ClearWay™

A white paper on improving safety and efficiency on our roads

A new model for dynamic pricing.

NAVTECH RADAR

A white paper on improving safety and efficiency on our roads

A new model for dynamic lane pricing: reducing the infrastrucuture burden

Dynamic pricing on US highways is an innovative approach to managing traffic flow and improving throughput by adjusting tolls or fees based on real-time demand and congestion levels. There are a multitude of available technologies used to measure traffic and this paper focuses on the use of the Navtech Radar Clearway Count and Classification capabilities as an alternative.

The bigger picture: complexity of managing multiple roadside technologies

The implementation of Intelligent Transportation Solutions (ITS technology on our roadways improves safety, efficiency, and sustainability across the globe. With many options available for applications such as Automatic Incident Detection (AID), Count and Classification, Wrong-way Driving and Shoulder Monitoring, many road operators are faced with the very real challenge of having multiple types of 'sensors' all integrated to a single Traffic Management System (TMS).

This means a greater amount of infrastructure to manage, ongoing service and maintenance and the need to have roadside teams working in near proximity to moving traffic. Whilst to the everyday driver, this means roadworks and closed lanes which cause frustration, delays, and greater emissions.

What if the type and number of 'sensors' could be reduced? What would be the real-world benefit? Here at Navtech, we believe that 'safety is everything' and we're sharing some initial information about how our radar-based AID technology can be used for another application on our roadways — dynamic pricing.

A new dynamic lane pricing model, using Navtech Radar Clearway technology, **aims to reduce road infrastructure complexity and improve traffic efficiency through real-time toll adjustments.**

Dynamic pricing and how it improves journeys

Dynamic pricing on US highways is an innovative approach to managing traffic flow and improving throughput by adjusting tolls or fees based on real-time demand and congestion levels. **Here's a description of how dynamic pricing achieves this:**

Dynamic pricing, also known as congestion pricing or value pricing, is a sophisticated traffic management strategy that leverages technology and economic principles to optimize the use of highways and improve throughput. This approach involves the following key elements:

Measuring traffic flow

- Real-Time Data Collection: Dynamic pricing systems utilize advanced sensors, cameras, and data analysis tools to constantly monitor traffic conditions on highways. This real-time data includes information on congestion levels, traffic speed, and overall demand.

Applying this data to achieve key objectives

- Demand-Based Pricing: Instead of charging a fixed toll or fee, dynamic pricing adjusts these charges based on the current traffic conditions. When congestion is low, prices are generally lower. However, as traffic increases, the pricing algorithm gradually raises tolls to manage demand.
- Encouraging Off-Peak Travel: Dynamic pricing incentivizes drivers to consider alternative travel times or routes. By offering lower tolls during off-peak hours, it encourages drivers to shift their travel schedules, reducing congestion during peak periods.
- Smoother Traffic Flow: By effectively managing demand, dynamic pricing helps maintain a more consistent and predictable traffic flow. This results in reduced stop-and-go traffic, fewer accidents, and smoother driving experiences for commuters.
- Enhanced Safety: Reduced congestion and smoother traffic flow contribute to increased safety on highways. Fewer accidents and less aggressive driving behaviour are often observed as a result of dynamic pricing.
- Reduced Environmental Impact: Dynamic pricing can lead to reduced emissions and fuel consumption since smoother traffic flow results in fewer idling vehicles and shorter travel times.
- Customization to Local Needs: Dynamic pricing strategies can be customized to suit the specific needs and challenges of different regions, cities, and highways. This flexibility allows for tailored solutions that address local traffic issues effectively.

Overall, dynamic pricing enhances throughput on US highways by efficiently managing traffic demand, reducing congestion, improving safety, and promoting sustainable transportation practices. It is a forward-thinking approach that not only optimizes highway usage but also contributes to a more efficient and environmentally friendly transportation system.

It is a key funding mechanism to increase revenue for infrastructure. The additional revenue generated from dynamic pricing can be reinvested into improving highways, expanding public transportation options.

Typical technologies deployed for dynamic pricing

Dynamic pricing on US toll roads typically relies on a combination of technologies to monitor traffic conditions, collect tolls, and adjust pricing in real-time. The specific technologies deployed can vary by location and the level of sophistication of the tolling system, but here are some common components:

Electronic Toll Collection (ETC) Systems: ETC systems are at the heart of dynamic pricing. They use various technologies to collect tolls electronically, such as radio-frequency identification (RFID) tags or transponders (e.g., E-ZPass in the Northeastern United States,) license plate recognition (LPR) cameras, or smartphone apps. These systems enable tolls to be collected without the need for physical toll booths.

Traffic Monitoring Sensors: To assess current traffic conditions, toll roads often employ various sensors, including inductive loop sensors embedded in the road surface, radar detectors, and cameras. These sensors provide real-time data on traffic volume, congestion, and vehicle speeds.

Data Analytics and Algorithms: Advanced data analytics and algorithms are used to process the information collected from traffic monitoring sensors. These algorithms analyze current traffic conditions and make pricing decisions based on predefined criteria, such as congestion levels, time of day, and historical data.

Communication Infrastructure: To transmit data and pricing information in real-time, toll roads rely on a robust communication infrastructure. This includes cellular networks, dedicated fibre optic lines, or other communication technologies to ensure seamless communication between various components of the tolling system.

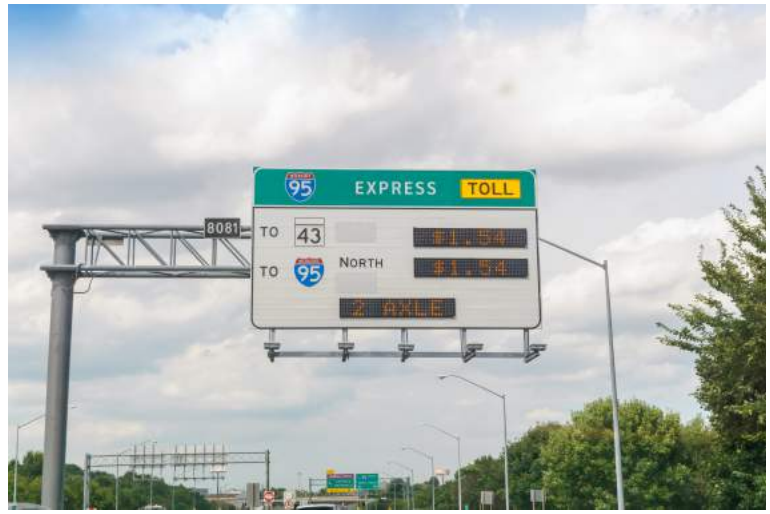
Dynamic Pricing Software: Toll operators use specialized software to calculate and adjust toll rates in real-time. These systems take into account the traffic conditions, demand patterns, and pricing objectives to set optimal toll rates. The software may also consider factors like weather conditions and special events.

Variable Message Signs (VMS): Variable message signs placed along the toll road display real-time pricing information and other messages to drivers. These signs inform drivers of current toll rates, lane availability, and alternative routes.

Customer Payment Portals: For drivers without transponders, license plate recognition (LPR) cameras are often used to capture vehicle license plate information. The toll bill is then mailed to the registered vehicle owner, who can pay online or through other payment methods.

Back-End Systems: Behind the scenes, toll operators have back-end systems that manage customer accounts, process toll transactions, and generate reports for analysis and auditing purposes.

Mobile Apps and Online Services: Many toll roads offer mobile apps and online services to provide drivers with real-time pricing information, account management, and convenient payment options.



Security Measures: Security is crucial to protect both the tolling infrastructure and customer data. Toll operators employ various security measures, including encryption, firewalls, and physical security measures, to safeguard their systems.

Integration with Traffic Management Systems (TMS): In some cases, toll road operators integrate their systems with broader traffic management systems to coordinate pricing with traffic flow optimization strategies.

Overall, the combination of these technologies enables toll road operators to implement dynamic pricing strategies that help manage traffic congestion, optimise toll revenue, and enhance the overall efficiency of the transportation network.

How might the Navtech Radar ClearWay solution improve this?

Navtech Radar's ClearWay is a technology designed for AID, particularly for highways and tunnels, with additional modules for count and classification. Until now, this technology has not been utilized within a Dynamic Pricing system.

At its core, the solution combines rich data captured by the ClearWay FMCW Imaging Radar which is analyzed by bespoke software analytics. The radar rotates four times a second and delivers 1,140,000 data points every rotation. This radar data detects the speed, size and direction of new objects in the environment, and can be analyzed in various ways to deliver different types of actionable information. With 360° coverage across the entire freeway and consistent operation in all weathers the system is both comprehensive and reliable.

These are some of the potential capabilities aligned with the solution becoming a Traffic Monitoring Sensor option for dynamic pricing:

Real-Time Traffic Data: real-time data on traffic conditions, including vehicle speed, density, and flow. This data can be valuable for assessing current traffic congestion.

Congestion Detection: Stopped and slow-moving vehicles are monitored meaning this information can be integrated.

Accurate Vehicle Counting: ClearWay is capable of accurately counting the number of vehicles passing through specific sections of the road. This data can be used to monitor demand and occupancy in different lanes or toll plazas.

Image 1: ClearWay KTS radar installation on the US roadside

Dynamic Lane Management: With the ability to detect real-time traffic flow and congestion, ClearWay can assist in dynamically managing lanes.

Emergency Response and Incident Management: In addition to dynamic pricing, the technology can be used to detect incidents promptly.

Integration with Tolling Systems: Navtech Radar ClearWay data can be integrated with existing tolling systems.

Feedback Loops: The data collected can be used to create feedback loops, enabling toll operators to continuously refine their dynamic pricing algorithms and strategies based on real-world traffic conditions and driver behaviour.

Overall, we developed a hypothesis that the integration of Navtech Radar ClearWay into a dynamic pricing system could provide valuable real-time data and insights, helping toll operators optimize toll rates, reduce congestion, and enhance the overall efficiency of the toll road or highway. In order to do this however, we must first demonstrate that the Count and Classification capability within the ClearWay solution is capable of delivering the required accuracy.

This, coupled with the ability to provide comprehensive real-time AID from the same system, could greatly reduce the amount of roadside infrastructure and ongoing maintenance requirements for operators. So, the next step was to implement this in the real-world, on a US highway to test our hypothesis.

The Trial

Test Site and Installation

The trial site was located on the east coast of the United States of America and provided the opportunity to use the 360° Imaging Radar across a multitude of scenarios, as well as in comparison to a flat panel radar solution already implemented. We were able to monitor the expressway and highway, with the added option to monitor the ramps located on either side.

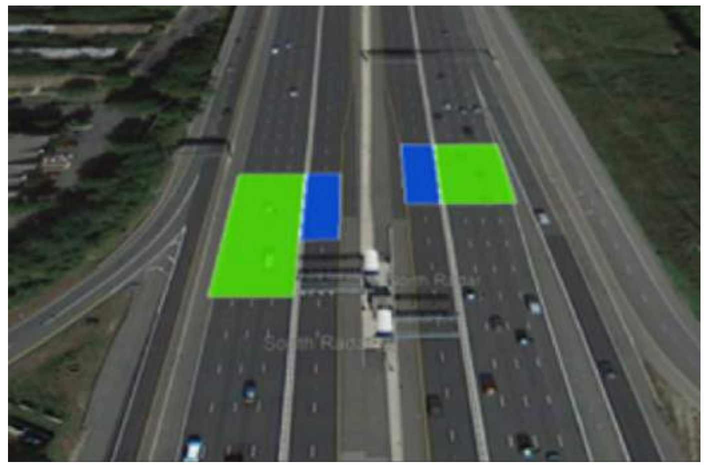


Figure 1: Count area on expressway and main carriageway

Due to limited infrastructure for this trial, two Navtech KTS350-X (35GHz) radars were located on gantry legs approximately 30 metres apart. This is an unusual system design for ClearWay as normal spacing would be approximately 500 metres, however it did allow the trial to represent a multi-radar system.

During the optimization period, each section of road had two counting areas analyzed. **Figure 1** shows both the count area on the expressway (indicated in blue) and the main carriageway (indicated in green). To ensure lane-by-lane accuracy specifically for the Count and Classification functionality, each of these locations were situated within 150 metres of the radar.

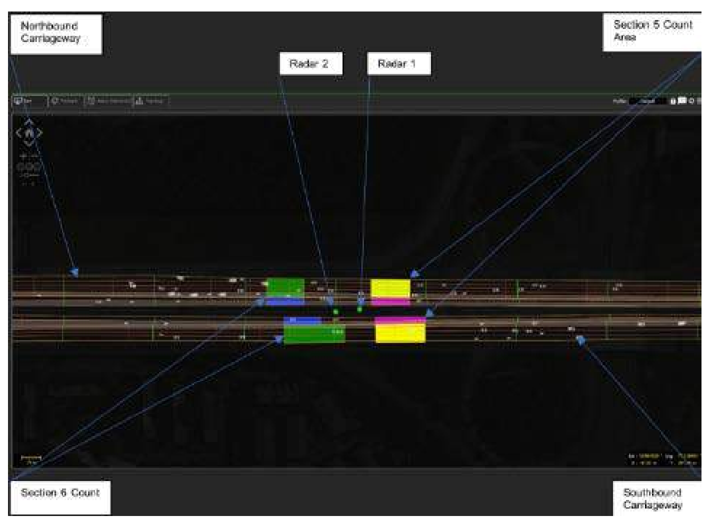


Figure 2: ClearWay user interface for trial site

Figure 2 shows the ClearWay user interface for the trial site. The green and blue areas correspond to the count areas on the main carriageway and toll road respectively, where Radar 1 is covering the main carriageways and Radar 2 the toll roads. The yellow and purple sections are alternative count sites that were also analyzed in the configuration stage of this trial but are not operational.

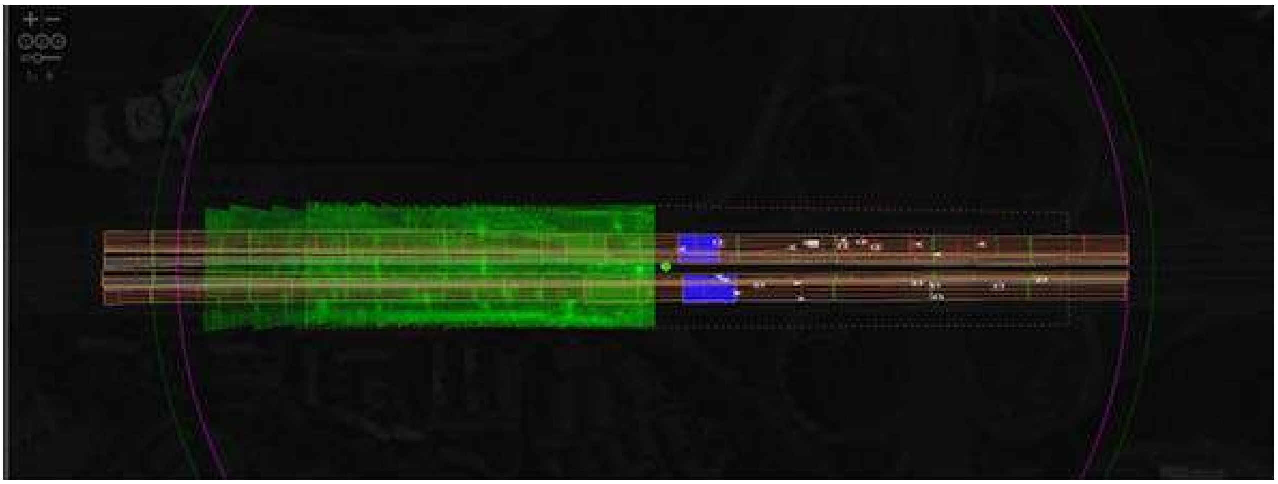


Figure 3: Navtech ClearWay user interface, showing raw radar data (left) and process data (right).

Once the system was installed, the counting areas were analyzed and optimized for best vehicle tracking. In a typical deployment one radar would cover the entire area, with optimum positioning having been identified through our project delivery process.

Data Processing

Figure 3 demonstrates the characteristics between raw radar data & processed radar data from the chosen location, and the tracks embedded over the processed data. The image is intentionally split in half to illustrate the stages of converting the raw data to vehicle tracks to then process for count and classify.

Initially, the green raw data is what the radar sees without any processing conducted. As vehicles travel through the detection area, the radar raw data produces reflections from objects that corresponds to their movements.

A stationary radar image is then used to subtract from the raw data, to then process moving objects in the area which comes in the form of processed data, which is seen in the right image as red signal. Corresponding to the movement and size of the processed data, the tracking algorithm overlays a vehicle track, which includes information on its positioning, size, speed, bearing, etc. As these tracks travel through the highlighted green and blue count sections, they are counted and classified based on the track characteristics they display within the area, which is then aggregated and output over the XML feed, or into a CSV file.

Testing Methodology

Once the radars were installed and the road layout on the software were in place, a two-stage tuning, and assessment approach was used:

1. Initial calibration of ClearWay output relative to manual count
2. Cross validation of a second recording of ClearWay data to second manual count and/or flat panel radar data.

The Manual Count used in phase 1 and comparison in phase 2 was carried out by human visual analysis of recorded CCTV data. This requires the type and lane of every vehicle passing the camera to be logged by hand. As such it is subject to potential error, estimated as up to 5%, deriving accuracy of manual count at 95%. Bars have been added in the resulting graphs to show the potential variance. The comparator technology, a flat panel radar, provides lane by lane count of vehicles every 20 seconds and is stated as 95% accurate; therefore, variance bars have again been added to the panel radar results. The data output from all three methods is then compared: both total data and the changes over time.

Results

Count Results

The results of a randomly chosen 10-minute data set comparison can be seen below showing output by lane type and the three counting methods.

Manual Count data with an estimated five percent potential error, shown next to ClearWay and Flat Panel Radar Count data and their percentage variance from the Manual Count.

	Manual Count (Ground Truthing)	ClearWay		Flat Panel Radar	
		Count	Variance from Manual Count	Count	Variance from Manual Count
NB Toll Lanes	130	132	1.54%	125	-3.85%
NB Main Lanes	675	695	2.96%	701	3.85%
SB Toll Lanes	108	105	-2.78%	107	0.93%
SB Main Lanes	791	771	-2.53%	798	-0.88%

Figure 4: Table of aggregated count data

The Manual Count and ClearWay Count demonstrate good alignment with under 3% variance on each section of road. This is comparable with the total variance seen with panel radar, of approximately 3%. This information is plotted with variance bars in **Figure 5**.

When comparing the vehicle count over time of the two deployed technologies the trend is a strong correlation, with alignment being visible in **Figure Six** below with data gathered over twenty-four hours.

These results have been assessed using a CSV output from panel radar and XML output from ClearWay. ClearWay can be configured as default to use XML or CSV standard data output for count and classification data. For both systems other outputs can also be configured.

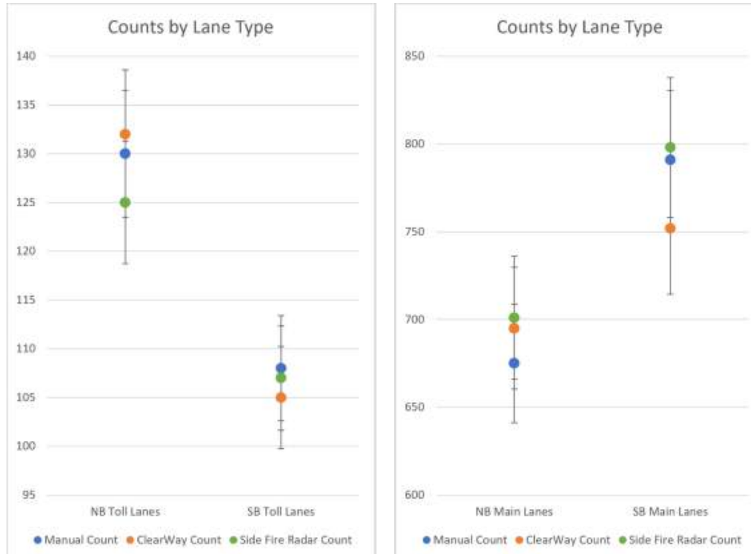


Figure 5: Graph of aggregated comparison counts.

Comparison of ClearWay and Flat Panel Counts over a Twenty-Four Hour Period

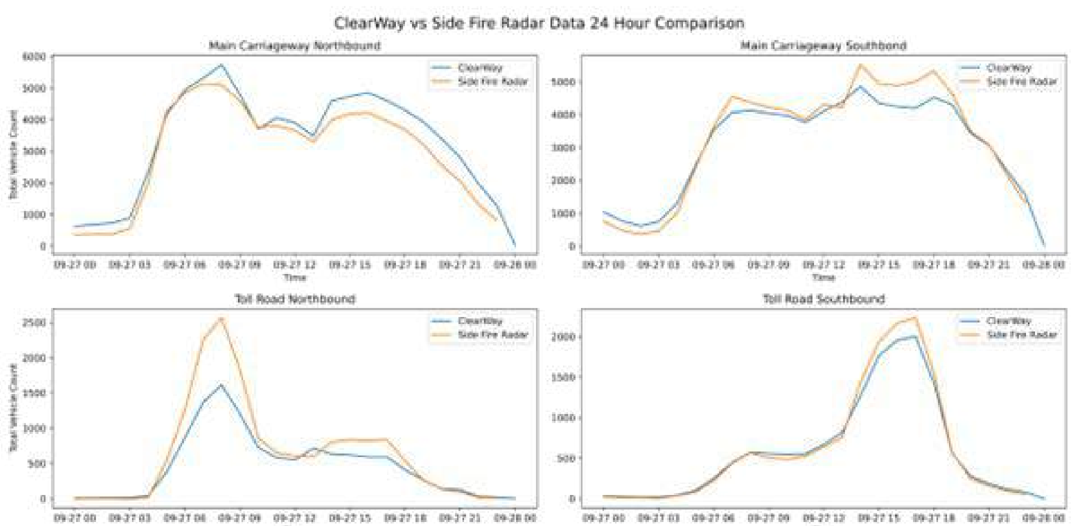


Figure Six: Graph of vehicle count over time

Conclusions and Summary

Count performance of the ClearWay radar was consistently seen to be within three percent of the Manual Count, exceeding the specifications and performance delivered by the existing equipment.

The overall performance for counting vehicles by lane with the Clearway radar matches panel radar.

Lane level count for ClearWay radar is expected to further improve with the use of a formal installation process and optimal site design. As such we have confidence in consistently matching and exceeding the performance of the comparable technology.

Total vehicle counts over larger periods of time provides confidence that the system can scale and provide meaningful results that match up with daily usage of the roads.

In summary we've seen that through the implementation of a real-world trial, on a busy roadway in the US, comparing one of the traditional technologies used for this application, the Navtech ClearWay 360° Imaging Radar could be effectively used within a Dynamic Pricing implementation and match the performance of current technologies.

Additionally, the same system would be able to deliver multiple additional applications, thereby reducing the infrastructure burden and overall system complexity and enabling the road to be operated more safely, efficiently, and sustainably.

Count performance of ClearWay was consistently seen to be within three percent of the manual count, **exceeding the specifications and performance delivered by the existing equipment.**

Navtech Radar Limited
Home Farm, Ardington, Wantage,
Oxfordshire, UK, OX12 8PD

+44(0)1235 83241

sales@navtechradar.com

navtechradar.com