

## **Modernizing A Proven Automated Transit System to Enhance Cost Effectiveness**

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Authors:

Justin Searcy Williams, Kansas State University Student, 2079 Rathbone Hall, Manhattan, Kansas, USA 66506, 913-539-6528, [jsw4444@ksu.edu](mailto:jsw4444@ksu.edu)

**ABSTRACT**

Despite controversial political beginnings, the West Virginia University Personal Rapid Transit (PRT) system in Morgantown, WV is now receiving the credit it deserves. With over thirty years of operation and no fatalities nor major injuries, the system continues to be an efficient and reliable example of automated transit. When expansions are considered, however, the price tag is always a shock. We can utilize modern technologies to implement a system similar to WVU PRT and take advantage of its robust, efficient, and flexible operating premise. This implementation lays a solid foundation for future exploration of techniques to extend the capabilities of the vehicles by utilizing contemporary equipment in order to alleviate some of the major costs associated with the complex guideway structure.

## INTRODUCTION

In the 1960s West Virginia University was rapidly growing and expanding beyond what the downtown area (the origins of the campus) would allow. Expansion to a remote campus location (Evansdale campus) was required to accommodate the expanding student population. This remote expansion brought about major congestion on the two roads connecting the areas. In 1969 Dr. Sammy Elias, as chairman of WVU's industrial engineering department, won a Housing and Urban Development grant which funded a feasibility study of connecting these campuses. The next year, the Department of Transportation founded the Urban Mass Transportation Administration. This body set out to research and implement new transportation technologies and continued funding the study and eventual implementation. Boeing Aerospace Company eventually took over design and construction of the system which was built in two phases, 1975 and 1979 (1).

The current system, still in operation, consists of five stations and traverses 3.6 miles between the end stations. After thirty years of efficient and reliable transit for faculty, staff, and students, there have been no fatalities and no major injuries. The system operates all year round only stopping for the very worst of snow storms when the University is closed anyways. Over the years the PRT has gained recognition and respect from the engineering community. In 1972 the National Society of Professional Engineers (NSPE) named the system one of the year's top ten engineering achievements. And in 1998 the PRT was chosen over Disney's monorail as *The New Electric Railway Journal's* pick for the "best overall people-mover" (2).

Even with its 1970's technology the system still operates with the same efficiency and level of safety as it did thirty years ago. Plans are being developed to replace the vehicle control and communication system (VCCS) with modern hardware. Other plans to modernize the system are projected to take the system through another twenty years of operation or more. Obviously there is an underlying control structure within this system that works.

It seems logical that a modern implementation of this PRT system would be equally reliable, efficient, and safe. When expansion of the WVU PRT system is considered, it is the price tag that inhibits the additions. The cost of building new guideway is substantial due to the amount of integrated technology within it. The guideway houses the power rails from which the vehicle draws its power, steering rails, inductive communication loops, station stop transmitter units, switch tone transceiver units, and presence detectors for collision avoidance (3). Modifying the PRT system using modern sensing and communication equipment would eliminate many of these elements from the construction of the guideway, making expansion or even initial implementation of such a system much more cost effective. Changing many of the mechanically controlled systems to electrically controlled systems as well as trading the old 70hp DC motor for newer lighter propulsion technology would have substantial affect on the weight of each vehicle and hence the necessary guideway support system.

## THE MORGANTOWN SYSTEM RENEWED

My research focuses on implementing the Morgantown PRT control concept with non-contact sensing and wireless communication technologies into a scale model demonstration system. This research will pave the way for future work in extending this vehicular control technology to a point at which substantial guideway cost reduction is seen. The Morgantown vehicle system implements these five basic features: speed and acceleration control, steering control (wall following) including switching between right and left, communication with central control, position detection and collision avoidance, and a vehicle power solution.

### Speed and Acceleration Control

#### *Morgantown*

The Morgantown vehicle measures vehicle speed and acceleration through a tachometer fixed to the 70hp DC motor (3).

#### *Research System*

My vehicle implements the same measurement capability using an optical encoder geared down from the onboard DC motor. A real time control system running on the PowerPC MPC555 processor appropriately adjusts the pulse width of the Electronic Speed Controller input signal according to a closed loop system with proportional control.

### *Full Scale Implementation*

These two systems are generally the same concept only differing in scale. A full scale implementation of the system used in my research would closely resemble the sensing and control system used in the Morgantown PRT system.

### **Steering and Switching**

#### *Morgantown*

The Morgantown PRT vehicle's steering and wall following function is a completely mechanical solution. A guide wheel (attached to the guide axle) rolls against the guideway wall holding the steering axles and wheels into a turn of one degree into the wall, keeping the guide wheel in contact with the guideway wall (3). Switching on the Morgantown vehicle is performed by mechanically throwing the guide axle to the other side therefore steering the vehicle into the other wall (3). A fore-and-aft torque tube connect the front and rear wheels implementing four-wheel turning. This allows negotiation of thirty foot radius turns. This mechanical sensing and steering solution is complex and heavy.

#### *Research System*

The vehicle I designed uses two (one on each side of the vehicle) ultrasonic ranging devices to measure the distance to the side walls. This measured distance is the feedback in a closed loop proportional-derivative (PD) control system implemented on the target MPC555 processor. This control system adjusts the pulse width input to the servo motor steering the front wheels of the vehicle. My design simply adjusts in software which ranging device (right or left) is currently utilized by the steering control system.

#### *Full Scale Implementation*

The non-contact ultrasonic sensing provides a lighter, smoother, and simpler solution over the mechanical system used by the Morgantown vehicles. Dramatic weight is dropped by the vehicle using this system since the entire guide axle assembly can be discarded. Transitions between sides and even continuous wall following can be much more smooth and enjoyable for the rider. Eliminating the complexity of the mechanical wall following system would eliminate some maintenance costs and improve system reliability.

### **Communication**

#### *Morgantown*

Communication between the Morgantown PRT vehicles and the central control computer occurs through inductive loops embedded in the guideway. Fixed frequency control tones are transmitted and received through these loops (3).

#### *Research System*

The communication in my scaled system is standard RS232 full duplex serial communication at 9600 baud over Bluetooth wireless communication standard. The range between the RS232 Bluetooth devices is 30m which covers the size of the proposed test track.

#### *Full Scale Implementation*

The obvious advantage to wireless communication, more specifically generic broad band secure communication is that it is relatively inexpensive to implement and needs no housing in the actual guideway structure. Wireless access points would be placed throughout the system to provide seamless coverage. Instead of control tones through fixed inductive loops each vehicle is in constant communication with central control. This solution not only makes the guideway less complex and less expensive, it makes the entire system infinitely more adaptable. Now vehicles can communicate with each other as well as a central computer. If it is decided later that a new piece of information would be useful if communicated between vehicles it can be easily implemented. While communicating, each vehicle has a unique identification which helps with vehicle tracking and collision avoidance.

### **Position Detection and Collision Avoidance**

#### *Morgantown*

The Morgantown guideway has embedded magnetic sensors that alert the hardware in the guideway when a vehicle (with a fixed permanent magnet) passes over it. This presence detecting system is used as a backup collision avoidance system. Each fixed block, separated by these presence detectors, transmits a safe tone over an inductive

loop within that block. The safe tone is turned off in blocks immediately to the rear of a vehicle. A vehicle approaching another from the rear will apply emergency brakes if it encounters the “off” signal (3). The primary collision avoidance system is the moving point system implemented by the central control computer. As a vehicle is about to leave a station the central computer gives the command for the vehicle to accelerate at a time when the predefined acceleration will land the vehicle on top of a logical moving point kept track of in the central control computer. Since the speed of the vehicle is regulated, the vehicle will remain on that logical point which should never approach another vehicle nor fall behind in the flow of traffic (3).

#### *Research System*

In my system, the presence detectors are replaced by infrared transmitters on the track. The IR transmitters sit on the guideway continuously transmitting a standard data sequence followed by an identification number. When a vehicle passes the transmitter it receives the data sequence, recognizes it and reads the identification number following the sequence. Now the vehicle knows where it is within the system. Before proceeding, the vehicle procures permission to enter the next block from the control center. If the next block is currently “open” it travels into that block while the control center takes note and logically closes that block. When that vehicle reaches the next IR transmitter and asks to proceed, the control center reopens the block behind it (Figure 1).

#### *Full Scale Implementation*

Infrared transmitters and receivers would not be the appropriate technology for a full scale implementation of position detection. GPS technology complemented by dead reckoning and even Radio Frequency Identification (RFID) would be a more logical choice for a full scale system. GPS was not an option for my research since I needed a technology that would work indoors. RFID was a poor solution due to its cost, and the relatively large detection range of the tags. A vehicle could conceivably read a tag meant for an adjacent piece of track since the scale demo is small. Of the full scale positioning technologies only the implementation of RFID would require that hardware be fixed to the guideway. Once again, this means that the guideway is simplified and hence its cost is reduced.

### **Power**

#### *Morgantown*

The Morgantown system receives its power from three power rails consisting of three phase 575VAC through either the right or left power collector, depending on which wall it is following (3).

#### *Research System*

My model system is battery operated, however, even in a full scale model hybrid technology (DC batteries and internal combustion engines) or even fully battery powered vehicles is not out of the question.

#### *Full Scale Implementation*

It is quite conceivable for a vehicle to run under its own power, whether it is stored energy, liquid fuel, a combination of both, or some other energy system yet to be popularized. Eliminating the power rails along the guideway simplifies the construction and maintenance of the guideway and as has been a common theme in this paper, guideway cost is reduced.

### **FUTURE WORK**

The scale model system will consist of three or four of the autonomous cars and folded landscape edging acting as the edges of the guideway for the car to follow (Figures 2 and 3). The landscape edging promotes transportability of the demo and also represents the relative simplicity of the guideway structure. I have done testing with one vehicle following the landscape edging and reporting position readings to the control computer. More vehicles will be constructed and programmed and when I can attain more space, a circular track with three interior connectors (intersecting in the middle) will be constructed out of the landscape edging (Figure 1). The central control algorithm will be programmed into the computer providing the capability of multi-vehicle movement with the intersection of paths.

Beyond the scope of my research lies an endless field of research in extending the capabilities of each vehicle so far as to eliminate all complexities of a dedicated guideway rendering the structure virtually a simple roadway. It is quite possible that vehicles will be capable of visual navigation enabling the vehicle to follow mere visual cues and

alleviating the need for these expensive structures for the vehicles to follow. Control and sensory technology of the future may even allow vehicles to traverse the same sidewalks and roadways used by pedestrians and autos.

**ACKNOWLEDGEMENTS**

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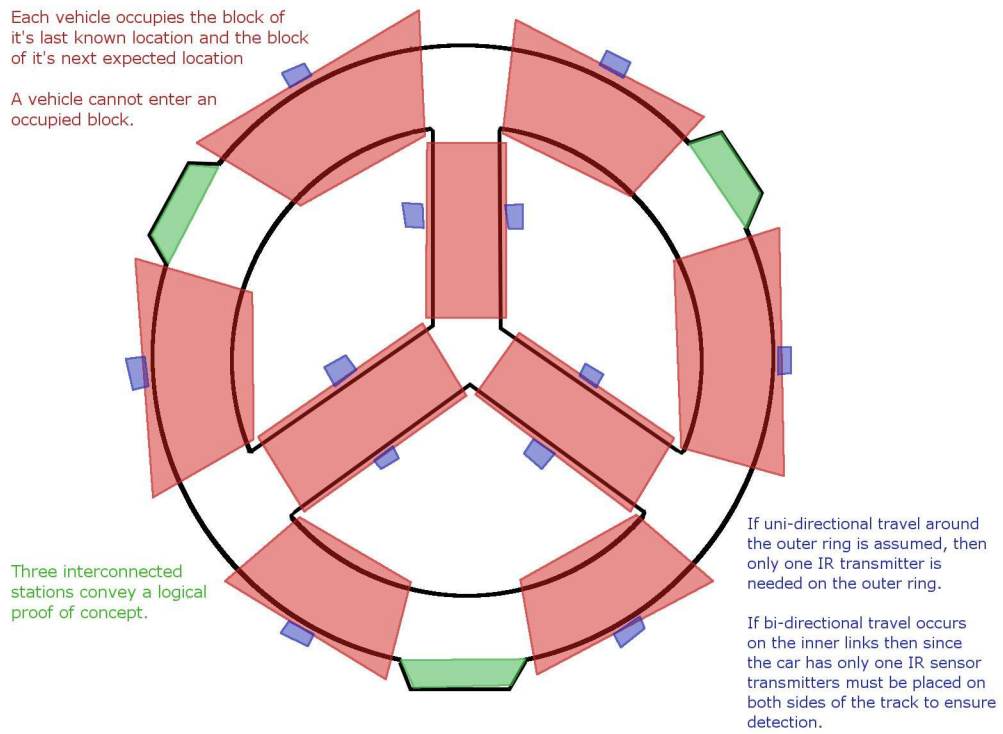
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**LIST OF FIGURES**

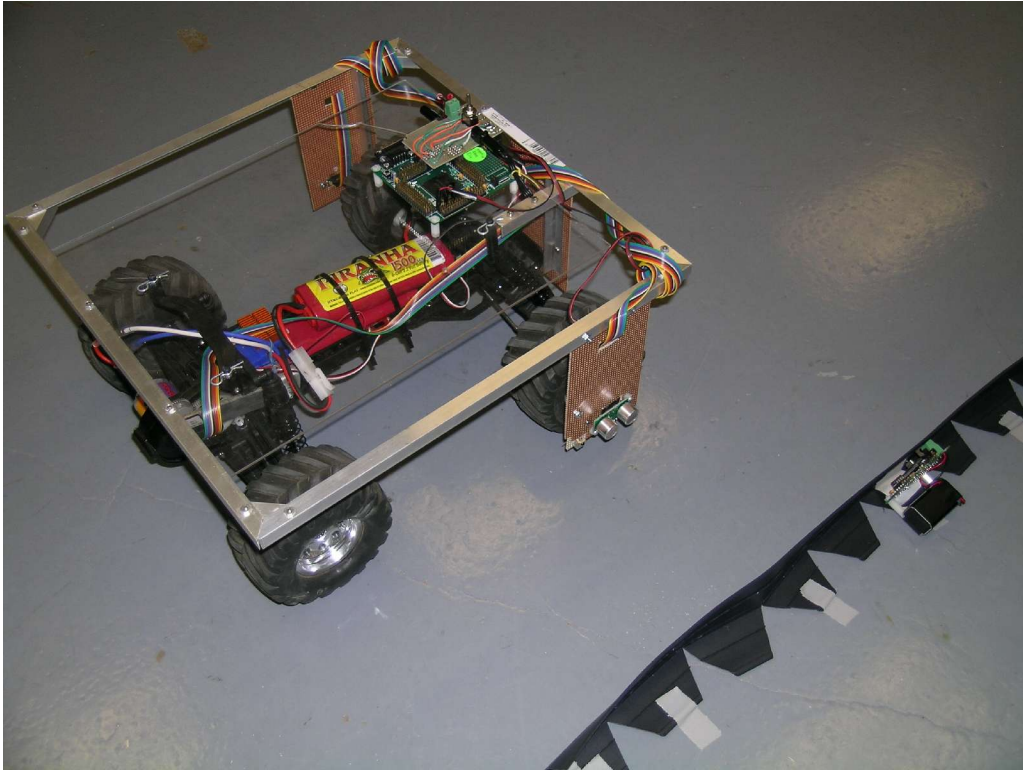
FIGURE 1 Image illustrating the proposed track layout with stations, IR transmitters, and logical fixed blocks

FIGURE 2 Image of the autonomous vehicle following a piece of track on the right with an inserted infrared transmitter.

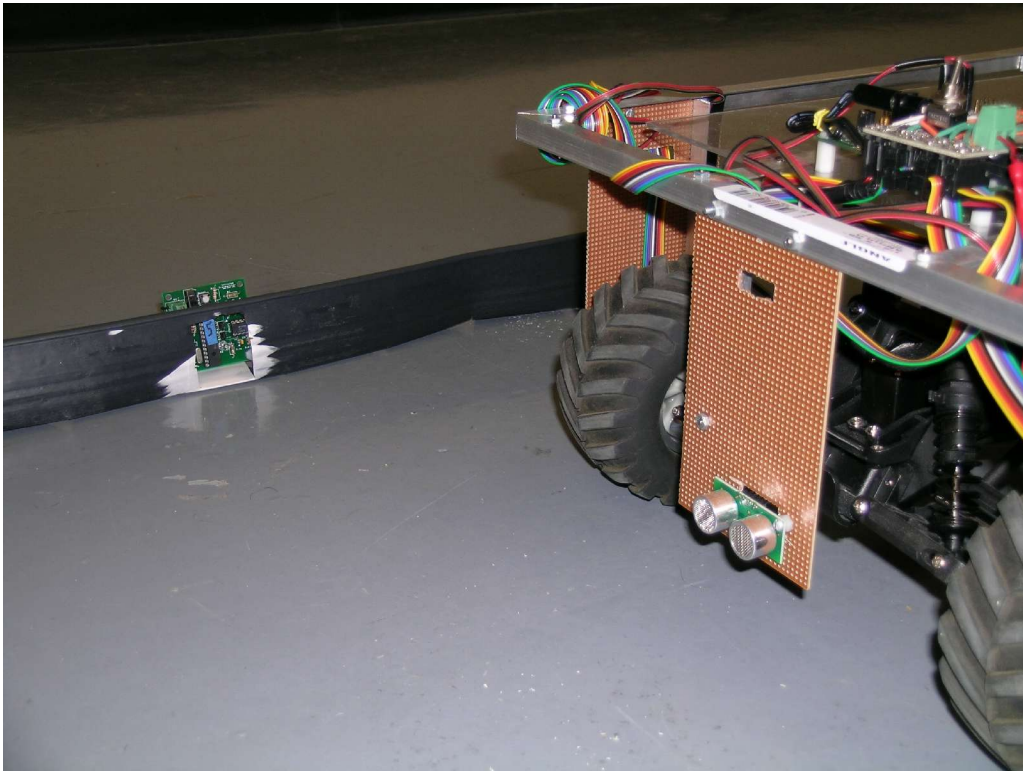
FIGURE 3 Image illustrating the integrated IR transmitter into the landscape edging track



**FIGURE 1** Image illustrating the proposed track layout with stations (green), IR transmitters (blue), and logical fixed blocks (red).



**FIGURE 2** Image of the autonomous vehicle following a piece of track on the right with an inserted infrared transmitter.



**FIGURE 3** Image illustrating the integrated IR transmitter into the landscape edging track.