data to send early warnings or possibly even adjust the bus schedule for overcrowding issue to not happen, if data supported it.

Furthermore, I could further develop the system by adding additional sensors around the bus to get the complete scope of crowding throughout the entire bus and not just around the doors [5]. This might provide further detail, for smarter decisions, and improved management. [17] Another potential idea might be for this system to send SMS alerts to the administrators or bus managers so that when this system detects dangerously high levels, then they could make more immediate decisions.

In the long run, I ultimately hope to work with officials in public transportation to scale this system into implementation, test it in real routes with real riders utilizing the bus and then digest the feedback from passengers and operators into further system design and refinement. [5][17][18]
Ultimately, the aim is to have this system as an installed safety feature on the bus used reduce injury, improve and enhance public transit as a safer and more enjoyable travel option for all.

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