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Investigating RFID for Linear Asset Management

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16. Abstract

A linear asset is defined as an asset whose length plays a critical role in its maintenance. Such assets include road, pipeline, and railroad track. For instance, major features of a roadway asset include traffic lights, number of lanes, speed limit, guardrail, and highway billboards. Linear assets along with their features are hard to physically access and therefore inventory information files that were captured previously may be inaccurate. To address this problem, some of transportation agencies are investigating technologies that will assist in solving this asset inventory problem. Radio Frequency Identification (RFID) is a technology that uses communication via radio waves to exchange data between a reader and an electronic tag attached to an object for the purpose of identification and tracking. The primary focus of this paper is to evaluate the feasibility of utilizing RFID as a means of gathering, verifying, and storing information for linear assets. The study investigates confluence factors that affect the performance of RFID. The factors investigated in this study incorporate driving speed, tag location on signposts, delineators, and guardrails. The study tested the active RF code type of RFID technology. The results indicate that for the three (10mph, 20mph, 30mph) vehicle speeds tested, tag readability decreased with an increase in speed.

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Abstract

A linear asset is defined as an asset whose length plays a critical role in its maintenance. Examples of such assets include roads, pipelines, and railroad tracks. Major features of a roadway asset include traffic lights, number of lanes, speed limits, guardrails, and highway billboards. Linear assets, along with their features, are hard to physically access; therefore, previously captured inventory information files may be inaccurate. To address this problem, some of the transportation agencies are investigating technologies that will assist in solving this asset inventory problem. Radio Frequency Identification (RFID) is a technology that uses communication via radio waves to exchange data between a reader and an electronic tag attached to an object for the purpose of identification and tracking. The primary focus of this paper is to evaluate the feasibility of utilizing RFID as a means of gathering, verifying, and storing information for linear assets. The study investigates the convergence of factors that affect the performance of RFID. The factors investigated in this study are driving speed, tag location on signposts, delineators, and guardrails. The study tested the active RF Code type of RFID technology. The results indicate that for the three (10mph, 20mph, 30mph) vehicle speeds tested, tag readability decreased with an increase in speed.

Chapter 1 Introduction

1.1 Background

A linear asset is an asset whose length plays a critical role in its maintenance; examples include roads, pipelines, or railroad tracks. The major characteristics of a linear asset are that it has a start and end-point, features that change over its span, and it can be maintained in segments for specific work and track progress. Features of a linear asset consist of traffic lights, number of lanes, speed limits, guardrails, and highway billboards. For example, the speed limit is an attribute of a highway (a linear asset) with multiple possible values (40 mph, 50 mph, and so on). A roadway beginning at mile 0 and ending at mile 60 may have variable speed limits: a speed limit of 55 mph may be in effect for the miles 0 through 20, and a speed limit of 65 mph may be in effect for the miles 20 through 60. At the same time, the number of lanes might be three lanes from miles 0 - 40, and four lanes from miles 40 - 60. Similarly, there are different types of guardrail that are available. Therefore, one can specify that "type" is an attribute of a guardrail, and then designate a value for each type of guardrail.

Radio-frequency identification (RFID) is a technology that uses communication via radio waves to exchange data between a reader and an electronic tag attached to an object. It is used for the purpose of identification and to track people or objects. RFID technology has been utilized for many years, and during World War II (WW II) it was used to distinguish between enemy planes and a country's own planes returning from a mission (Roberti, 2011). Since (WW II), RFID technology has been applied in many disciplines with various goals: asset tracking, highway toll collection, opening car doors with key chain devices, tracking a population of wild animals, hospital operating rooms for tracking operating equipment, and so on.

In the transportation industry, RFID has been used since the mid-1980s with tags attached to chassis carriers to serve as “license plates" (The basics of RFID, 2011). In recent years, RFID technology has been investigated for its applicability in the construction industry (Ross et. al., 2009), managing right of way utilities (Lodgher et. al., 2010), and managing roadway assets (Yates, 2009; Liu and Cai, 2007; Fedrowitz, 2007; and Wang, 2006). Based on the findings of the aforementioned studies, this study hypothesizes that RFID technology can be used to manage linear assets.

1.2 Problem Statement

Linear assets, along with their features like traffic lights and highway billboards, are hard to physically access and previously captured information files may be inaccurate. Local Departments of Transportation and Departments of Roads are investigating technologies that will assist in solving this asset inventory problem. The focus of this project is to evaluate the feasibility of utilizing RFID as a means of gathering, verifying, and storing information.

1.3 Project Objectives

In order to utilize automated technologies for more effective asset management, pertinent information must be accessible and collected in a reliable way. In this proposal, we evaluate a means for accomplishing these goals by investigating RFID. We hypothesize that RFID technology can be used to automate data collection of linear assets, including roads and guardrails, as well as reducing out-of-date and inaccurate information that is currently being stored in databases.

1.4 Report Organization

The following is an overview of the organization for the remainder of the report. The next chapter is a review of literature from both private and public transportation agencies that is

related to managing linear assets from various sources. The third chapter presents the methodology used to achieve study objectives; followed by the fourth chapter, which discusses the data collection process. Chapter five offers the data analysis and discussion, and finally chapter six presents the conclusions drawn in this study and provides recommendations for future research.

Chapter 2 Literature Review

2.1 RFID for Managing Roadway Assets

Researchers from many organizations are testing RFID technology for managing roadway assets. At Virginia tech, (Yates, 2009; Fedrowitz, 2007) researchers are investigating the use of RFID for the Virginia Department of Transportation to manage highway assets located in the right of way. For static testing, researchers tested the effect of the horizontal distance between the tag mounted on a metal mile marker and a hand held reader. For dynamic testing, the studies investigated the effect of vehicle speed and horizontal distance between the tag mounted on a metal mile marker and a reader mounted on a vehicle. The horizontal distances tested were 5, 10, 25, 50, 100 ft from the tag, as well as recording the maximum distance that the reader can detect a tag. The four vehicle speeds tested were 10, 20, 30, and 60 mph. The study found that the long-range system could read a tag mounted to a mile marker sign from up to 115 ft away under static conditions (vehicle not moving). Similarly, the maximum dynamic read range of the long-range system traveling at 10 mph was 115 ft. At a highway speed of 60 to 65 mph, the long-range system was not very consistent and was capable of reading a tag at a maximum distance of only 25 ft.

Liu and Cai (2007) investigated the performance of passive long-range RFID tags to locate highway reference markers along Loop 1 in Austin, Texas. The RFID tag with marker information including sign's location, type, size, height, and condition was attached to 25 traffic signs at 2.65 ft above ground. Readers were mounted in official vehicles to query the signs and to encode sign condition. The system was able to query tag data at high vehicle speeds (more than 55mph). The read range of this system was up to 40 ft and the locating resolution reaching

less than 13 ft. The life span of the whole system can be up to 10 years and the cost of each RFID tag is less than $2.00.

The research team at the Texas Transportation Institute (TTI) and Prairie View A&M University (PVAMU) investigated the feasibility of using RFID technology to manage assets in the Texas Department of Transportation (TxDOT) right-of-way (ROW). The project focused on using RFID to support managing utilities, outdoor advertising, ROW marker/survey control, and other highway infrastructure features and attributes. The research team conducted laboratory evaluations of the performance of RFID tags in selected buried applications, developed an integration schema for RFID application, and assessed the feasibility of TxDOT using or requiring RFID to manage assets in the ROW, and identified implementation opportunities for RFID in ROW applications. The research team found that RFID technology, while widely used for inventory control, has limited application for a transportation agency in the highway right-of-way. Based on the findings obtained from their research, the research team does not recommend the use of RFID technologies for managing assets in the ROW. However, the research team found that there might be some benefits that arise when using RFID technology in limited applications, such as utility relocation projects and survey monumentation (Lodgher et. al. 2010).

2.2 Limitations of Current Investigations

The recent investigations in managing roadway assets using RFID has shed light on the developments and applications of RFID technology in transportation. Based on the reviewed studies, the following limitations were identified:

- With the exception of underground utilities, most studies have investigated RFID performance on managing metal assets located on the roadways. Therefore, there is a

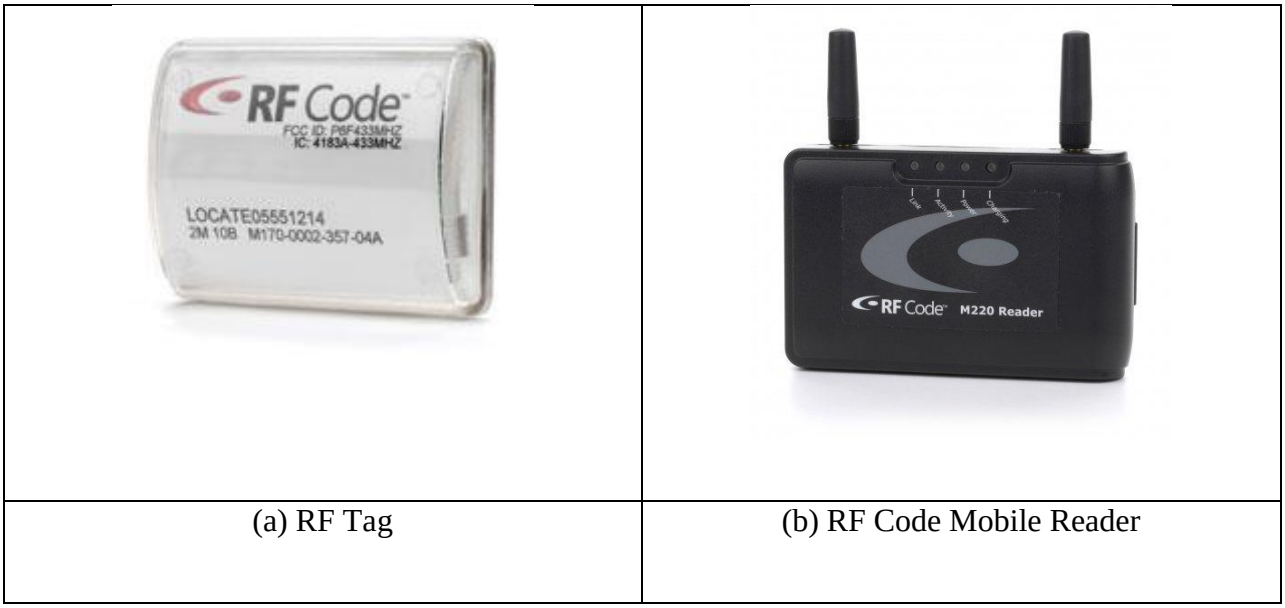
need for investigating RFID performance with tags attached to other materials commonly used for fabricating roadway assets.

- Passive RFID tags were used for studies that used mile markers and signposts to investigate the feasibility of using RFID for managing roadway assets. Thus, there is a need for similar studies using active RFID tags, in order to compare further the performance of the two types of tags.
- Furthermore, most studies investigated RFID performance with just one reader location. It would be essential to investigate the effect of reader location on RFID performance and to compare the results with those that positioned the reader at just one location on the vehicle.

Chapter 3 Methodology

3.1 Type of Tag and Reader

The study used RF Code, an active RFID-enabled infrastructure, for real-time asset management. The 433 MHz M171 Durable Tag is a battery-powered RF transmitter designed with a sealed, water-resistant, crush-proof enclosure for general-purpose asset tracking. Every tag broadcasts its unique ID and a status message at a periodic rate, which is programmed at the factory. The M171 operating temperature is -20° C to +70° C, operating humidity is less than 95%, RH non-condensing, and is not recommended for outdoor applications. Figure 3.1(a) shows a picture of an M171 tag similar to those used in this study.



(a) RF Tag | (b) RF Code Mobile Reader

Figure 3.1 The M171 Tag (a) and M220 Mobile Reader (b)

The study used a RF Code M220 reader, which is a battery-powered, portable reader that processes active RFID tag data and links directly to a computing device. It is equally valuable for the performance of on-demand audits and field inventories. It can be worn on a belt clip,

mounted in a vehicle, stowed in a pocket, or used in a variety of ad-hoc applications. The M220 operating temperature is -20° C to +45° C and operating humidity is 10% to 90% non-condensing. Figure 3.1(b) shows a picture of an M220 mobile reader similar to the one used in this study.

3.2 Static Pilot Study Design

The static pilot study was designed to measure RFID readability at different horizontal and vertical distances between the tag and the reader. The horizontal distances measured from the tag were 5 ft, 10 ft, 25 ft, 50 ft, 75 ft, 100 ft, 150 ft, 200 ft, and 230 ft. Based on the RF Code user manual, the mobile reader interprets and reports the radio frequency messages emitted by RF Code M171 active RFID tags at distances of up to 70meters (229 ft). Further, the research team investigated two reader heights; the maximum waist height represented by the tallest person in the research team, and the minimum waist height represented by the shortest person in the research team.

With respect to the material type on which the tag is attached, the research team investigated metal represented by signposts and guardrail, and plastic represented by delineators. In addition, the research team investigated different tag heights on the signposts, which were 4ft and 7ft. To understand the effect of metal obstruction on tag readability, the research team attached the tag at three positions: low point, medium point, and high point on the back of the signposts. Figure 3.2 demonstrate these locations on square and triangular signs.

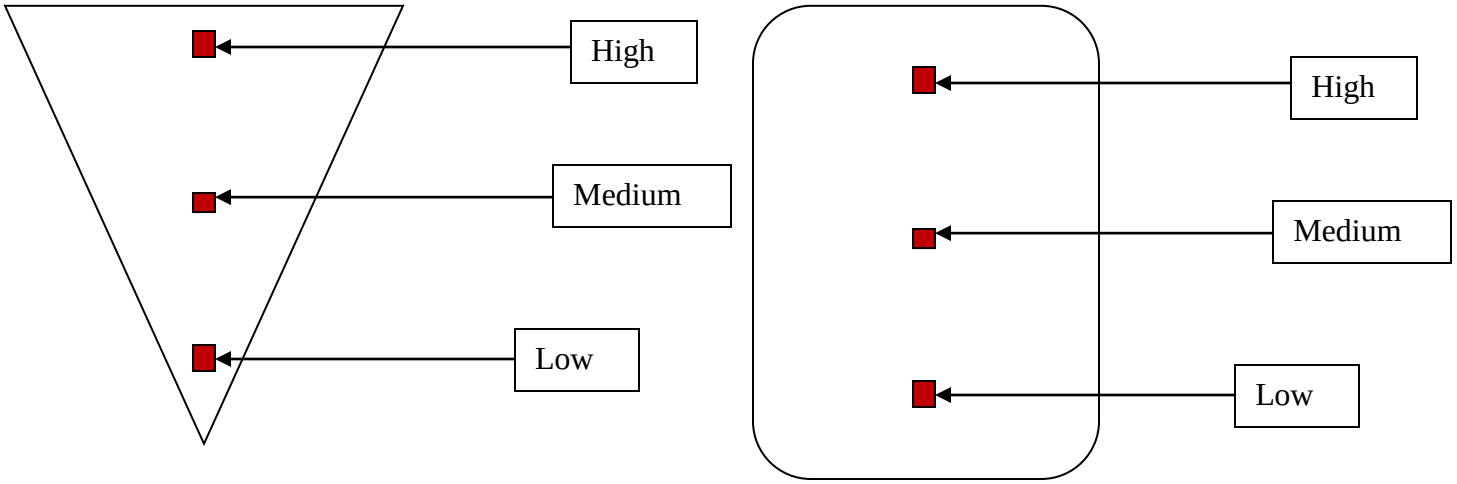


Figure 3.2 Tag Locations on the Back of the Sign

3.3 Dynamic Pilot Study Design

In the dynamic pilot study, vehicle speed was examined to understand its significance. The study tested three vehicle speeds; 10 mph, 20 mph, and 30 mph. Therefore, the dynamic pilot study was designed to measure RFID readability at different horizontal and vertical distances between the tag and the reader, but the reader was in motion rather than stationary, as in static pilot study. The horizontal distance was measured from the driving lane. Thus, driving on a lane close to the tag reflects the closest horizontal distance, and, similarly, the outer lane reflects the farthest distance. Further, the research team investigated two tag heights, namely 4 ft and 7 ft, on delineators and signposts. With respect to the material type on which the tag is attached, the research team investigated metal represented by signposts and guardrail, and plastic represented by delineators. The effect of metal obstruction on tag readability was investigated by attaching the tag at three positions; low point, medium point, and high point on the back of signposts. Figure 3.2 demonstrate these locations on square and triangular signs. Furthermore, it

is worth noting that in all scenarios in dynamic testing the reader was positioned at a fixed position, the passenger car window at 4.25 ft.

Chapter 4 Data Collection

4.1 Static Pilot Study

For the static pilot study, the research team aimed to investigate the performance of RFID technology with both the tag and the reader at a stationary state. Thus, an RF code active tag was attached to a feature of a linear asset, highway FM 1098, and a reader was mounted on the belt of the field personnel. The highway features that were tested include traffic signposts, guardrails, and delineators, which are common highway features. The data collection carryout for each feature is presented below.

4.1.1 Reader Location

Two reader heights were specified, namely, the maximum waist height and minimum waist height. The waist heights were determined by the heights of the data collection team; whereas the shortest person defined the minimum (2.92 ft) and the tallest person the maximum (3.25 ft). The walking person with a reader stopped at each pre-marked distance and checked the tag activity button on the reader. The recorder was then informed of the outcome. The intermittent flashing of the tag activity LED indicates that the reader has detected one or more tags. If there is a consistent on and off flashing of tag activity LED, then this indicates that the tags are not decoded. The recording personnel would mark “Y” for yes to tag detection and “N” for no. Figure 4.1 presents sample locations for the reader and tag.

(a) Reader at Maximum Waist Height

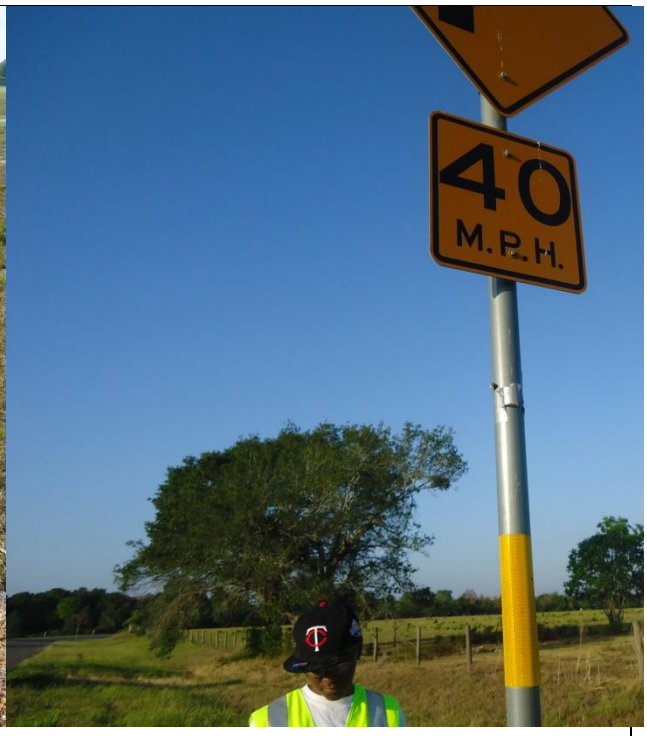
(b) Tag Attached to Sign Post

Figure 4.1 Tag and Reader Location

4.1.2 Tags on Sign Posts

The active RF code tag was attached to a roadway signpost at two different heights on the pole and three positions on the back of the sign: low, medium, and high points. The reason for varying heights and positions was to determine the optimal tag location on the signpost for recommendation to transportation agencies. On the signpost, the tag was placed on the pole at 4 ft and 7 ft, which was measured from the pole base. Figure 4.2 depicts such tag placements.

(a) Tag at 4 ft on a Sign Post



(b) Tag at 7 ft on a Sign Post

Figure 4.2 Tag Attached to a Signpost at 4 ft (a) and 7 ft (b)

Thereafter, the tag was placed at three different points, low, medium, and high, on the back of the sign itself. For each of these three points on the back of the sign, we used the same data collection procedures as described above to determine if the reader could read the RFID tag. Figure 4.3 depicts such tag placements.

(a) Tag at the Low Point on the Back of a Sign	(b) Tag at the Center Point on the Back of a Sign	(c) Tag at the High Point on the Back of a Sign

Figure 4.3 Tag Attached to the Back of a Sign

4.1.3 Tags on Delineators

Unlike signposts, which are typically made of metal, delineators are usually made of plastic. For the delineators, the tag was placed at 4 ft from the base and tag readability was recorded for both the maximum and minimum waist heights. The objective was to enable a performance comparison between metal and plastic. Figure 4.4 presents tag placement on the delineator.

Figure 4.4 Tag Attached to a Delineator at 4 ft

4.1.4 Tags on Guardrails

Guardrails are common features of highways and are ordinarily made of metal and concrete. They are designed to keep people or vehicles from straying into dangerous or off-limits areas. Since knowing its functionality is essential to transportation agencies, this study tested RF code performance when attached to the guardrail. The test site had only metal guardrails, thus the study results are only applicable to metal guardrails, and further research is required for concrete guardrails. Figure 4.6 presents a picture showing an RF tag attached to a metal guardrail.

Figure 4.5 Tag Attached to a Guardrail for Static Testing

4.2 Dynamic Pilot Study

The dynamic pilot study refers to a reader being mounted on a vehicle and therefore the reader is in motion. As opposed to the static pilot study, where the reader was stationary, the dynamic test was done to investigate the feasibility of RFID technology for transportation agencies to locate and collect asset status while driving at highway operating speed. Similar to the static pilot study, several factors were investigated to explore their effect on RFID technology performance. These factors include tag height, the material to which the tag is affixed, reader height, vehicle speed, and direction of travel. The data collection procedure for each of the aforementioned factors is presented in the following sections.

4.2.1 Tags at 4ft on Sign Posts and Delineators

In linear asset management, RFID technology is used for the purpose of identifying and tracking roadway features that could be missing, knocked down, and so forth. For this experiment, we attached eight RFID tags to several different roadway signs along highway FM 1098. Signposts made of metal that were utilized include a crosswalk, speed limit, Adopt-a-Highway, and caution. Delineators were equally represented by plastic material. Eight RF code tags were attached to features at 4ft; four to the signposts and four to the delineators Additionally, first the study was done with all of the tags located on one side of roadway, and then again with the tags spread over both sides of the roadway. Figure 4.6 shows tags located at 4ft on both a delineator and a signpost.

(a) Tag Attached to a Delineator

(b) Tag Attached to a Signpost

Figure 4.6 Tag Attached to a Delineator and a Signpost at 4 ft

4.2.2 Tags at 7 ft on Sign Posts

For dynamic testing, eight tags were attached on signposts at 7 ft on one side of the roadway, FM1098, and then again on both sides. This scenario served to explore the effect of higher heights on RFID performance because the tag height is relatively high compared to the reader height. Figure 4.7 shows a tag attached to a metal sign at 7 ft.

Figure 4.7 Tag Attached to a Signpost at 7 ft

4.2.3 Tags on the Back of Sign Posts

After testing a specific point in previous experiments, the tags were then attached to the low, center, and top points on the back of the signs. For each of the points, the research team

measured and recorded the height of each of the tags. Next, the vehicle with the reader mounted on the passenger window drove past the signs at 10, 20, and 30 mph to test the readability of the tags. Moreover, this was done for all tags located on one side of highway FM1098, and for the tags located on both sides of the roadway. Higher vehicle speeds were not tested because of low readability rates. Figure 4.7 presents tag positions on the back of the sign.

(a) Tag Attached to the Low Point on the Back of the Sign

(b) Tag Attached to the Center Point on the Back of the Sign

(c) Tag Attached to the High Point on the Back of the Sign

Figure 4.8 Tag Attached to the Back of a Sign

4.2.4 Tags on Guardrails

As previously stated, the test site had only metal guardrails so the study results are only applicable to metal guardrails, and further research is needed for concrete guardrails. Guardrails are designed to keep people or vehicles from veering off the road, preventing head-on collision, and so forth. Again, knowing its functionality is essential to transportation agencies. Figure 4.8 presents a picture showing an RF tag attached to a metal guardrail.

(a) Tag Height Measured	(b) Picture Showing Tag Attached to the Guardrail

Figure 4.9 Tag Attached to a Guardrail for Dynamic Testing

Chapter 5 Data Analysis and Discussion

5.1 Background

After data collection design, the information related to tag readability and radio signal strength was collected. In the field, the tag readability was coded as "Y" if a tag was detected and "N" if not. After tag detection, the first signal strength value displayed on the computer was recorded. The analysis was done using Stata 8.1 and the results are presented in detail in the following sections.

5.2 Static Pilot Study

This section presents the discussion of results for static pilot testing. The analysis covers all of the variables discussed in Chapters 3 and 4. The research team computed the tag readability rate for each study variable. The results show that the readability rate was 100 % for all of the scenarios investigated for the static pilot study.

5.3 Dynamic Pilot Study

This section presents the analysis of the results for dynamic pilot testing. The analysis includes all of the variables discussed in Chapters 3 and 4. The research team computed the tag readability rate and average Receiver Signal Strength Indicator (RSSI) for each study variable. The following subsections present the detailed analysis for each variable.

5.3.1 Tags on Guardrails

Tag Number: The tag readability rate and RSSI were analyzed for each tag. In total, the study used five tags for testing one side of the roadway, and all eight tags for testing both sides. By examining each tag individually, the study was able to investigate the difference in performance between each of the tags (figure 5.1). As observed, different tag placements yielded varied readability rates and signal strength. On average, the readability rates were higher when

all of the tags were located on one side of the roadway, as compared to both sides of the roadway. There is a need for further analysis because not all of the tags were attached to the same location, and height varied depending on the height of the guardrail to which the tag was attached. There was only a slight marginal difference in signal strength between the two tag locations.

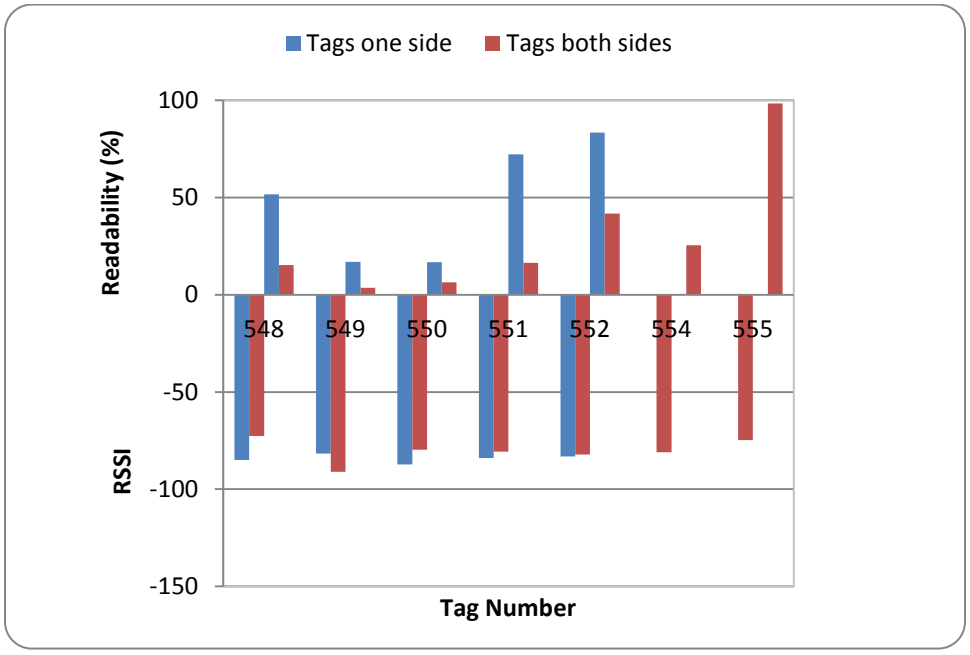


Figure 5.1 Tags' Performance when Attached to a Guardrail

Tag Height: Figure 5.2 presents the RSSI values and readability rate for different tag heights when attached to a guardrail. Readability rate varied with tag height; however, there was no clear pattern from which to draw reasonable conclusions. Marginally, the RSSI values for tags on both sides of the roadway were higher compared to those with tags on one side of the roadway.

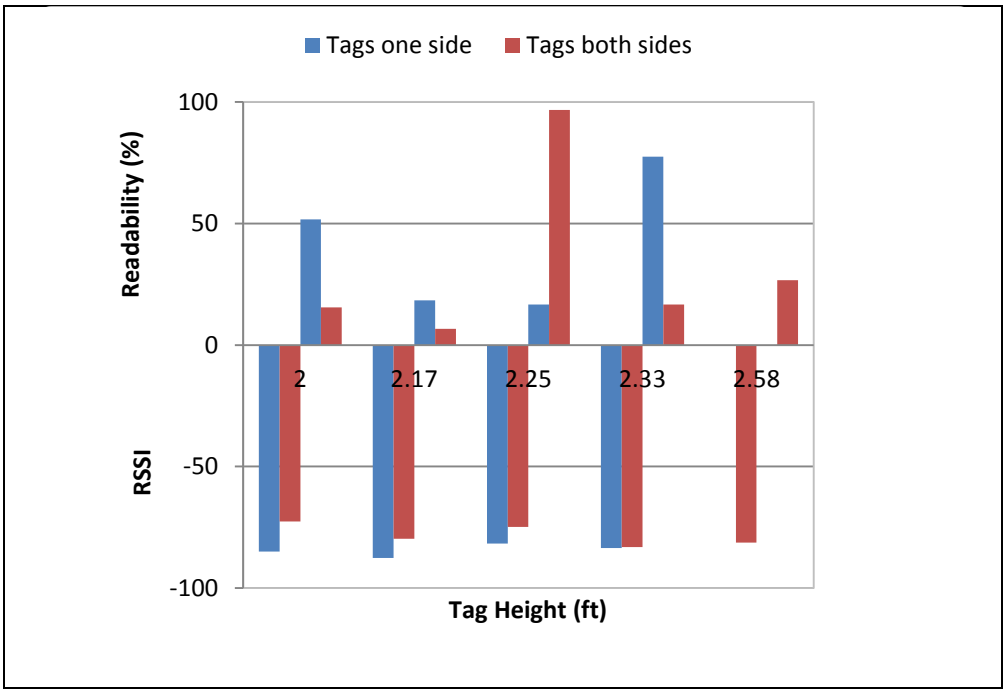


Figure 5.2 Tags' Performance with Varied Tag Heights when Attached to a Guardrail

Driving Direction: Figure 5.3 presents the readability rate and signal strength for north and south driving directions. The driving direction defines the increase and decrease in horizontal distance between the tag and a reader. For example, if the tags are located in the southbound lane, then a higher readability rate is expected when the reader is traveling in this direction because it is close to the tag. As expected, it was observed that when tags were located on one side of the road (south), the south readability rate was 6% better than when driving north. The driving direction showed only marginal differences in signal strength, however, the signal strength was slightly higher when driving south bound, for tags located both on one side and on two sides.

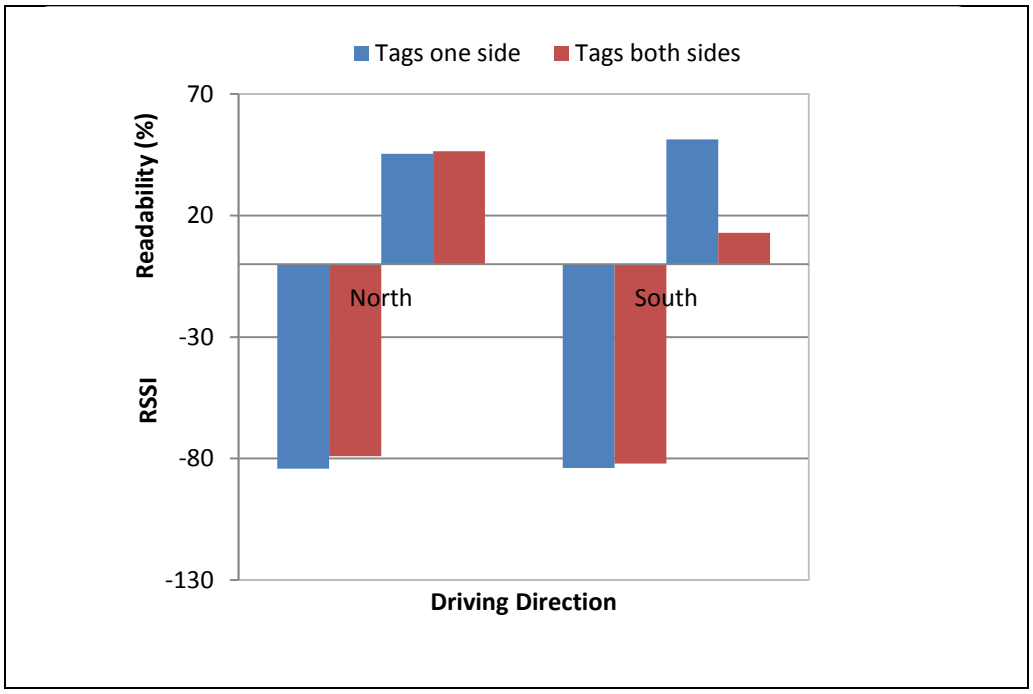


Figure 5.3 Effect of Driving Direction on Tags' Performance when Attached to a Guardrail

Vehicle Speed: The study tested three vehicle speeds, all of which were below the roadway speed limit, and it was expected that readability rate would decrease as the speed increased. As expected, regardless of the tags' location, the readability rates were higher for 10 mph and lower for 30 mph. The most significant difference in readability rate was for those tags located on both sides of the roadway. With respect to signal strength, for speeds of 20 and 30 mph, the tags located on both sides yielded higher values when compared to tags located on one side. However, for the 10 mph speed, the average signal strength was the same for both tag locations. The results of this analysis are presented in figure 5.4.

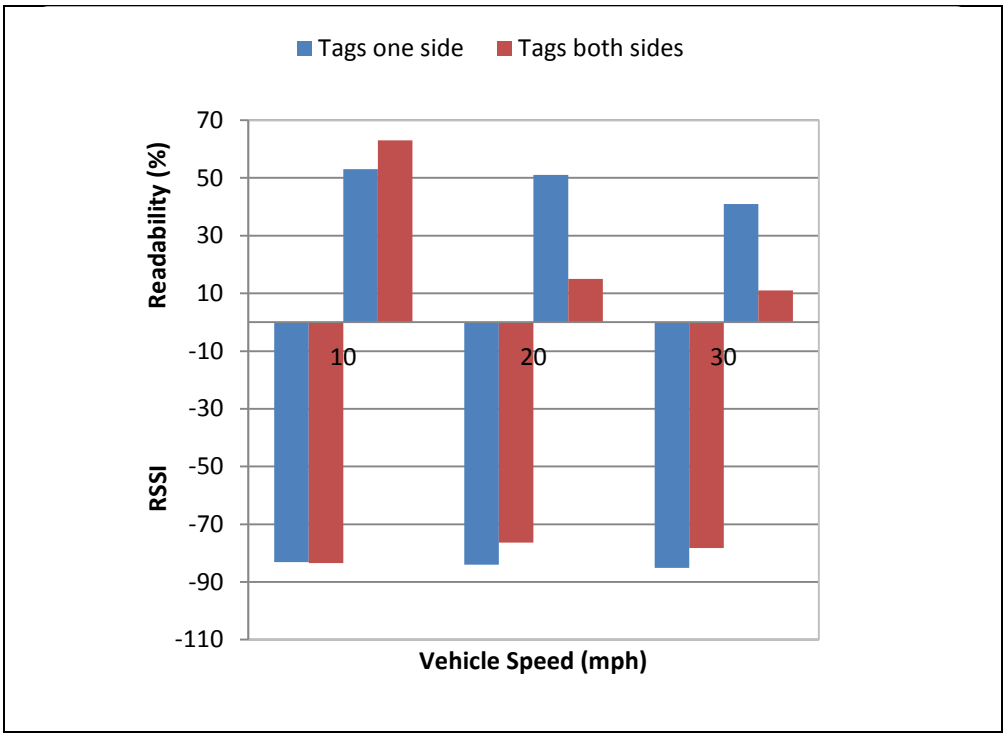


Figure 5.4 Effect of Driving Speed on Tags' Performance when Attached to a Guardrail

5.3.2 Tags at 4ft on Sign Posts and Delineators

Readability: The tag readability rate for tags attached to delineators and signposts at 4 ft is nearly 10%. Regardless of the tag location in terms of roadway side, tags attached to plastic showed a higher readability rate compared to those attached to metal. For tags on one side of the roadway, regardless of material type, driving close to the tags yielded higher readability rates compared to its counterpart. On average, lower vehicle speed yielded higher readability rates when compared to higher vehicle speeds.

For tags on both sides of the roadway, regardless of material type, driving in the northbound lane yielded relatively higher readability rates compared to driving south bound. This phenomenon needs further investigation. On average, higher speed showed a negative correlation with tag readability.

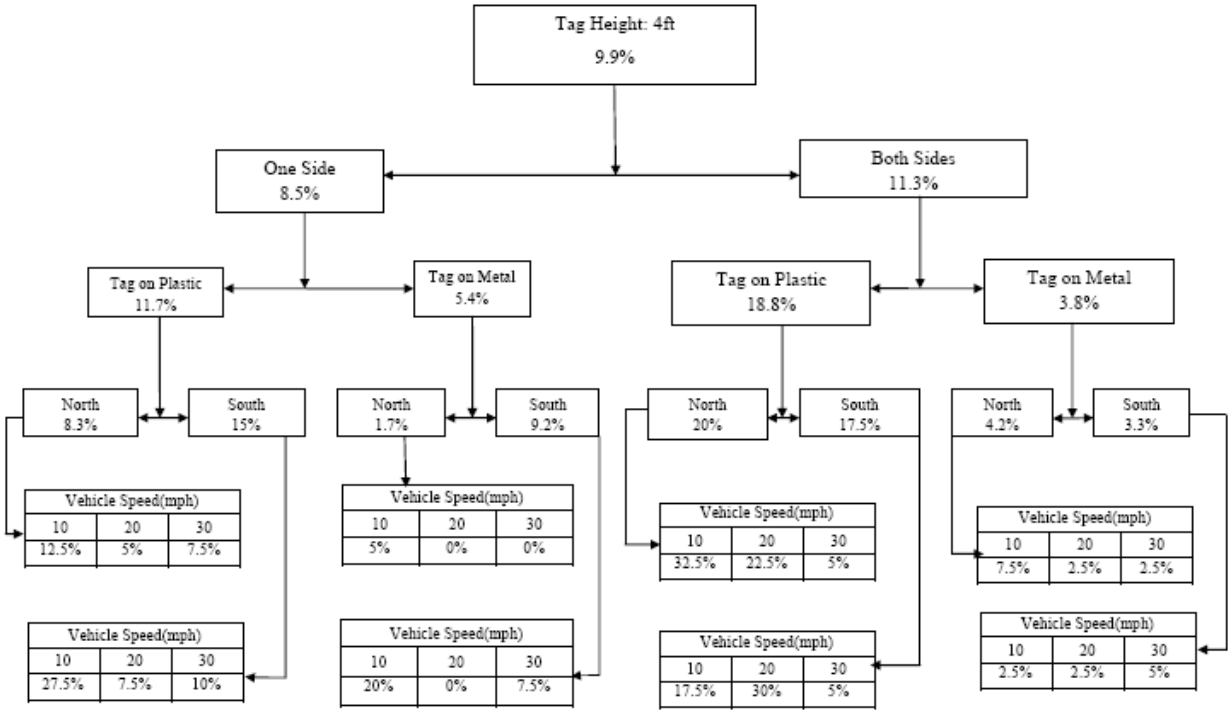


Figure 5.5 Readability of Tags at 4 ft on Delineators and Signposts

Signal Strength: Signal strength was higher for tags located on both sides of the roadway than for one side. When comparing metal and plastic, the latter yielded higher signal strength for tags on both sides and the former yielded higher signal strength for tags on one side, albeit both marginally. With respect to driving direction and vehicle speed, the results showed no pattern when comparing tags attached to plastic with those attached to metal. Figure 5.6 presents the results of the aforementioned analysis.

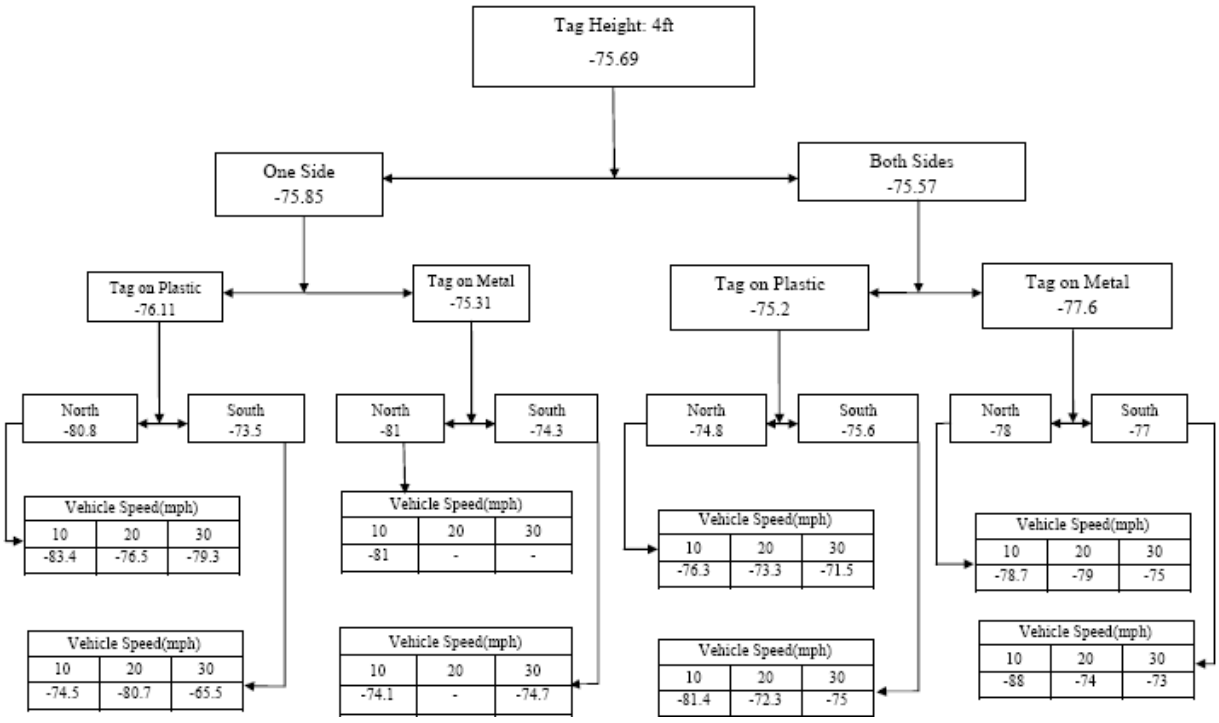


Figure 5.6 Signal Strength for Tags at 4 ft on Delineators and Signposts for Dynamic Testing

5.3.2 Tags at 7ft on Sign Posts

Readability: Figure 5.7 presents the readability analysis for tags located on signposts at 7 ft. Compared to 4 ft, on average; the readability rate at 7 ft is higher by more than 6%. Contrary to the 4 ft readability performance, tags at 7 ft yielded higher readability rates for those on one side of the roadway when compared to those tags on both sides. Regardless of the driving direction and tag location, readability rates decreases with an increase in vehicle (reader) speed.

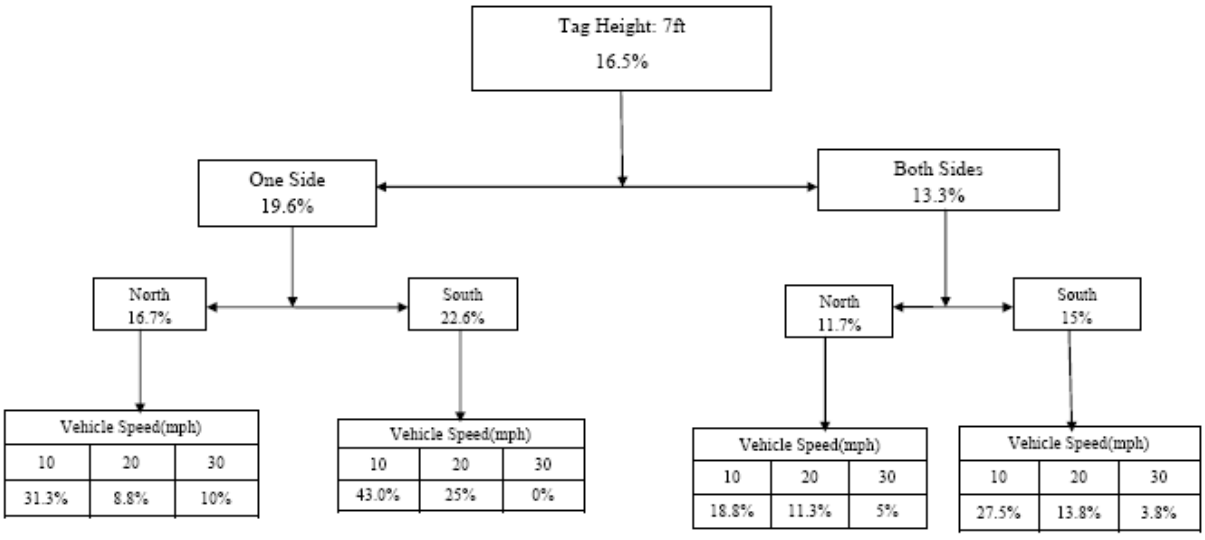


Figure 5.7 Readability for Tags at 7 ft on Signposts for Dynamic Testing

Signal Strength: Figure 5.8 presents the signal strength for tags mounted at 7 ft on signposts. When compared to those readings with tags on both sides of the roadway, tags located on just one side yielded readings with higher signal strength. On average, signal strength increases with a decrease in vehicle (reader) speed, as shown in figure 5.8.

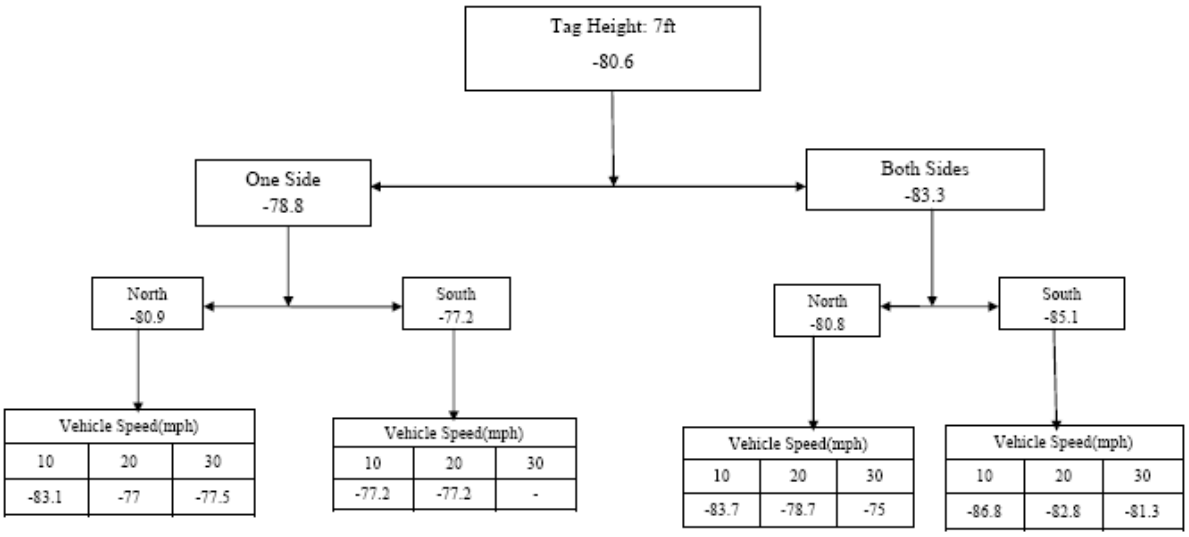


Figure 5.8 Signal Strength for Tags at 7 ft on Signposts for Dynamic Testing

5.3.3 Tags on the Back of Sign Posts

Tag Number: The research team did investigate the effect of metal interference on RFID performance. As noted in figure 5.9, for all tags, the readability rate is very low compared to other scenarios presented above. However, the scenario with tags located on both sides yielded marginally better results for both readability and signal strength compared to the scenario with tags placed on one side.

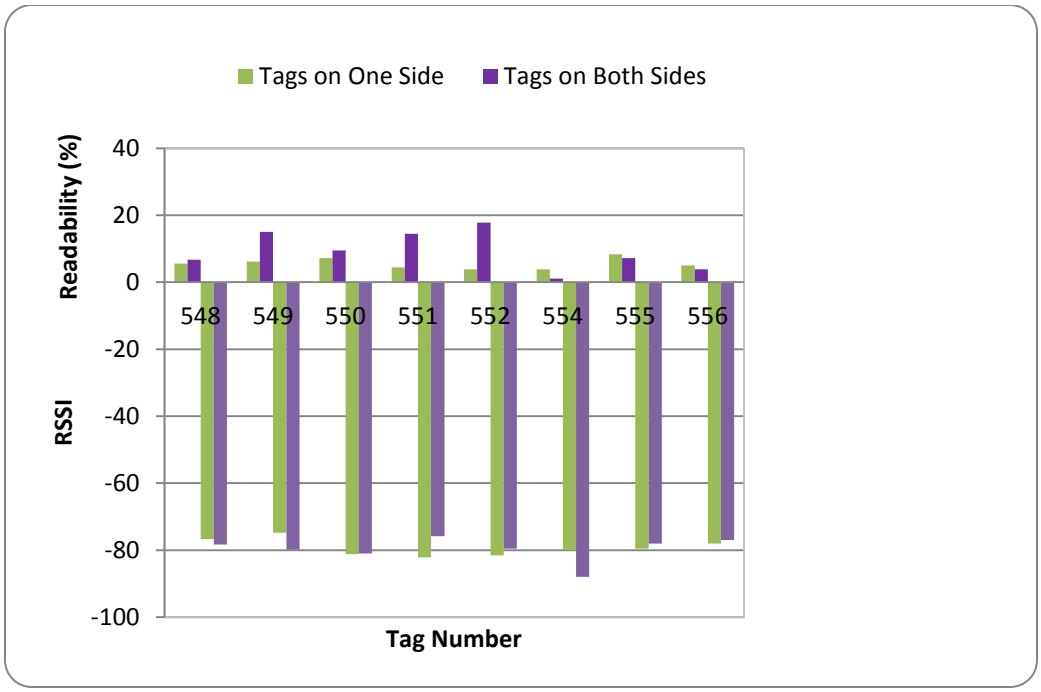
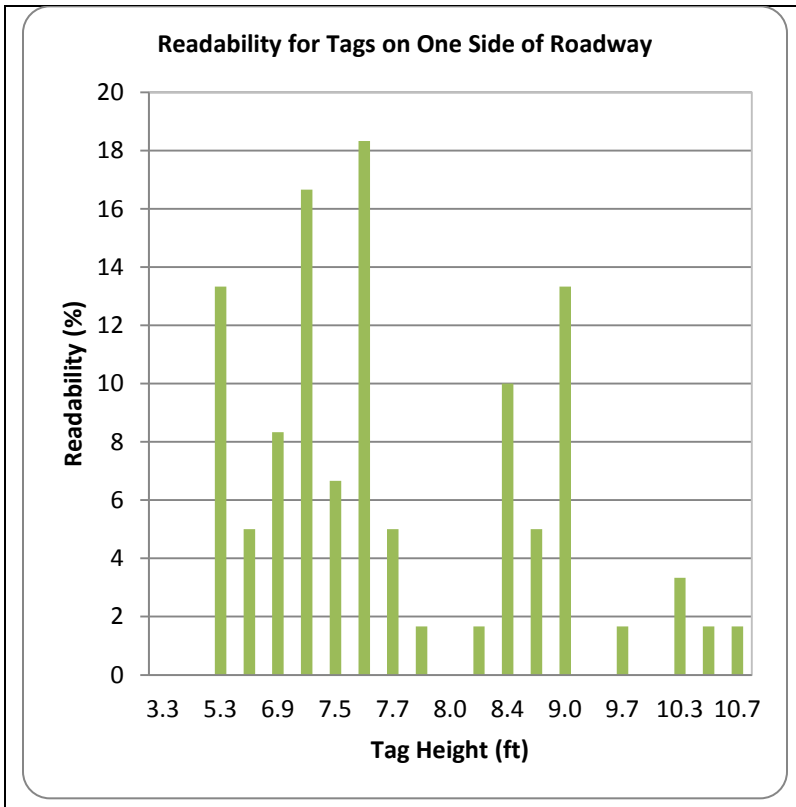
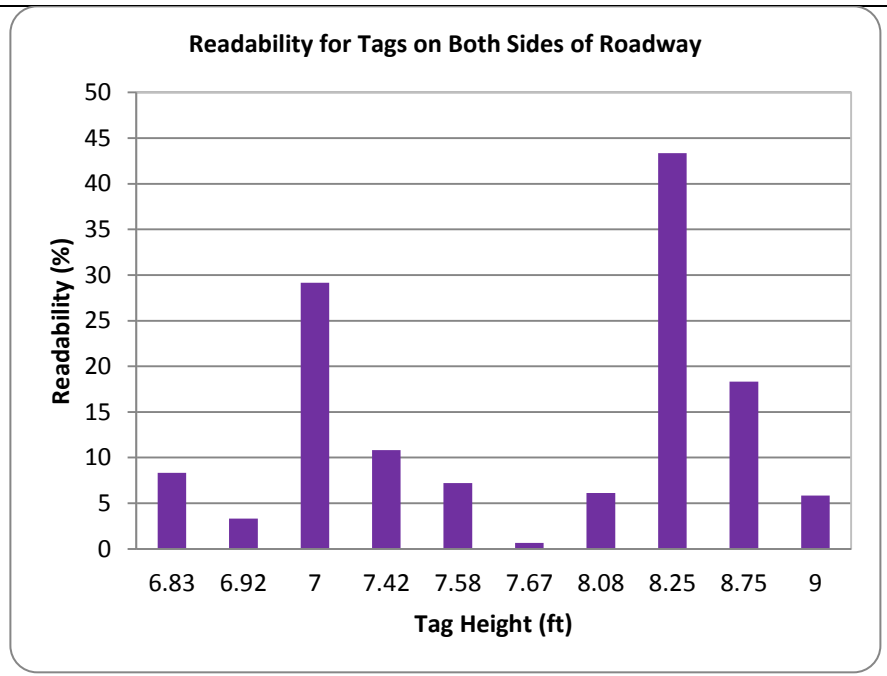


Figure 5.9 Signal Strength for Tags at 4 ft on Delineators and Signposts for Dynamic Testing

Tag Height: The effect of tag height on readability, when tags were attached to the back of the sign, showed no clear pattern, for both one side and two sides. However, as observed in figure 5.10 the scenario with tags on both sides yielded higher readability rates when compared to the scenario with tags on one side only. Likewise, the effect of tag height on signal strength, when tags were located at the back of the sign, showed no clear pattern, for both one side and two sides (figure 5.11).

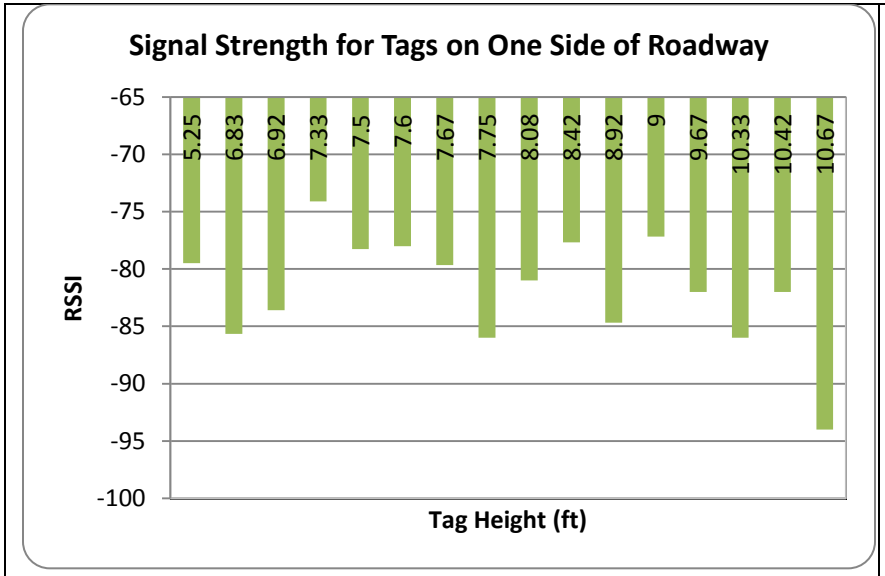


(a) Tag Readability for One Side

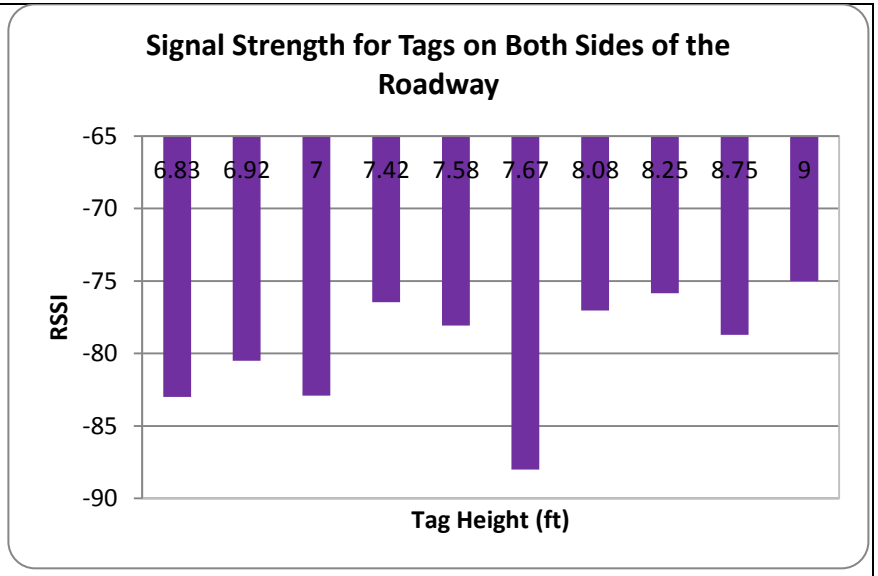


(b)Tag Readability for Both Sides

Figure 5.10 Readability for Tags on the Back of Signposts for Dynamic Testing



(b) Signal Strength for One Side



(b) Signal Strength for Both Sides

Figure 5.11 Signal Strength for Tags on the Back of Signposts for Dynamic Testing

Driving Direction: Driving direction may affect RFID performance by increasing or decreasing the horizontal distance between the tag and the reader. Figure 5.12 presents the readability for tags located at the back of signposts. As shown, the readability rates were different for the two driving directions. The northbound direction showed higher rates for tags on both sides of the roadway, whereas the southbound yielded higher rates for tags on one side of the roadway. However, driving direction caused only a marginal impact on signal strength.

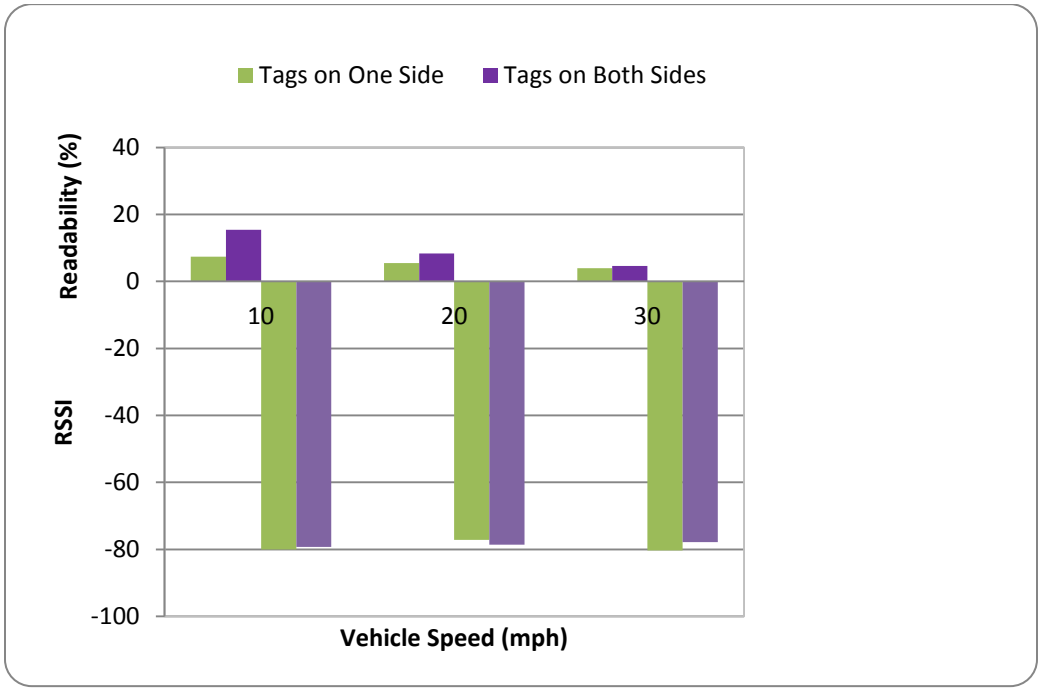


Figure 5.12 Readability for Tags on the Back of Signposts

Vehicle Speed: As discussed in earlier sections, vehicle speed showed a negative correlation with tag readability. Similarly, for tags on the back of the sign, the readability rate decreases with an increase in vehicle speed for both one side and both sides of the roadway

(figure 5.13). For tags located on both sides, signal strength showed a marginal increase with an increase in vehicle speed.

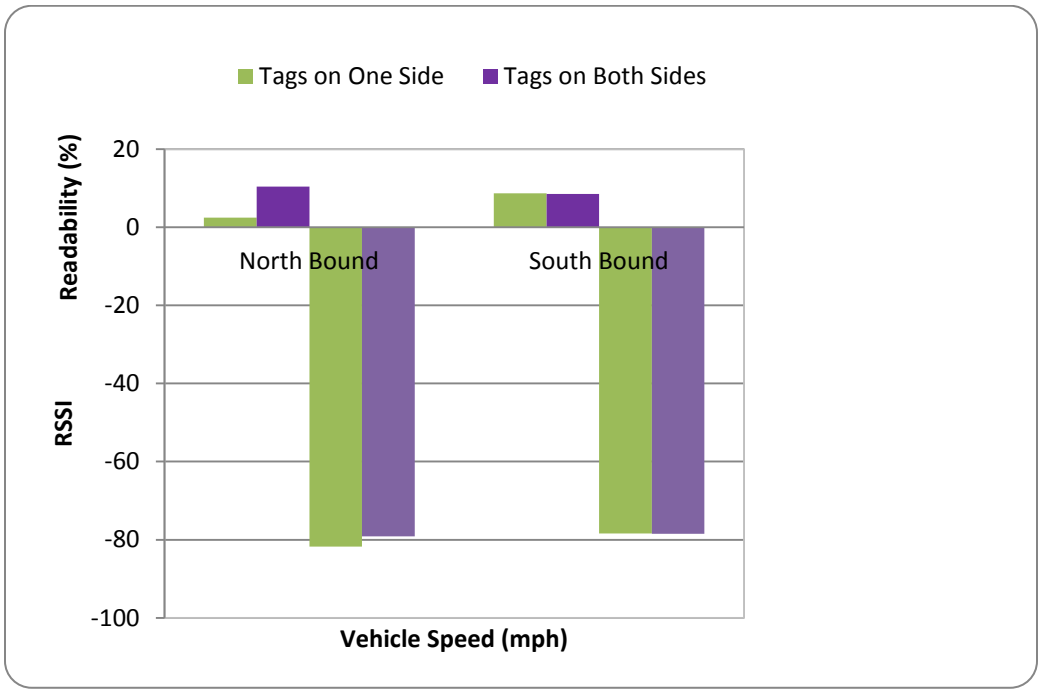


Figure 5.13 Signal Strength for Tags on the Back of Signposts

Chapter 6 Conclusion and Recommendations

6.1 Conclusion

The study investigated the feasibility of RFID in managing linear assets. The study analyzed confluence factors that affect the performance of RFID. The factors considered in this study were driving speed, tag location on signposts, delineators, and guardrails. The study tested the active RF code type of RFID technology and the following conclusions were drawn:

- The study tested three vehicle speeds, 10 mph, 20mph, and 30mph, and the reader was mounted on the passenger window at 4 ft 3 in. On average, tag readability decreased with an increase in vehicle speed, and thus reader speed, for most scenarios that were evaluated. On the contrary, signal strength, which corresponded with how many times the tag could be read per second or nanosecond, was found to positively correlate with driving speed.
- Horizontal distance between the reader and tag was found to have an influence on RFID performance. The closer the reader was to the tag, the higher was the readability rate.
- At 4 ft from the ground, the tags were attached to both metal and plastic to test the technology's performance when attached to different materials. The study found that at this tag height, the technology yielded superior performance for plastic (delineators) as compared to metal 9signposts).
- The study tested the RFID technology performance with metal obstructions. Compared to non-obstructed scenarios, the technology yielded poor performance with metal obstructions.

6.2 Recommendations

The study would like to offer the following recommendations for future research and practical implementations of RFID technology.

- The tested vehicle speeds were below the roadway posted speed limit and the RF code yielded low readability rates at 30 mph. Therefore, before transportation agencies decide to implement the technology, it is recommended that other types of RFID technology be tested at higher speeds, which is more applicable to transportation agencies.
- The test was performed on a two-lane undivided highway; therefore, the maximum horizontal distance between the reader and the tag would be a sum of the sign distance from the shoulder, shoulder width, and one lane width. The research team recommends further investigation on multi-lane highways for more extensive data on horizontal distances.
- With respect to material types, this study tested the performance of RFID technology with tags attached to metal and plastic materials. The results showed superior performance with tags attached to plastic compared to metal. Therefore, it would be beneficial to test the performance of tags covered with plastic adhesives, which are then attached to metal. These results could then be compared with those with the tags attached to the metal directly. Moreover, the study only tested metal guardrails, and not concrete. Hence, further study of RFID performance on concrete barriers and guardrails would prove valuable to transportation agencies.
- For the results presented herein, the reader was mounted on a passenger car window at 4ft 3in. Furthermore, the reader had stub antennas that are usually used for short-range inventory applications. Testing the ¼ wave helical antennas intended for longer range

searching applications would provide necessary data for future applications. Additionally, reader height has been known to influence RFID performance, therefore testing locations other than the passenger window would help determine if there is a more appropriate reader location.

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