Innovations Deserving Exploratory Analysis Programs

IDEA

NCHRP IDEA Program

A Portable Single Lane Traffic Counting Device

Final Report for
NCHRP IDEA Project 216

Prepared by:
Terry L Lee
Leetron Vision, LLC

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IDEA Programs
Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001

A PORTABLE SINGLE LANE TRAFFIC COUNTING DEVICE

IDEA Program Final Report

NCRP-IDEA Project 216

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Engineering, and Medicine

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1 EXECUTIVE SUMMARY

The majority of traffic count portable data collections is done by road tube. While the hardware unit costs for road tubes are low, installation requires workers to kneel in the middle of the road sujecting them to potential harm. In addition, road tubes do not provide the quality of data that transportation agencies need due to technical limitations.

Transportation agencies have yet to devise a system that can replace pneumatic road tubes without sacrificing quality and cost. This innovation presented in this paper creates a product that is not only safe for workers to install, but simple to work with while also being cost effective. More importantly, the innovation provides a solution to present technical limitations resulting in a higher level of data quality for the industry.

Prior to this project, Leetron Vision's research team had developed a portable real-time video-based multi-lane traffic counting unit, called AI (artificial intelligence) Count 100. The success of AI Count 100 provided the confidence and experience needed to take technology to the next level. While searching for alternatives to pneumatic road tubes, the team discovered that by concentrating on measuring a single lane, comparable data collection quality at competitive costs could be achieved. While this single lane system will not work on roads with more than two lanes in one direction, an internal study indicates that it will be suitable to replace most tube counts currently in use. This project develops a single lane system that offers a cost-effective alternative to pneumatic tube counts.

From a technical point of view, there is a fundamental difference between the traditional and AI based counting systems. Road tubes, Piezo and LiDAR are sensor-based devices. A variety of sensor points ranging from only a few to hundreds are used. Typically, a higher number of sensor points will result in higher accuracy. There are situations where the amount of sensors will not provide count and classification data. An AI-based system provides millions of sensor points (considering each pixel in video as a sensor point). It provides a vast amount of detailed features that AI needs to meet the most challenging of situations in counting and classifying different vehicles. The team termed an AI-based system "visual based", where the traditional method is termed, "sensor based". The challenge is whether detail features using a visual base can be used to solve the list of technical limitations on the "sensor based" systems. During the single lane product development, the team was able to identify solutions to each of the technical limitations. With the ability to solve these technical limitations on a traditional system, the single lane system could potentially achieve the level of data quality and stability better than any existing systems in the market today. The goal is to provide the highest data collection quality with favorable returns on investment rate. The idea is to concentrate on providing the data quality that transportation agencies desire first, and lower the unit costs in the future versions.

The project product has the capability to perform FHWA 13 classification, the standard classification scheme in the US. In addition, the same method is applied to the existing system AI count 100. The successful implementation of FHWA 13 classification solves the remaining hurdle for AI technologies being widely used for traffic count and classification.

The innovation of this project creates a visually based counting and classification device that is able to achieve expected results. Based on the internal evaluation results of the prototype, typical count accuracy is over 98%, and over 98% for the FHWA 13 bin classification scheme. It will take some time for the single lane device to have an impact in the industry. However, the FHWA 13 vehicle category classification implemented in the AI Count 100 system has been widely accepted by the industry. For example, over 15 states are currently using or in the process of ordering the device. There are over 100 AI Count 100 units currently in use by transportation agencies to collect traffic monitoring data.

FIGURE 1 Road Tube Installation

2 IDEA PRODUCT

The IDEA product is a portable video-based counting and classification device that utilizes AI (artificial intelligence). The key purpose of this device is to provide a superior alternative for traffic data collection to the current and more common practice that uses pneumatic road tubes (Figure 1: Road tube installation). Any new traffic data collection system must be safe to set out, simple to operate, reliable, provide good quality of data, and the costs must be competitive with that of pneumatic road tube systems. The final product, the single lane system, is shown in Figure 2: Production Unit. The three key components of the unit include the camera, computer and battery. The computer is placed inside a stainless-steel metal box as shown in Figure 3, and the batteries are stored inside the pole.

FIGURE 2 Production Unit

The AI Count 300 (single lane device) can be installed by following the four steps detailed below:

1. Mount the device to a stationary fixture like a pole or sign on the roadside.
2. Turn the unit power on.
3. Aim the camera at the first lane.
4. Press the push button located at the side of the box twice to begin the counting process.

FIGURE 3 System Interface on the Side of the Box

The unit will generate reports for volume counting and classification. Videos and pictures of individual vehicles are displayed in real time. Data are saved on an USB memory stick. The unit interface on the side of the box as shown in Figure 3 consists of an external power source connector, USB-C type connector, push bottom and LED indicator light.

Figure 4 External Battery for 7 Days Operation

- The external power source connector is used to connect an external battery. The unit is designed to run for 3 days. In the event 7 days data collection is needed, an external battery as shown in Figure 4 can be used.
- A USB-C type connector is used to access the computer through laptop. Wireless WIFI connection is another way to connect into the computer if needed.

- Push button is used to issue command to the unit.
- LED indicator light is used to indicate the data collection status.

3 CONCEPT AND INNOVATION

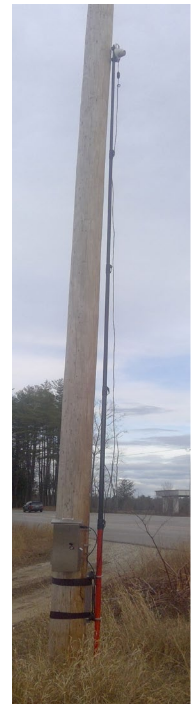

FIGURE 5
AI Count 100

Leetron developed a portable video-based device for traffic counting utilizing AI technology in 2018. This model is the AI Count 100 as shown in Figure 5. The camera is used to capture video which is then passed on to a computer to determine what vehicles are in the video. This is the same technology that is used for self-driving vehicles and facial recognition software. This technology has the capability to detect and classify vehicles. The successful deployment of AI Count 100 has demonstrated that AI technology is practical for collecting accurate traffic count data. This device is ideal for high-speed areas such as Interstates where it is neither safe nor practical to set out pneumatic tubes. However, higher unit costs may impact wide utilization. The industry would prefer a FHWA 13 bin classification scheme. The goal of this innovation is to provide highly accurate data collection with costs similar to that of pneumatic road tube counts. The technical challenges are as follows:

- The device must be able to utilize the FHWA 13 bin classification scheme.
- The period of data collection required by many organizations is 3 days. That is 1 day longer than the AI Count 100's capability of 2 days. Since the implementation of AI for counting traffic uses a large amount of processing power, it is a challenge to increase the data collection by 50% without increasing the battery capacity of the device.
- The setup procedure needs to be fully automated to allow fast installation and minimize the potential for operator error.
- The system needs to be reliable and able to function fully in all weather and traffic conditions.

FHWA 13 bin classification is a central part of this innovation. To our knowledge, this is the first video-based system that can classify the FHWA 13 bin classification scheme automatically. Using AI to classify vehicles into 13 classes rather than the traditional 6 is more complex than one would expect. Examples of the challenges the system faces includes identifying when wheels are up or down on a tag axle and detecting whether a pickup truck has a dual-wheeled rear axle or single wheeled rear axle. The solution to solve these specific problems is to combine the power of AI with image processing to resolve each issue individually.

One drawback of an AI system is that it requires large amounts of processing power to function properly. Apart from a computer's CPU, an additional processor such as GPU is normally used to meet supplementary processing requirements. In order to simplify the device and lower the unit cost, it was decided not to use an additional processor. To add to the challenge, the unit will need to be able to last one additional day, increasing the collection period from 2 days to 3. To solve this problem, a hybrid image processing and AI object detection method was developed. This method uses image processing primarily for finding the presence of vehicles and uses AI object detection when necessary. This results in 50 to 70% savings in processing power. With this method, a battery with the same capacity will last over 4 days instead of 2.

The research team made the decision early in the project to monitor a single lane only. The main reason for this decision is vehicle occlusion. Occlusion occurs when the camera is mounted on the side of the road to measure multiple lanes. There will be cases where a vehicle in lane 1 totally blocks the view of a vehicle in lane 2, resulting in the vehicle's presence not being recorded and a missed count. Using data from a single lane eliminates this occlusion issue. Another benefit is that the unit does not need to be mounted high to avoid occlusion, resulting in a much simpler system that can be built in one piece. This has a large impact on setup time and unit costs.

Over the course of the project development, the potential quality of data collection improvements appears to be much more significant than initially anticipated. A study of collection results derived from the traditional systems shows many technical limitations. These technical limitations were overcome using the new developments discovered while using this device. Details of each limitation for each sensor are listed in the Table 1.

Technology Categories	Road Tube	LiDAR	AI Video Based by Leetron
Safety	Unsafe, intrusive	Safe, non-intrusive	Safe, non-intrusive
Type of Vehicle Classifications	Wheel Based	Length-Based	Visual Based
Counting Limitation	Need through traffic Trailers post challenges	Need through traffic Trailers post challenges	No problem on congestion and stop &go No issues with trailers
Classification Limitation	Difficult to differentiate between passenger car, pickup truck, bus, and motorcycle	Not able to do FHWA 13 class classification.	FHWA 13 class classification. Have solutions to limitations from road tube
Environmental Issues/Concerns	Not practical for higher or variable speed	Occlusion cause missed count.	It's single lane, no occlusion issue
Setup Time	15 to 20 min.	15 min.	5 min. Estimate at 25% more productive.
Material Costs	$20-$25 per measurement.	Electric Charge	Electric Charge
Labor intensity	Stress on knees	Typical	Typical
Verifiable data	No	No	Yes
Unit Costs	Low	Average	Average

TABLE 1 Counting Device Comparison

4 INVESTIGATION

While the objective of providing a superior alternative to pneumatic road tubes remains a primary goal, the final system is drastically different from the original design. Key areas include using a windows 10 operating system instead of Linux, the use of image processing to detect vehicle presence instead of a LiDAR sensor, the use of a more powerful single board computer rather than the original low-cost single board computer and employing the use of a much higher capacity battery. The steps taken in the development of this project are as follows:

4.1 FIRST PROTOTYPE

First prototype: A prototype was built based on the initial design as shown in Figure 6. This prototype has the ability to collect data by both LiDAR and camera. After evaluating the learning curve and potential issues involving the Linux software development, the term realized that the learning curve required to develop software for the device was much steeper than anticipated. To keep the project on track, the term decided to build a prototype with a single board computer using the Microsoft Windows 10 operating system.

FIGURE 6 First Prototype

4.2 SECOND PROTOTYPE UNIT

The second prototype unit was built based on the Microsoft Windows 10 operating system, as shown in Figure 7. The goal of this prototype is proof of concept. The unit is built based on a structural frame to allow for flexibility in hardware changes and adjustments. A rugged, weatherproof physical box is designed after all the components are finalized. A new wide angle camera possessing a higher image quality and improved performance in low light conditions has replaced the Raspberry Pi specific camera. The new camera has a wider viewing angle that provides a better ability to handle longer-length vehicles contained in the FHWA 13 classification system.

FIGURE 7 Second Prototype

The second prototype unit has been used regularly in the field to collect data. This data is used for software development. Details of the sensors' data are listed under the software development section below

For the second prototype unit, development using Microsoft Windows-based software was straight forward. Many of the required functionalities were available and ported from an existing system at Leetron. The main software-development task requirements are listed below:

1. Acquire LiDAR data from the sensor
2. Acquire video images from the camera
3. Create a synchronization mechanism to match LiDAR point cloud and camera image data
4. Vehicle start and end detection
5. A database to save vehicle information on both LiDAR and the camera
6. Offline (post-data-collection) counting and classification processes
7. 13 class FHWA classification scheme
8. Graphic user interface
9. Reporting
10. Video Processing
11. Build processes for on-line processing
12. Build a LiDAR base neural network
13. Build a 6 class neural network, which is used for all vehicle lengths
14. Build a 13 class neural network, which is used only for long vehicles

4.3 FHWA 13 CLASS CLASSIFICATION

As mentioned in the earlier section, there are some technical limitations to sensor-based devices. The list of limitations is listed below:

- Issues in accurately reporting counts when traffic speed varies due to congestion and "stop and go" conditions.
- Ineffective on higher speed roadways.
- Issues regarding counting vehicles with trailers of various lengths and wheel counts.
- Unable to remove occlusions with LiDAR system.
- Unable to detect trucks with tag axles that have their wheels up or down with the LiDAR system.
- Unable to identify rear axles with dual wheel for pickup trucks.
- Difficulty in separating buses from trucks consistently.
- Difficulty identifying car with long wheelbases, such as SUVs.

Cases of technical limitations for traditional system:

Case 1 Wheelbase Length: As shown in Figure 8, Class 2 Minivan with a similar wheelbase and length as a class 3 postal truck is difficult for wheel based and length-based data collection methods to differentiate. This is not an issue for AI with visual based classification.

Case 2 Bus: Bus (class 4) with a wheel length differing from a typical bus as shown in Figure 9 will often be misclassified as a light truck (class 5) with a sensor-based device. It is not an issue with a visually based system.

FIGURE 9 Wheel Based Classification Will Misclassify

Case 3 Tag Axle Wheels Up/Down

Construction trucks normally have their tag axle wheels up when there is nothing loaded as shown in Figure 10. In this case the vehicle is classified as class 6. When the vehicle is hauling a full load and the wheels are down, the same truck will be classified as class 7. While it is not a problem for a pneumatic tube counter, it is a limitation for LiDAR. While the visually based system can ascertain whether the truck's tag axle wheels are up or down, it faces some challenges in attributing the correct classification using the AI system. To solve this issue, special functions are added with image processing to detect if the wheels are up or down.

FIGURE 10 Wheel Up and Down Will Classify Differently

Case 4 Dual Wheel: According to FHWA 13 classification, a pickup truck with single wheel is class 3, while dual-wheel is class 5. Sensor based devices will not have enough capability to detect a rear axle with dual-wheels installed. Alternately, there are many visual clues that can be used to detect a rear axle equipped with dual-wheels as shown in Figure 11. By adding additional image processing methods, the prototype is able to detect dual-wheeled pickup trucks.

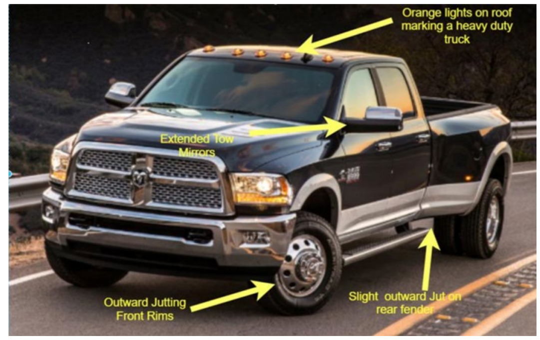

FIGURE 11 Dual-Wheel Will Classify Differently

The development of the classification method was done mostly on the AI Count 100 system. Since the algorithm classification methods are used for both AI Count 300 (single lane) and AI Count 100 (4 lanes) the classification accuracies are expected to be a match between the two systems.

The key technology used for classification is AI. While AI is a powerful tool to identify what is in the picture, it requires a vast amount of manual work prepare data for the training processes. For each cycle of training, the team reviewed 300,000 images from 5 data collections. Out of the 300,000 images, typically 200 images are found to be detected incorrectly by the AI system. These 200 images are entered into the training database for retraining. The re-training process normally takes a week with GPU computers. Over the course of this development, there have been over 20 rounds of re-training. The classification accuracies are improving over time. The accuracy started at 90%. It did not take long to improve to 95%. But the process to get to over 98% is taking some time.

Since there are many transportation agencies that are interested in AI Count 100 with FHWA 13 classification, over 10 DOT agencies and contractors have performed evaluations on the AI Count 100 system. So far all results are positive. The counting accuracies are relatively consistent at 99% and the classification accuracies are in the range of 97% to 99%. Some of the evaluation results are listed as follow:

Early in the 13 class development in 2020, NYSDOT performed an evaluation between Leetron AI Count, tube count and manual count. It indicated a large amount of difference in class 4 and 6 between tube count and NYSDOT manual counts. The results revealed that while the counts are matching well, there is room for improvement in classification for both systems. The low percentage on class 4 and class 6 for road tube are the direct result of technical limitations on road tube.

NYSDOT performed an hour classification evaluation in late 2020 on 3 lanes of state highway HWY 87.

Class	Leetron Count	Accuracy	Tube Count	Accuracy	NYSDOT Count
1	4	75.0%	3	100.0%	3
2	220	95.0%	234	89.3%	209
3	91	98.9%	90	97.8%	92
4	2	100.0%	6	33.3%	2
5	27	100.0%	20	74.1%	27
6	9	100.0%	1	11.1%	9
7	0	0.0%	2	50.0%	1
8	7	70.0%	10	100.0%	10
9	4	57.1%	5	71.4%	7
10	0	NA	0	NA	0
11	0	0.0%	1	100.0%	1
12	0	NA	0	NA	0
13	0	NA	0	NA	0
Total Volume	364	99.2%	372	97.0%	361

TABLE 2 NYSDOT evaluations on AI Count 100 and Tube Count

The evaluation was between Leetron AI Count 100 and NYSDOT manual count. The data shows a high correlation between the two methods on both counts and classification.

Count Group	Leetron Count	Manual/Found missed	Manual Found extra	Manual Found Missed Classified	Count Accuracy	Classify Accuracy
1	1	0		0	100.0%	100.0%
2	1319	4	4	1	99.4%	99.9%
3	378	5	0	2	98.7%	99.5%
4	7	0	0	0	100.0%	100.0%
5	116	0	0	1	100.0%	99.1%
6	16	0	0	1	100.0%	93.8%
7	5	0	0	0	100.0%	100.0%
8	24	0	0	1	100.0%	95.8%
9	90	0	0	3	100.0%	96.7%
10	25	0	0	1	100.0%	96.0%
11	0	0	0	0	N/A	N/A
12	0	0	0	0	N/A	N/A
13	0	0	0	0	N/A	N/A
Total	1981	9	4	10	99.3%	99.5%

Table 3 NYSDOT Evaluations on AI Count 100 Classification

Since the last NYSDOT test does not have data in higher classes, Leetron performed an internal classification evaluation based on the saved class images on one day. The AI Count 100 classification counts and manual counts are matched well at higher classes as shown in Table 4. Note, since class 13 vehicles are not allowed on HWY 87, there was no data for class 13 on this road.

Classes	Total Count	Correct Classified	Misclassified	Accuracy %
1	18	17	1	94.44%
2	23587	23555	32	99.86%
3	5753	5740	13	99.77%
4	94	93	1	98.94%
5	896	885	11	98.77%
6	227	222	5	97.80%
7	38	38	0	100.00%
8	226	218	8	96.46%
9	1898	1877	21	98.89%
10	312	305	7	97.76%
11	38	37	1	97.37%
12	19	19	0	100.00%
13	0	0	0	N/A
	33106	33006	100	99.70%

TABLE 4 Leetron Internal Evaluations on Classification

In late 2021, Caltrans, using four AI Count 100 units, performed extensive evaluations under various conditions. One of the evaluation results is showed in Table 5. The evaluation is for 7 days of data collection on Leetron 100, pneumatic tube counter and piezo sensors. For ground true comparison, one hour with higher traffic is selected by Caltrans to perform a manual evaluation. Both Caltrans and Leetron performed manual evaluations and the data is in agreement. Only Leetron manual evaluation results are shown in the table. The data indicates that AI Count 100 is closely matched with the ground true (manual count) while

	Leetron Manual Count	Leetron AI Counter	Peek Sabre (Dual Hoses)	Peak Sabre (Loop-Piezo-Loop)
Total Count	250	248	247	245
Class 1	1	1	1	0
Class 2	138	137	131	157
Class 3	78	78	71	57
Class 4	0	0	3	4
Class 5	6	6	20	8
Class 6	2	3	2	2
Class 7	0	0	0	0
Class 8	8	7	2	0
Class 9	16	15	16	15
Class 10	0	0	0	0
Class 11	1	1	1	2
Class 12	0	0	0	0
Class 13	0	0	0	0
Class 14	0	0	0	0

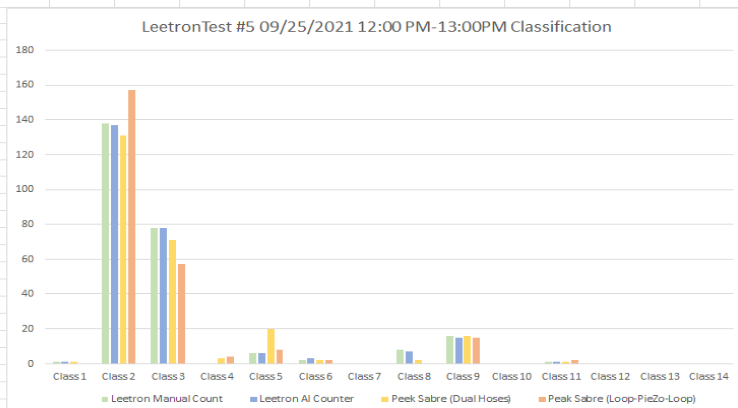

TABLE 5 Evaluation by Caltrans with 3 Counters

pneumatic tube counter and piezo sensors is not closely matched. In fact, the variations are larger than expected. Since the technician is an expert on data collection and the hardware used was carefully selected and tested, operator errors and hardware errors should not be an issue.

Conditions

For any traffic counting device, especial for video based systems, the most important evaluation factors are how the device performs under various traffic and weather conditions. Evaluations were conducted on both portable and year round counting stations for the past two years with 100s of data collected for state DOTs. The evaluations concluded that the system has the capability to operate under various conditions. Views of the frequently observed conditions are listed below.

Traffic Congestion:

AI Count 100 was selected to count vehicles on the 2021 New Hampshire NASCAR. The device was used due to its ability to count vehicles under heavy congestion conditions

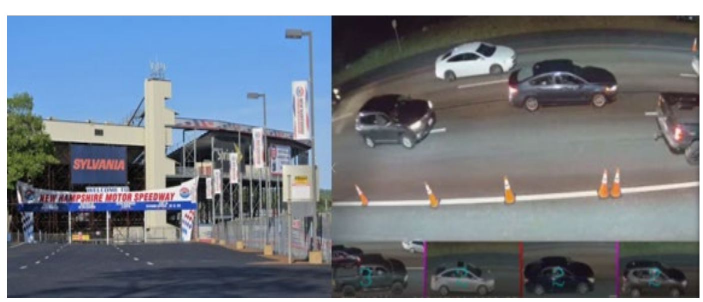

FIGURE 12 Traffic Congestion Image

as shown in Figure 12.

Nighttime:

Nighttime conditions and nighttime conditions under heavy rain are shown in Figure 13.

FIGURE 13 Night Condition Images

Weather conditions

Weather conditions for sunrise/sunset, shadows, snow and heavy fogs.

FIGURE 14 Sunset Condition Image

FIGURE 15 Shadows Condition Image

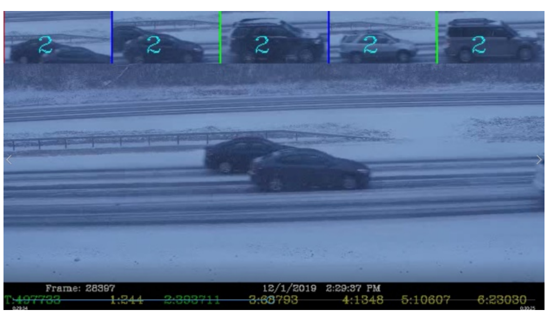

FIGURE 16 Snow Condition Image

FIGURE 16 Heavy Fog Condition Image

The evaluations above are based on AI Count 100, indicating a high correlation to true ground for count and FHWA 13 classification. Since the same methods are used for single lane devices, the classification results should match between the two systems. The assumption is confirmed by evaluation data collection results throughout the development cycles. The Table 6 Single Lane Evaluation is one of the evaluations with one hour of manual data. While this particular evaluation does not show the full picture since there is no higher class data, it is an indication that the count and classification match well.

4.4 THIRD PROTOTYPE

The main purpose of the third prototype is to improve image processing and design the housing for the system.

	Leetron Manual Count	Leetron AI Counter
Total Cour	390	389
Class 1	7	7
Class 2	301	300
Class 3	79	80
Class 4	0	0
Class 5	3	2
Class 6	0	0
Class 7	0	0
Class 8	0	0
Class 9	0	0
Class 10	0	0
Class 11	0	0
Class 12	0	0
Class 13	0	0
Class 14	0	0

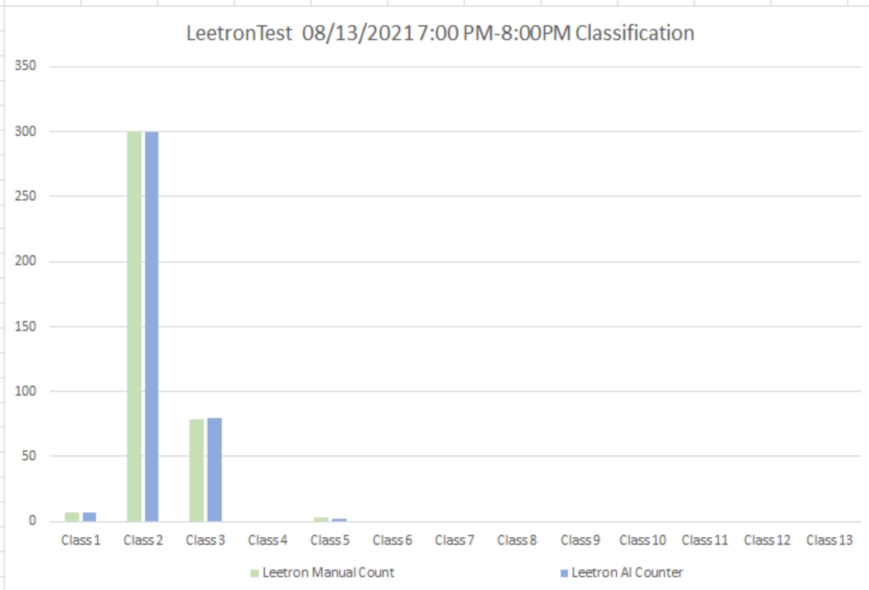

TABLE 6 Single Lane Evaluation

Detect Presence of Vehicles by Employing the Fast Image Processing Method:

Detecting the presence of vehicles by AI object detection is simple to implement. However, it is quite taxing regarding CPU usage. The initial design for this device implemented LiDAR to detect the presence of a vehicle. It was later discovered that LiDAR has a post light conflict with the camera IR light and is limited by device location placement. If the device is installed near the ground, there may be a potential problem regarding dust and water splashing from the wet roadway. The fast image processing method was proposed. The task of identifying the presence of vehicles using image processing methods is more complicated than one would expect. Specific functions are needed to handle various traffic and environmental conditions. Presently, this method is working as anticipated. However, there are potential cases that may need special attention when units are deployed.

Housing: The device is contained in one piece of equipment. The camera is mounted directly onto the counter housing, which is then mounted to a pole where the batteries stored. With this configuration, the unit is much easier to set-up and deploy. The unit is built to handle extreme weather conditions and is intended to survive rough handling on a regular basis.

4.5 PRODUCTION VERSION

FIGURE 17 Sample Device Image View

User Interface: The conventional wisdom regarding data collection dictates that the less resources the user interface requires, the faster the installation time and less prone to errors the system will be. A typical video-based computer system requires a fair amount of setup to help the device adapt to differing collection environments. Since the Leetron device is collecting single lanes only, there is an opportunity to automate the device's setup procedures. To accomplish this goal of minimizing setup requirements, the new functionalities were developed. To identify lane locations in images, the camera angle must adjust rotation automatically and auto-zoom automatically. The result is a simple installation procedure of aiming the camera on the road and turning on the power. While the user does not need to connect into the unit for data collection, the system can be accessed with portable devices such as a laptop and smart phone through WIFI. Figure 18 is a sample view of a collection image window.

Housing: The production version that is intended to be delivered to end user. The plastic housing has been replaced with a custom-made housing of stainless steel. High volume air flow is added to the body of the housing in order to handle high temperatures. The interfaces include an LED light push button, a charger port and USB port all added to the side of the housing.

The benefits of this product over traditional counting methods are as follows:

Safety: All states take safety seriously and desire an alternative solution to pneumatic road tubes in order to remove their workers from the risks involved with intrusive data collection. This device will no longer require workers to be put in harm's way in order to perform their duties.

Labor-intensive work can introduce repetitive motion injury: The constant kneeling, repetitive motion, and the force with which an individual is required to use a hammer to drive nails into the pavement to secure the pneumatic tubes to the ground can causes stress on joints and muscles. This may lead to joint pain and muscle related injuries later in life. Due to this increased risk, states are having difficulty finding and retaining workers willing to perform these tasks. With this new traffic monitoring device there is no labor-intensive work involved regarding machine setup.

Productivity gain: Installation time will be shortened dramatically. Rather than the typical setup time of 15 to 20 minutes involved with pneumatic road tubes, it will only take a few minutes to mount and turn this device on. Based on the feedback of current workers who have utilized both systems, productivity has increased 25% to 35%.

Material Costs: For each data collection, there is also an estimated additional material cost of $25.00 for nails, tape, and tubes that can be eliminated with the use of this product.

Count and classification accuracy: Though the cost of this device is not as low as anticipated, the added accuracy of volume and classification data it provides outweighs the additional cost.

To get a better understanding for the cost of ownership, the following table calculates the breakeven points calculating cost versus increased productivity. The calculation is based on using two single lane systems to collect two lanes of data versus a road tube. The table shows the unit cost difference is $4,000. When taking material costs and productivity gain into consideration, the years taken to break even is 2.8. When taking collections rejection rates into consideration, the years taken to break even is 0.66. Please note that the numbers used in the calculations are assumptions provided by industry experts. Agency experiences could be different. This analysis indicates that while the cost of the hardware is a lot higher, it does not take long to recover the investment. In addition, the device is safe and easy to operate and provides stable and high quality data collection. Please note that the data collection rejection rate for road tube is due to typical collection issues such as tubes not secure to the pavement; tube functionality depreciating over time and installation errors. A single lane device does not have the “contact” issues on the street that road tubes have and the collection reject rates are lower.

Cost of Ownership Analysis

	Single Lane	**Road Tube**	**Variations**
Unit Costs			
	$2,500	$1,000	
Two units for two lanes road	$5,000		
Unit Costs Difference			**$4,000**
Annual Operation Cost			
Material			
Material Costs per collection	$25	0	
Collations per year	43		
Material Cost per year			$1,075

Productivity			
Collections per week	35	46	
Productivity increase		23.9%	
Average collections per year	42		
Average Salary	$50,000		$341.61
Productivity Gain per units			
Annual Yearly difference			$1,417
Years to break even			**2.8**
Valid Collections			
Average rejection rate	12%	2%	10%
Rejects difference per year			151
Labor cost per collection	$33		
Reject difference in costs			$5,000
Years to break even			**0.66**
Other difficult to evaluate factors			
Keep operators off the road			
No labor intensive work			
No damage to pavement with nail			
No problem on traffic congestion			
Able to identify bus accurately			
Able to detect motorcycle accurately			
Accurate FHWA 13 classes classification			

TABLE 7 Cost of Ownership Analysis

5 PLANS FOR IMPLEMENTATION

The plan for implementation can be outlined in three steps: The first step is customer evaluation; the second step is a small scale data collection study and the third step is full scale product promotion and sales. For the first step, the initial batch of 10 production version devices will be made ready within a 4 to 6 week timeframe. Four of those units will fill the pre-order from NYSDOT and Tri-State Traffic Data (a private contractor). The other units will be provided to interested transportation agencies for evaluation. This step will involve external evaluations under various traffic and weather conditions, and will take another 3 to 6 months. Completion of this step will confirm the device's capability and determine whether the device is ready to be used for data collection.

During the second step, the device will be used for data collection in the field. Since NYSDOT has shown the desire to promote the use of new technology throughout the state once the device's capability is proven, a small order is expected from NYSDOT. In addition, Leetron will work with Tri-State Traffic Data to gradually use single lane devices in place of pneumatic tube counters to fulfill their current NYSDOT data collection contract. This step should take from three to six months. At the end of this period, feedback from the data collection will be the decisive factor to determine if the unit is ready to go on to the next step.

The third and last step will include promoting and marketing the device to all transportation agencies.

Leetron will use the existing sales channels and will work with distributors in the field to promote the product. For the first phase of marketing, it is important to take the step of having the device in customer's hands to use. Once a small group of customers are using the devices, more will follow by reference since traffic counting is a small community. The market for a single lane device is expected to be much higher than AI Count 100. In additional to State DOTs, cities and municipalities are important customers as well. To properly service the market, Leetron will assemble a sales team to introduce the product throughout the United States. Based on discussions with industry experts, the consensus is that there is strong demand for this product, possibly generating thousands for this product.

6 CONCLUSIONS

For years, transportation agencies have required high quality alternatives to pneumatic road tube counting devices. Successful completion of the three-step implementation plan for this device satisfies this need. In additional to the safety, ease of operation, and cost justification, it will provide solutions to the technical limitations of traditionally used sensors. It is expected that this innovation will provide a new level of data reliability that has yet to be seen. Potentially the device can set a new standard in the collection of traffic data.

7 APPENDIX: RESEARCH RESULTS

WHAT WAS THE NEED?

When one considers all the amazing technology that surrounds us, one must question why transportation agencies are still using pneumatic road tubes are to monitor traffic. Why are workers still being put in harm's way, kneeling in the middle of the road hammering nails into the pavement to install road tubes? The short answer is that the industry has not yet devised a system that can replace road tubes without sacrificing quality, increasing costs, or both. It is the objective of this innovation to be that replacement.

WHAT WAS OUR GOAL?

The goal is to provide a safe, cost effective method of collecting count and classification data. Additionally, an important aspect of the goal is to provide solutions to the technical limitations of the traditional systems.

WHAT DID WE DO?

During past three years the development work has not been as straightforward as initially anticipated. We ended up making some major changes in a few key areas as listed below:

1. Develop the first prototype with a Linux operating system, a Raspberry Pi single board computer, camera and LiDAR. While we can get the basic functionality working, it is taking considerably more time regarding software development than anticipated The learning curve for developing Linux based software development is high. To keep up with the development schedule we set for ourselves, we decided to use a Microsoft Windows based Operating System instead.
2. Develop a prototype unit based on Windows software. This prototype is a functional unit that we have used to collect data in the file.
3. The field test indicated that the LiDAR sensor used did not provide reliable data. In addition, it interfered with the IR light in the camera. A new method of identifying the presence of vehicles was needed.
4. We developed an image processing-based method to identify the presence of vehicles that uses low processing power.
5. Develop a neural network to classify vehicles based on the FHWA 13 bin classification scheme. In addition to the technical challenges, large amounts of effort are required in the training process. The training process initially started with half of a million images. Following the initial training period, training was performed on a three-month cycle to improve accuracy. For each training cycle, data collected from approximately ten studies were reviewed to identify the improperly classified images. These images were then added to the training database for re-training purposes.
6. Develop a pre-production prototype. This includes newly designed hardware and builds, software

integration and developments and many varied iterations of testing and refinement.

7. Develop a production version. This includes designing and creating the custom designed housing, testing of the user interface methods and various other refinements.

WHAT WAS THE OUTCOME?

The final outcome is a high quality, commercially viable product. This product has the potential to become the most accurate device on the market today for recording volume counts while also having the ability to collect classification counts utilizing the FHWA 13 bin classification tree. It achieves the goal of being safe and simple to operate. In terms of cost effectiveness, the unit costs are higher than what was initially anticipated. However, it is still cost effective when taking all the additional costs and factors involved with other methods of data collection into consideration. To increase the cost effectiveness, we added the capability to collect data from two lanes instead of one for low traffic volume roadways.

Another future development for this device is to make this portable count unit into a permanent traffic monitoring device. This will include adding solar power capabilities as well as cellular communication.

WHAT IS THE BENEFIT?

This device provides a safe and simple to operate method of collecting volume and classification data. More importantly, it provides a new level of data quality that is not presently available when employing traditional devices.