Fig. 1. PRT - Morgantown, WV. Adapted From [1]

Improving the PRT through Data Capture and Analysis

PRT Capstone (Group 4)
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Contents

1 VISION

The Personal Rapid Transit (PRT) system is a staple of West Virginia University's Morgantown campus. The PRT is a relatively efficient system, moving thousands of students directly from their start position to their end destination across campus daily [2]. While the PRT, in its current state, serves WVU's students appropriately, the system is not without its faults.

1.1 Problem Statement

Despite a movement rate of 15,000 students per day, there are times when commuters are left waiting at a platform as empty cars leave or certain stations are without vehicles for people to board [2]. The PRT can be improved to avoid some of these scenarios. Equipping cars with sensors to track data such as power consumption, GPS location, and passenger capacity allows said data to provide insights into how the PRT can be more efficient in transportation and energy consumption.

1.2 Functional Specifications

The solution lies in equipping the PRT vehicles with a telematics device. This device will allow for onboard data collection. The proposed solution and its necessary functions are listed below:

1. Equip a PRT car with a Raspberry Pi 4 model B.
2. The Raspberry Pi should be in an enclosure with a footprint that does not exceed the limitations presented by the PRT team.
3. The enclosure should fit in PRT cars so as not to be seen by the occupants.
4. Collect PRT car movement via GPS tracking.
5. Collect PRT energy consumption via a current clamp.
6. Collect occupancy via Lidar or Infrared.
7. Sync data from the car to the database at PRT stations.
8. Transmitted data is encrypted.
9. Analyze collected data to generalize PRT car behaviors.
10. Store data in an SQL database.
11. Present data through a single-page front-end display

1.3 Constraints

As development goes on, there are many facets to consider. The nature of the project places dimensional constraints on the solution. The PRT car should prioritize its surface area for the movement of passengers. Therefore, the data collection solution should not fill seating or standing space from riders, implying that the Raspberry Pi board and appropriate housing will need to maintain a small footprint.

As well as dimensional constraints, there are time constraints. The PRT must be fully available to service students during its working hours. Our solution must not affect the function of the PRT as it operates. The data collection will remain an add-on for easy removal for service upgrades, completely independent of the PRT car and system.

A topic to keep in mind during the design phase is cybersecurity. Our system must communicate securely because of the location data we will collect. Underlying cybersecurity is the need for rider privacy and safety, as the project should not allow outside forces to hijack the PRT housing the device. Components of the project regarding occupancy should avoid controversial surveillance methods, preferably finding another option entirely.

One final major constraint arises out of the disconnectedness of the PRT cars. Any kind of wireless communication we include will need to be added by us. We must keep wireless communication in mind when implementing our system.

2 BACKGROUND RESEARCH

2.1 PRT Background and History

The Personal Rapid Transit (PRT) is a transportation system designed exclusively for West Virginia University students in the early 1970s. The 69 electric car system has traversed more than 35 million miles of track while serving an estimated 83 million riders throughout its lifetime. The PRT system was a solution to address transportation challenges that had arisen for students regarding traffic congestion and parking. During its initial development phase, the PRT exclusively serviced the route between the Walnut and Evansdale stations. However, in the late 1970s, the network expanded to encompass the Health Sciences Center, enhancing connectivity across the campus. This expansion provided swift access to various parts of the university and surrounding areas, drastically reducing travel times. The journey between the farthest stations– Health Sciences and Walnut–now spans just over 11 minutes [2].

The PRT has met the need for efficient student mobility between campuses, moving 15,000 people daily on average between the five stations (Walnut, Beechurst, Evansdale, Towers, and Health Science) since its opening in 1975. This statistic represents a remarkable improvement in transportation efficiency compared to traditional modes such as buses or personal vehicles [2].

2.2 Prior Works

The collection and use of GPS data for transportation purposes has proven beneficial in past projects. In 2006, a project developed in Beijing for their Bus Rapid Transit (BRT) Systems used GPS data to calibrate a traffic flow simulation software, VISSIM, to improve the operational efficiency of Beijing's BRT systems. The project emphasizes the use of GPS data and its use for algorithmic analysis [3]. The data collected from their GPS is not dissimilar to the data that WVU's PRT would produce. The PRT is a railed transport, while the BRT is road-based and deals with traffic signals, intersections, and turning ratios at each intersection. Although the data differs from our design, it achieves similar goals–optimizing the system for better performance.

It is crucial to determine the number of passengers on public transportation in cases of emergency. A study in 2023 covers an option for counting passengers by using passive infrared sensors at the entrance and exit of a public bus. The sensors connect to a wireless sensor network for real-time monitoring [4]. These sensors enable quick detection and response time while saving energy consumption and cost by removing cabling from the equation. This design differs from the PRT, as both doors on it function as an entrance and an exit. There are no designated entrances and exits, removing the possibility of using infrared sensors to count passengers as this study did previously. Instead, the PRT capstone design aims to use a LiDAR sensor to determine the number of passengers in each cart. The LiDAR sensor would be used in a wireless sensor network similar to the study described above, connecting to a Raspberry Pi microcontroller.

2.3 Justification

Due to the lack of realization of this capstone project in previous years, our group can be the first to implement this necessary solution. The lack of ability to analyze data associated with PRT use is detrimental to understanding the system and its points of inefficiency. The PRT has diligently served the students of West Virginia University for nearly 50 years. At that time, technology has advanced drastically. Now, there is more reason than ever to invest time and energy into capturing data for analysis to provide future Mountaineers with an efficient and reliable form of rapid personal transportation.

Our proposed solution is inexpensive, requiring only already-made components. The novelty of the design lies in how we combine components to solve the problem elegantly. Using a LiDAR sensor allows for real-time high accuracy and speed to identify the number of passengers on board the PRT while maintaining minimal costs. The sensor is also largely automated, saving time and resources by reducing the need for human intervention for data collection. A Raspberry Pi as a microcontroller provides a cost-effective solution for transmitting data to PRT engineers at the central maintenance station and incorporating devices like LiDAR and GPS. When connected to a GPS, the Raspberry Pi will determine its precise location in real time and provide flexibility with the configuration of a GPS.

3 REQUIREMENTS SPECIFICATION

3.1 Functional Requirements

1. Analyze location and power data.
2. Display data in a single-page user interface.
3. Track vehicle occupancy.
4. Track vehicle location and time to complete a ride.
5. Supply data to PRT officials to increase the efficiency of the PRT system.

3.2 Engineering Requirements

1. Equip PRT cars with a Raspberry Pi 4 model B.
2. Attach additional sensors (GPS, Current Clamp).
3. Devices should be non-visible to the occupants.
4. Data will be transmitted to the database while at PRT platforms.
5. Data will be transmitted wirelessly.
6. Data transmitted will be encrypted.
7. Data will be stored in an SQL database.
8. The database will be kept securely to ensure the confidentiality of data.
9. Use of Infrared or Lidar to determine vehicle occupancy.
10. Use data collected to make predictions.

3.3 Marketing Requirements

1. An automated design for monitoring GPS, AC power, and passenger amount.
2. Low-cost devices compared to dedicated hardware.
3. Reduce congestion at PRT stations.
4. Protect PRT carts from combustion due to higher-than-normal voltage.
5. Prevent carts from unintentional shutdowns.

3.4 Mapping of Marketing Requirements to Engineering Requirements

Most of the requirements for our project's marketing and engineering aspects are directly proportional to each other. The specifications on hardware and devices in both sets of requirements require automation and wireless communication, which satisfies both sets. However, our engineering requirements will not directly cause lower congestion times, protection from combustion, and unintentional shutdowns. This is because we will collect the data from our project and send it to the PRT engineering team, who can then make decisions to improve the PRT based on the data.

3.5 Engineering and Marketing Requirements trade-off chart

Table 1: Engineering & Marketing Rade-off Chart w/ Legend

✓ : Meets Requirement	- : Low	+ : High

	Speed	Performance	Cost	Security	Real-time Efficiency
Data transport (TCP)	-	+		+	
Data encryption (TLS)	+	+		+	
Data storage (micro SD)	+				
GPS			-		
Wireless Modem					✓
SIM Card (LTE)	-	-	**-/mo**	+	✓
SIM Card (4G)	+	+	**+/mo**	+	✓
Wi-Fi	++		-	-	-
AC power sensing (Current Clamp)					
Raspberry Pi	✓	✓	-		
LiDAR	+	+	+/-		

Note: SIM Card cost is an ongoing cost encurred monthly

3.6 Competitive Benchmarks

The product we hope to design meets a niche need. Because of that, there are few to no direct competitors. There are related systems worldwide, but their data analysis systems are proprietary information. Our closest competitor is the group working on the same project in CSEE481. At the current time, their work is inaccessible to us.

3.7 Various applicable constraints and standards

- **Legal:** This project will have no negative impact on students riding the PRT, so there will not be any legal constraints for our PRT project.
- **Privacy:** There isn't going to be any personal information collected on students riding the PRT. Instead, we will use LiDAR to determine car capacity.
- **Sustainability:** This device can be used for several years to get data from the PRT. The device will also have secure housing to prevent outside forces from damaging it, increasing its sustainability.
- **Economic:** Any sensors that will attach to the Raspberry Pi for this project or in the future should be inexpensive and within WVU's budget.

3.8 Broader Requirements and Constraints

This project will not have much effect on other industries, as this project is focused on improving and collecting data for WVU 's PRT system, and will be used entirely for and within WVU's PRT system. In terms of maintenance of the device over the course of its usage it would not require a lot of human interference other than some software updates to keep the device to date, so overall it should be simple to keep maintenance of the device.

4 REFERENCES

4.1 Sources

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4.2 Contribution Table

Andrew DeGarmo	2.2 Prior Works 3.3 Marketing Requirements	Source gathering and citations	
Sam Desai	1.1 Problem Statement 1.2 Functional Specifications 3.1 Functional Requirements 3.2 Engineering Requirements		
Emma Kupec	1.3 Constraints 2.3 Justification	Document layout and assignment drafting	Editing
Kevin Meyers	3.8 Broader Requirements and Constraints	Brainstorm/Information Gathering related to Requirements Specification	
Omar Ndiaye	2.1 PRT Background and History		
Greyson Weimer	3.8 Broader Requirements and Constraints	Conversion to LaTeX	Editing