White Paper — V2X

Connecting the Dots
Exploring the Potential of Vehicle-to-Everything Communication

Compiled by: A-to-Be®
#v2x #infrastructure #transportation

Executive Summary

Vehicle-to-everything communications (V2X) have been on the horizon and in the minds of road operators for years, but they are still in the process of moving from the drawing board to the real world. Its development is mostly in the form of trials: for example, in 2023, Virginia Tech and Transurban collaborated to trial V2X use cases on their 395 Express Lanes in the Washington, D.C. area, and **A-to-Be and various other partners in road operation and telecoms trialed V2X use cases across Europe in a series of EU-funded projects.**

There are a lot of potential use cases for V2X communications — especially for safety, convenience, and eventually tolling. Additionally, V2X communications may live side-by-side for a time with other innovative tolling technologies like apps and Bluetooth-based mobile tolling. We still have several years until there are enough V2X cars on the road to make a difference — but road operators should take advantage of this window of time to prepare to embrace the most relevant V2X use cases.

For the purpose of this white paper, **we have organized V2X use cases into possible implementation groups** to facilitate description and discussion:

⚠️	👍	🚗
Safety	**Convenience**	**Tolling**
Communication technologies to enhance safety in transportation systems.	Transforming the driving experience beyond safety.	Connected technologies to streamline toll-collection processes.

Use Cases Day 1 | Safety.

Whether we call it *Vision Zero* or *Every Day Without A Road Death* (Project EDWARD), **all road operators and technology providers want to make driving safer, and V2X can certainly help.** This is a key reason why safety use cases are often considered the "Day 1" use cases for V2X, or the ones that should be refined and made available first. These include uses like notifications about hazards or obstructions in the roadway, inclement weather, alerts for slow traffic, speed limits, construction in the roadway, emergency vehicles approaching, and more. Today, much of this information can be delivered through **variable messaging signs (VMS) connected to an Automated Traffic Management System (ATMS) like A-to-Be's Atlas,** and through mapping applications like Waze, Apple Maps, or Google Maps as well as roadside signage, and road assistance vans displaying dynamic information. **With V2X, these messages can become more tailored, more responsive to current road conditions, and free from the limitations of VMS locations or mapping apps. The ability for real-time interaction and exchange is also a major benefit,** for instance, for broadcasting a warning for a queue that just formed after an accident or a sudden breakdown of a vehicle.

The next part of the "Day 1" challenge lies in how to implement V2X for safety use cases. Road operators must provide safety information that is timely and relevant, without being a distraction. **Having been born from a road operator with more than 50 years of**

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experience, A-to-Be knows that this is a delicate balance to achieve. The best way to

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find this balance will be through pilots and trials, testing a variety of implementations, and identifying the best option for drivers based on test results, local conditions, in-vehicle communication possibilities, human-machine interface, and local driving habits. The time to test and find that balance is now, before the mass adoption of V2X capabilities.

Use Cases Day 1.5 | Convenience.

Day 1.5" goes beyond the data exchanges supporting "Day 1" use cases and really starts to unveil the power of V2X technology. These use cases will **rely on the protocols and communication techniques established for the previous group of safety-related use cases**, so technology developers should keep them in mind. Day 1.5 for V2X is currently slated to focus on convenience and driver experience**.**

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These can **include parking information, fueling and EV charging information, traffic information, routing directions, and access management for neighborhoods or corporate campuses.** It can also include cases where infrastructure responds to vehicles' requests, such as prioritizing an emergency vehicle at traffic lights, potentially for that vehicle's whole route. "Day 1.5" is where the infrastructure starts playing its arbitration role and will be a pillar for future support for deeper traffic optimization measures, namely directed at Autonomous Vehicles, taking traffic management to a whole new level.

Like with "Day 1" use cases, road operators will need to identify the best ways to deliver this information to drivers without being a distraction. Additionally, as **convenience information is less critical than safety information, driver preferences and car manufacturers' established communication patterns can play a greater role in how and**

how much information is communicated. Already, drivers are becoming accustomed to viewing some of this information at the start of a journey. For instance, some EVs will provide charging station options when the driver uses the car's built-in navigation system to choose a route that exceeds the car's current charge level. Drivers' expectations of how a "connected car" system will communicate relevant, but not critical information, is already being formed. **Road operators will need to take these preferences and emerging habits into account when they design ways to communicate information from their systems,** like parking availability or the presence of emergency vehicles.

Use Cases 2: Tolling

At A-to-Be, we see V2X as the future of tolling. We're already preparing for a future without transponders, where tolling transactions use **Bluetooth and GPS capabilities of a phone or car, and eventually where tolling infrastructure uses the car's V2X capabilities to provide payment information and handle transactions.** We believe that tolling is one of the most important use cases in the "Day 2" frontier for V2X technologies. V2X doesn't just represent a direct replacement for current technology – **it can improve tolling for both the driver and the agency.**

It can reduce barriers to interoperability through national standards, and it can work with geofencing and similar technologies to enroll eligible drivers in a tolling account when they enter a given area, or to **facilitate distance-based charging** schemes like Road

> We are already preparing for a future without transponders using Bluetooth and GPS capabilities.

User Charging, also known as Mileage-Based User Fees or Vehicle Miles Travelled fees. By communicating with roadside infrastructure, authorities can track a vehicle's journey within certain areas without having to access the car's full GPS data. At the same time, **authorities can charge much more precisely** than a system simply relying on periodic odometer readings, by being able to exclude out-of-state or private roads from the charging scheme.

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Despite these advantages, V2X technology will need to meet a high bar to eventually replace a reliable and low-friction toll charging method like transponders or RFID stickers. To compete alongside transponders, which rely on proven technology with a multi-decade track record and a "set it and forget it" account system (when all runs smoothly), vehicle-to-tolling point communications must be equally, or more, reliable, and frictionless. The next few years offer technology providers as well as road operators, a priceless opportunity to test, refine, and optimize vehicle-to-tolling point communications and to identify more ways to improve the customer experience through this new technology.

In Conclusion

Today, using A-to-Be's V2X infrastructure, hundreds of connected vehicles per day are already providing probe data to the roadside infrastructure and emitting safety messages such as queue warnings. V2X is not just the future – it is already arriving. Road operators should take advantage of this time before widespread V2X adoption to test the use cases that currently, or could in the future, interest them and their patrons. We have already seen a few promising pilots and implementations in the U.S. and Europe, but they remain relatively small in scale. In 2024, we expect to see Wave V2X standards roll out in the U.S., opening the door for more road operators to do their own trials, and to potentially receive USDOT funding. This is a golden opportunity to prepare for the next great advancement in roadside technology.

We hope you enjoyed this white paper from **A-to-Be.**

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Our Road to Connectivity

A-to-Be has been developing V2X safety use cases since 2008, piloting the technology as early as 2009. Our first road trial took place with Northwest Parkway in Denver, Colorado.
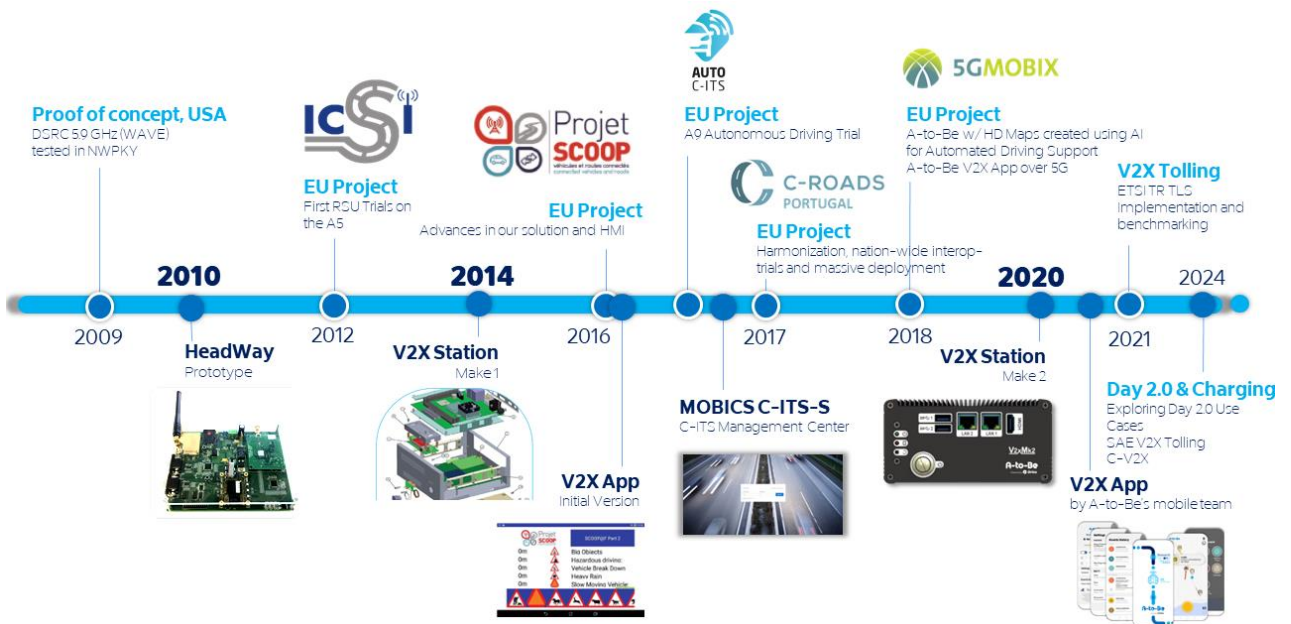
Fig.1 – A-to-Be's V2X timeline.

During this event, which received local media coverage, a bus successfully received emergency brake warnings from a vehicle ahead using A-to-Be's prototype OBUs with the US Wave V2X stack.

Since then, our V2X solution has evolved and been trialed in European projects such as AUTO C-ITS, C-ROADS, and 5G-MOBIX, achieving V2X coverage across more than 300 miles of motorways [for more detail see ref. 1-4]. Building on Day 1 use cases, another important V2X use case group trialed by A-to-Be involves providing infrastructure support for autonomous driving.
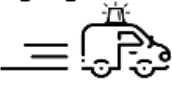
Service	Use Case	
Probe Vehicle Data (PVD)	PVD-VDC: Probe Vehicle Data - Vehicle Data Collection	
	PVD-EDC: Event Data Collection	
Hazardous Location Notification (HLN)	HLN-APR: Animal or person on the road	
	HLN-WCW: Weather Condition Warning	
	HLN-SV: Stationary vehicle	
	HLN-TJA: Traffic Jam Ahead	
	HLN-EVI: Emergency Vehicle in Intervention	
	HLN-OR: Obstacle on the road	
	HLN-TSR: Temporarily slippery road	
	HLN-UBR: Unsecured Blockage of a Road	
	HLN-AWWD: Alert Wrong Way Driving	
	HLN- AZ: Accident Zone	
Road Works Warning (RWW)	RWW-LC: Lane closure	
	RWW-ROVI: Road Operator Vehicle in Intervention	
	RWW-RM: Road Works – Mobile	
	RWW-WM: Winter Maintenance	
	RWW-RC: Road Closure	
In Vehicle Signage (IVS)	IVS-DSLI: Dynamic Speed Limit Information	
	IVS-TS: Traffic Signs	
	IVS-FT: "Free Text"	

Fig.2 – C-ITS Day 1 use cases implemented by A-to-Be in EU projects.

More recently, A-to-Be has focused on Day 2 applications, implementing two V2X tolling protocols based on ETSI standards [for more detail see ref. 5]. We are currently testing our implementation of the SAE J3217 V2X-Base Fee Collection protocol.

Fig.3 – A-to-Be connected vehicle during trials HD maps trails in 5G MOBIX EU project.

Fig.4 – A-to-Be V2X mobile app allows driver to communicate with the infrastructure.

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