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Comparing the Accuracy and Utility of Different Vehicle Counters in Public Land Contexts

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Comparing the Accuracy and Utility of Different Vehicle Counters in Public Land Contexts

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Abstract

Creating accurate use estimates is important to support a variety of businesses needs for the Bureau of Land Management (BLM) and other land management entities. Automated counting devices are nearly universally used for estimating use, but the scientific literature demonstrates the need to calibrate these devices to ensure they are accurate. However, there is scant research on the differences between the accuracy of automated vehicle counters when used on public lands and in similar protected areas. This research compares the accuracy of different automated vehicle counter technologies through a calibration process. Results show that pneumatic tube and radar counters are much more accurate than magnetic counters, so much so that calibration is rarely warranted. A qualitative assessment of these technologies is also provided to support field staff in selecting the appropriate equipment for their unique conditions.

1. Introduction

1.1 The Need to Understand the Use of Public Lands

Information about the use of public lands and other protected areas is critical for their effective management. Uses for this information include recreation planning, travel management, infrastructure development, facility maintenance, staffing requirements, damage assessments, resource impact assessments, economic impact estimations, communications with stakeholders, and fulfilling reporting and monitoring requirements. This includes both recreation and non-recreation use. Recreation use involves people entering public lands for recreational experiences. Non-recreation use involves people entering public lands for non-recreational experiences. These may include commuting, in-holding access, employees, contractors, researchers, leases or mining claimants, and a variety of other uses (BLM 2023, Ziesler and Pettebone 2018).

1.2 Automated Counters for Estimating Use

Automated counters have emerged as a primary way to estimate and monitor use on public lands (Lynch et al. 2002, Pettebone et al. 2010, Rappaport et al. 2024, Ziesler and Pettebone 2018). These automated counters generally include pedestrian counters, vehicle counters (including counts of off-highway vehicles), bicycle counters, and some counters that can classify different types of use (i.e., bicycle and vehicle). Although automated counters are nearly universally used by public land managers due to perceptions of being efficient in time and money (Lynch et al. 2002, Rappaport et al. 2024), a variety of issues exist in ensuring accurate and reliable use estimations. Staffing and funding is a primary challenge, but the technical skills and understanding of social science methods among field staff also represent a barrier (Lynch et al. 2002, Pettebone et al. 2010, Rappaport et al. 2024). This includes the appropriate placement and installation of equipment and required calibration procedures.

The vast majority of research on automated counters estimating use on public lands and in other protected areas focused on infrared trail counters. These counters use an infrared beam to detect human movement. When the beam is broken, a count is registered. A variety of studies demonstrated that although these types of counters are reliable, they are unlikely to be accurate (Andersen et al. 2014, Lynch et al., 2002, Muhar et al. 2002, Pettebone et al. 2010, Vaske et al. 2008). Reliability is how consistent a measure is, and automated counters are generally reliable. Accuracy is how close a measure is to a true value, and automated counters may need adjustments to achieve accuracy. Weather (i.e., snow, bright light, wind, and/or heat), visitor behavior, site design, and equipment installation choices can all influence accuracy.

To ensure the accuracy of use estimations from automated counters, calibration may be necessary. Calibration is simply the process of comparing automated counts to actual counts. This is usually done by physically observing and recording use and comparing it to automated counts over a specified period of time. Generally, at least 5 hours of calibration is sufficient for accurate counts from automated devices (Pettebone et al. 2010). Research indicates that infrared trail counters will have some level of inaccuracy and that each counter should be calibrated. Critically, there is no one generalized calibration factor that can be applied—each unique counter requires its own calibration process (Pettebone et al. 2010). On busy trails in Yosemite National Park, researchers found that counters were consistently undercounting visitation by 56–83%. In the most extreme case, for every 100 automated counts there were actually 183 people (Pettebone et al. 2010). For detailed information on how to execute calibration, see the manual composed by Meyer and Rempel (2022).

Unlike infrared trail counters, automated vehicle counters are understudied on public lands and other protected area contexts. Automated vehicle counters also use many different technologies, including magnetic sensing, pneumatic road tubes, and radar. Lastly, automated vehicle counters are generally developed for municipal and highway use. Application of these technologies to public lands and other protected areas may create unanticipated challenges. Anecdotally, these challenges can include rough dirt roads, wildlife damage to pneumatic tubes, slower than normal traffic speeds, congestion and gridlock near key attractions and parking areas, and maintenance unique to public land settings (i.e., plowing sand to create a road through sand dunes regularly).

2. Purpose of This Technical Note

The purpose of this technical note is to support public land managers in choosing the most appropriate type of vehicle monitoring equipment for their unique contexts. Two approaches are used. First, a quantitative assessment examines the accuracy of three different types of automated vehicle counters placed in approximately the same location. Accuracy is assessed through a calibration process that examines automated counts compared to observed counts. Second, a qualitative assessment of the equipment provides managers with additional insights to help further inform their decisions about using the various types of monitoring equipment.

3. Methods and Equipment

3.1 Quantitative Assessment of Automated Vehicle Counter Accuracy

Three automated vehicle counters with different technologies were selected for collecting data. A MetroCount RoadPod VT5900 tube counter (pneumatic tube technology), Houston Radar Armadillo model counter (radar technology), and a TRAFx Magnetic G4 counter (magnetic technology) were used. Capitol Reef National Park, Utah served as the study location. The counters were placed in approximately the same location on the 7.9-mile Scenic Drive. This paved road has two-way directional traffic, with almost all vehicles returning on the same road after visiting various sites. The road's width ranges from 17 to 22 feet, and the speed limit is 25 miles per hour. As a result of its width, congestion can occur when vehicles are either slowing down or pulling over for sightseeing, taking photos, or when large vehicles and RVs pass each other. Counters were placed on a straight section at the beginning of the drive, far from any trailhead turnoffs, so that traffic remained relatively free flowing. The counters were intentionally placed away from nearby pullouts where visitors are likely to stop.

The settings on the automated vehicle counters were modified according to their respective manufacturer's instructions. Some devices, such as the magnetic counter, required more sensor setting configuration with the software during installation, while others like the radar counter are more dependent on the specific positioning of the sensor rather than specific software settings. Prior to testing, setup also involved observing the device in operation, attempting to optimize settings, and positioning the counter. This step is important, as optimizing each counter's settings and setup and not simply using the default settings can increase accuracy and potentially reduce inaccuracies between device counts and actual counts.

A single trained researcher collected physical observation counts for a total of 8 hours over Memorial Day weekend, 2022 (Saturday May 28, 13:00–16:59; Sunday May 29, 09:00–12:59). Collecting data during different time periods provided a variety of traffic conditions, including multidirectional congestion patterns that are more likely to challenge device accuracy. Following guidance from Pettebone and others (2010), sampling for a period > 5 hours yields robust results for calibration.

3.2 Qualitative Assessment of Equipment

Experienced field staff and scientists reviewed manuals and drew on their own experience to provide additional context for guidance when selecting automated vehicle counting equipment. Key findings from their comprehensive review of information and field experience are summarized in Table 4, Section 4.

4. Results

4.1 Vehicle Counter Accuracy

Tables 1–3 display the data for all physical observation counts, vehicle counters, and associated calibration factors. The tube counter ranged from an hourly calibration factor of 0.97 (a 3% overcount) to 1.02 (a 2% undercount), with an overall calibration factor of 0.99 (Table 1). The radar counter ranged from an hourly calibration factor of 0.93 (a 7% overcount) to 1.04 (a 4% undercount), with an overall calibration factor of 0.99 (Table 2). The magnetic counter ranged from an hourly calibration factor of 1.20 (a 20% undercount) to 1.40 (a 40% undercount), with an overall calibration factor of 1.31 (Table 3). It is important to emphasize that calibration only corrects for the accuracy of estimating vehicles. Calibration does not convert vehicle estimates into visits (i.e., three people per vehicle might equal three visits).

Table 1. Hourly counts from visual counts, pneumatic tube counts, and calibration factors.

Date and Time	Visual Counts	Tube Counts	Calibration Factor
May 28 13:00–13:59	180	186	0.97
May 28 14:00–14:59	183	181	1.01
May 28 15:00–15:59	209	205	1.02
May 28 16:00–16:59	136	139	0.98
May 29 09:00–09:59	70	71	0.99
May 29 10:00–10:59	92	95	0.97
May 29 11:00–11:59	157	159	0.99
May 29 12:00–12:59	182	184	0.99
Cumulative Data	**1209**	**1220**	**0.99**

Table 2. Hourly counts from visual counts, radar counts, and calibration factors.

Date and Time	Visual Counts	Radar Counts	Calibration Factor
May 28 13:00–13:59	180	184	0.98
May 28 14:00–14:59	183	176	1.04
May 28 15:00–15:59	210	208	1.01
May 28 16:00–16:59	139	140	0.99
May 29 09:00–09:59	70	72	0.97
May 29 10:00–10:59	93	93	1.00
May 29 11:00–11:59	156	167	0.93
May 29 12:00–12:59	182	186	0.98
Cumulative Data	**1213**	**1226**	**0.99**

Table 3. Hourly counts from visual counts, magnetic counts, and calibration factors.

Date and Time	Visual Counts	Magnetic Counts	Calibration Factor
May 28 13:00–13:59	180	142	1.27
May 28 14:00–14:59	183	133	1.38
May 28 15:00–15:59	209	155	1.35
May 28 16:00–16:59	136	113	1.20
May 29 09:00–09:59	70	50	1.40
May 29 10:00–10:59	92	73	1.26
May 29 11:00–11:59	157	125	1.26
May 29 12:00–12:59	185	134	1.38
Cumulative Data	**1212**	**925**	**1.31**

4.2 Qualitative Assessment

A qualitative assessment of the automated vehicle counting equipment showed a wide variety of functions, considerations, and utilities. The authors assessed 13 questions to help guide field staff in the selection of equipment that best meets their needs. Overall, pneumatic tube and radar technologies were more similar to each other than the magnetic technology.

Table 4. This table summarizes a qualitative assessment of automated vehicle counting equipment, by equipment type.

	Pneumatic Tube Counter	Radar Counter	Magnetic Counter
Is calibration necessary for accuracy?	Generally, NO May be required on dirt roads.	NO	YES
Can the device record direction of travel?	YES	YES	NO
Can the device record speed?	YES	YES	NO
Can the device record vehicle type?	YES FHWA* size classes.	YES Small/ Medium/Large classes.	NO
Can the device provide hourly level data?	YES	YES	YES
Can the data be remotely downloaded?	YES Requires cell signal and additional equipment.	YES Requires cell signal and additional equipment.	NO
How is the data generally downloaded?	Computer connection required. Some units may allow Bluetooth retrieval.	Retrieval via Bluetooth on tablet or computer.	Retrieval without computer using a shuttle dock, or with computer.
What is the installation process?	Tubes are installed across the road. Requires large nails to secure tubes and adhesive rubber on the roadway. No computer is required.	Device is fixed to a post on the side of the road base. Settings adjusted primarily via direction of radar counter. Prior setup via a computer required.	Generally placed on the side of the road out of sight. Settings should be adjusted based on location. A computer is required.
What is the battery life?	Extensive. Unit can run for very long periods without need to replace batteries.	Battery recharging is required approximately every 2 weeks. A booster pack doubles the length between charges, and a solar panel can eliminate the need to recharge.	Battery life depends on the settings. Generally, batteries can last a season without replacement.
How much data can the device store?	Extensive. Can likely run more than a year without filling memory.	Can store about 315,000 vehicle counts at a time. Regular data retrieval is recommended on roads with a high volume of traffic.	Depends on device settings. Can generally go months without filling memory.
What other maintenance is needed?	Tubes need regular replacement and inspection every few weeks, as they loosen over time or can become damaged. Road maintenance equipment, like snowplows or graders, will damage tubes if not removed.	Occasional inspections to ensure the device is operating correctly.	Batteries should be checked frequently, with higher use areas having faster battery depletion. Moisture damage should be mitigated, especially with devices on the ground.
How much do the devices cost?	Starting at $750 per unit. Tube packages are about $150. Does not include shipping or software costs.	Starting at $3,000 per unit. A fully outfitted, solar-powered unit likely around $5,000.	Starting at $550 per unit. Does not include shipping or software costs.
Are there other considerations?	Dirt road installation likely requires calibration and will increase tube damage. Devices require traffic moving > 25 mph and tires must strike tubes perpendicular (not angled or turning).	None known at the time.	These devices use a common data platform that services other types of devices, like infrared trail counters. Devices can be set in additional modes (i.e., off-highway vehicle mode).

* Federal Highways Administration

5. Discussion

This study compared different automated vehicle counter technologies, including their accuracy and utility. Overall, the results showed differences in accuracy among the technologies. Both pneumatic tube counters and radar counters demonstrated near perfect accuracy when installed correctly. For the magnetic counter, systematic undercounts were recorded. Adjusting the settings of the magnetic counter, such as increasing the delay or threshold setting, may improve the magnetic counter's performance. However, dense and/or simultaneous two-way traffic may often make magnetic counters more likely to undercount, regardless of settings. Additionally, the calibration process should be completed every time the device is moved, or at least once a year. For pneumatic tube and radar counters, the counts are so precise that staff time spent calibrating is rarely warranted.

The social science-based skills and the technical knowledge needed to set up and calibrate automated counting equipment represents one barrier for public land managers in gaining high-quality, reliable, and accurate information. However, staffing is consistently reported as the largest barrier (Lynch et al. 2002, Rappaport et al. 2024). The time spent calibrating equipment represents one cost in terms of staffing, but many other aspects should be considered when choosing equipment.

The qualitative assessment of automated vehicle counting equipment provides managers with a range of considerations. Magnetic counters are relatively inexpensive but require technical skills and time to create accurate estimates. They are also more limited in type of information in that they only provide counts. Users must physically visit the device and manually connect to it to extract data, which may increase staff time. However, the equipment is part of a widely used set of monitoring devices, including infrared trail counters largely used by public land managers.

Pneumatic tube counters require a more intensive set up, but when properly installed require no calibration to estimate vehicle counts. They are the highest maintenance of all the equipment assessed, in that tubes need to be checked and replaced frequently. However, they provide a variety of information about vehicles, and remote retrieval of data is possible with additional equipment. This would reduce staff time needed to access the data, though the need for maintenance may render this unnecessary.

Radar counters are easy to set up and have no external parts, which reduces maintenance. They provide a variety of information about vehicles and can operate in an array of field settings, including dirt roads, without the need for calibration. Tube and radar counters are able to differentiate the direction of traffic between incoming and outgoing vehicles, which allows for a better isolation of vehicle entrance counts and increases the potential for more in-depth pattern analysis. They also provide remote retrieval of data as an option. Lastly, with added equipment to extend the battery life, the radar counters may greatly reduce the need of field staff to service the device.

It is worth noting that all 3 device types require specialized proprietary software to initially open any files received from the device. While the data can then be exported into sharable file types (like CSV or Excel files), familiarization with these programs is an additional personnel task.

6. Conclusion

Field-deployed automated counters are likely to continue to be universally utilized by public land managers to monitor use. For automated vehicle counters, a wide range of technologies exist. This technical note demonstrated the accuracy of these counters and assessed the utility of them in a public lands context. Managers can use this information to balance cost of equipment, staff time, and information needs in choosing the best equipment to meet their objectives.

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