(IVWS) In- Vehicle Warning Systems /Conventional / (RASX) Remote Active Signage Systems- Cost, Effectiveness and Implementation Analysis

Peter Woodford

(peter.woodford@lsm.com.au)

LSM Technologies

20th July 2025

Table of Contents

1. EXECUTIVE SUMMARY. 4
2. TECHNICAL STUDIES / TRIALS. 4
2.1 NTSB Study SS-98-02 (1998). 4
2.2 NTSB Study SS-98-03 (1998). 4
2.3 La Trobe University Trial (2013). 5
2.4 Beanland et al. (2018) / Larue et al. (2015). 5
2.5 Nadri et al. (2023). 5
2.6 ATSB Report RS-2021-001 (2024). 5
2.7 Comparative Table of Key Findings. 6
3. EXPANSION ON STUDIES / TRIALS. 6
3.1 1997–2000: Illinois Pilot of Advisory On-Board Warning 6
3.2 Late 1990s: Multi-State ITS Grade-Crossing Projects. 7
3.3 2016–2021: U.S. DOT FRA’s V2I-Based RCVW. 7
3.4 Academia & Emerging Tech (~2019-2021) 7
3.5 Evaluation Takeaways. 7
4. SUMMARY & CONCLUSIONS: EFFECTIVENESS OF IVWS VS ITS- HUMAN FACTORS. 7
4.1 Key Conclusions. 7
4.2 Overall Conclusion. 8
5. IVWS vs ITS- A Brief Comparison. 8
6. IVWS (in- vehicle WARNING systems)- PUSHBACK. 9
6.1 Support for In-Vehicle Warning Technology. 9
6.2 Limitations on In-Vehicle Warning Technology. 9
6.3 Summary. 9
7. IVWS (IN- VEHICLE WARNING SYSTEMS)- Counterpoint. 9
7.1 “Limited Market Penetration”. 10
7.2 “Over-alerting / Driver Distraction”. 10
7.3 “No National Mandate or Policy”. 10
7.4 “Technical Complexity and Integration Barriers”. 10
7.5 “Inconsistent user Interfaces Across OEMs”. 10
7.6 Pushback: “Driver Non- compliance or Inattentiveness”. 10
7.7 Strategic & Economic Advantages. 10
7.8 Summary Table. 11
8. CONVENTIONAL VS RASX VS IVWS TECHNOLOGIES. 11
8.1 Features Comparison. 11
8.2 Benefits Comparison. 12

8.3 Disadvantages Comparison. 12
8.4 Summary. 12
9. CONVENTIONAL vs RASX- COST ANALYSIS. 13
9.1 Cost Insights. 13
9.2 Cost Drivers- Why RASX Is Less Expensive. 13
9.3 Real-World Rollouts. 13
9.4 Summary. 13
10. LIFECYCLE MAINTENANCE COSTS. 14
10.1 Maintenance Schedule – Callaghans Lane (NSW Trial). 14
10.2 Maintenance Cost Drivers. 14
10.3 Comparative Maintenance Cost Outlook. 14
10.4 Strategic Cost Summary. 15
10.5 Summary. 15
10.6 Estimate Total Cost for RASX Fit out. 15
10.7 Key Assumptions. 15
10.8 Estimated National Rollout Cost. 15
10.9 Additional Notes. 15
10.10 Strategic Implication: 16
11. RASX MAINTENANCE STRUCTURE. 16
11.1 Maintenance Tasks (Monthly). 16
11.2 Replacement Intervals. 16
11.3 Estimated Annual Maintenance Cost. 16
11.4 National Maintenance Cost Estimate. 17
11.5 Comparisons & Efficiency. 17
11.6 Summary. 17
12. RASX vs CONVENTIONAL ACTIVE SYSTEM- COMPARED. 17
12.1 Capital Cost Comparison. 17
12.2 Annual Maintenance Cost Comparison 18
12.3 10-Year Cost Comparison (Per Crossing). 18
12.4 National Scale Comparison (18,400 Crossings). 18
12.5 Conclusion 18
13. IVWS VS RASX: COST AND EFFECTIVENESS. 19
13.1 Registered Vehicles in Australia. 19
13.2 In-Vehicle Warning System. 19
13.3 RASX (Rail Active Crossing System). 20
13.4 Cost Comparison (10-year and 20 years). 20
13.5 Summary. 21

13.6 Remote Active Signage Systems (RASX). 21
13.7 Safety and Effectiveness Trade-offs. 21
13.8 Coverage and Incident Avoidance / Cost per Collision. 21
13.9 Summary. 22
14. ROLLOUT- RASX vs IVWS. 22
14.1 RASX (Rail Active Crossing System). 22
14.2 IVWSystem. 23
14.3 Comparison Table. 23
14.4 Summary. 24
14.5 Strategic Insight. 25
14.6 Summary Conclusion. 25
15. TECHOLOGY ROLL-OUT / DELIVERY / MANUFACTURE. 25
15.1 RASX Systems – 18,400 Units. 25
15.1.1 Supply Chain Estimate. 25
15.1.2 Estimated Timeframes. 26
15.2 IVWS Systems – 5.0 Million Units. 26
15.2.1 Supply Chain Estimate. 26
15.2.2 Estimated Timeframes. 26
15.3 Summary Table. 26
16. SUMMARY OF CORE FINDINGS. 26
16.1 IVWS (LSM TrainSense®) – In-Vehicle Warning Systems. 26
16.2 RASX – Remote Active Signage Systems. 27
16.3 Comparative Effectiveness. 27
16.4 Supporting Evidence from 30+ Years of Trials. 28
16.5 Human and Environmental Factor Mitigation. 28
16.6 Strategic Rollout & Policy Implications. 28
16.7 Integration with Modern Vehicle Safety Systems. 28
16.8 Overall Conclusion. 29
16.9 Final Recommendation. 29

STRICTLY IN CONFIDENCE

1. EXECUTIVE SUMMARY.

The following are references made to discussion papers that should be read in conjunction with this analysis / discussion paper:

- 2024-LSM TrainSense (int.pat.pend) CAS Concept Fact Sheet V2 dd 20th Oct 2022 (v1).
- 2025-LSM TrainSense- BridgeSense (int.pat.pend)- Position Paper v2 dd 10th May 2024.
- 2023-LSM BridgeSense® (int.pat.pend) Over- Height CAS V3.pdf

Rail Level Crossing Incidents (collisions / near misses) involving on-road vehicles continue to escalate across Australia and globally. Despite over three decades of trials and technological evaluations, an effective solution remains elusive.

This is especially in relation to addressing the influence of **Human Factors** in such incidents.

Similarly, over-height impacts with structures such as bridges and tunnels result in hundreds of millions of dollars in infrastructure and vehicle damage, traffic delays, emergency responses, and serious injuries or fatalities.

These incidents occur almost daily in Australia- and even more frequently in other global regions facing the same or greater challenges.

LSM Technologies is addressing these long-standing issues by developing advanced OH&S mitigation controls, including two In-Vehicle Warning System (IVWS) technologies:

- LSM BridgeSense® (int.pat.pend) *Vehicle Over- height (CAAS) Collision Awareness / Avoidance System*: designed to eliminate / avoid Over- height Vehicles / Loads and Over- width impacting on Bridges / Tunnels (overhead structures), as well as providing Over Bridge protection from vehicle mass.
- LSM TrainSense® (int.pat.pend) *Rail Level Crossing (CAAS) Collision Awareness / Avoidance System*: designed to eliminate / avoid Rail mounted Vehicle impacts with other Road Vehicles travelling over these Crossings.

This Technical analysis / discussion document is specifically in reference to LSM **TrainSense**® IVWS concept.

2. TECHNICAL STUDIES / TRIALS.

The following is a summary of key studies- ranging from nearly three decades ago to as recent as 2024- focused on identifying mitigation solutions for vehicle collisions at rail crossings.

Their findings are outlined briefly below.

2.1 NTSB Study SS-98-02 (1998).

- **Title:** "Safety at Passive Grade Crossings"
- **Focus:** Examined fatal collisions at passive highway-rail crossings.
- **Findings:** Identified lack of active warnings, driver misjudgement, and limited sight distance as major causes. Behavioural factors such as familiarity and complacency were key contributors.
- **Recommendations:** Promoted active warnings, better signage, and potential use of ITS and IVWS technologies.

2.2 NTSB Study SS-98-03 (1998).

- **Title:** "Safety Study: Highway-Rail Grade Crossing Active Warning Device Issues".
- **Focus**: Reviewed effectiveness of active warning devices (e.g., lights, gates).
- **Findings**: System failures and driver disregard were primary issues. Human factors like risk-taking behaviour were significant. Suggested ITS for proactive warning and data-driven interventions.

2.3 La Trobe University Trial (2013).

- **System**: DSRC-based (Dedicated Short Range Communications) IVWS.
- **Objective**: Warn drivers of approaching trains using DSRC alerts.
- **Findings:**
  - High incidence of false alerts and driver confusion.
  - Poor user acceptance and eventual system abandonment.
  - Highlighted importance of selective alerting and integration with map data.

2.4 Beanland et al. (2018) / Larue et al. (2015).

- **Technology**: GPS-based In-Vehicle Warning Systems (IVWS).
- **Focus**: Studied effect of GPS-enabled alerts at level crossings in rural / low-visibility areas.
- **Findings**:
  - Improved driver awareness and response time.
  - Reduced approach speed at crossings.
  - Acceptance depended on interface simplicity and low false alarms.
  - **Behavioural Factors:** Trust in technology, alert fatigue, and usability were pivotal.

2.5 Nadri et al. (2023).

- **Study**: Improving Safety at Highway-Rail Grade Crossings Using In-Vehicle Auditory Alerts.
- **Focus**: Investigated (IVWS) auditory-only warning systems as an enhancement to passive crossings.
- **Findings:**
  - Alert tones significantly improved driver detection and decision-making.
  - Better compliance observed under high workload conditions.
  - Low-cost, high-potential supplement to visual systems.

2.6 ATSB Report RS-2021-001 (2024).

- **Topic**: Review of level crossing collisions involving trains and heavy road vehicles in Australia.
- **Findings:**
  - Systemic human errors still dominate incidents at level crossings.
  - Strong support for integrated ITS and IVWS, especially for heavy vehicles.
  - Called for accelerated deployment of warning technologies and cross-agency data sharing.
  - **Behavioural Observations:** Habitual risk-taking, distraction, and familiarity bias prevalent.

2.7 Comparative Table of Key Findings.

Study / Year	Tech Focus	Key Findings- relevant to ITS & IVWS	Behavioural Factors Identified
NTSB SS-98-02 (1998)	Passive Crossings	Need for ITS to mitigate driver misjudgement	Familiarity, misperception, poor visibility
NTSB SS-98-03 (1998)	Active Warnings	Recommended ITS for data feedback and system reliability	Risk acceptance, impatience
Beanland et al. (2018)	GPS IVWS	Reduced speed & improved awareness	Alert fatigue, interface trust, distraction
La Trobe Univ. Trial (2013)	DSRC IVWS	Poor performance due to non-selective alerts	Alert confusion, distrust, rejection of tech
Larue et al. (2015)	GPS IVWS	Enhanced safety at rural crossings	Compliance linked to design and timing of alerts
Nadri et al. (2023)	Auditory Alerts	Better decision-making, especially under cognitive load	Sound recognition, workload sensitivity
ATSB RS-2021-001 (2024)	National Review	Urged adoption of IVWS for HVs and buses	Routine disregard, distraction, overconfidence

3. EXPANSION ON STUDIES / TRIALS.

The NTSB (National Transportation Safety Board) called upon federal agencies such as the U.S. DOT, FHWA, FRA, and NHTSA, as well as state departments and industry stakeholders, to explore and co-develop ITS-based in-vehicle solutions.

The NTSB concluded that ITS and IVWS could address a critical gap in grade crossing safety, especially where passive systems are prone to failure due to driver error. However, they stressed that robust field testing, inter-agency cooperation, and integration with broader safety strategies would be necessary before wide-scale implementation.

Since the 1998 NTSB **SS-98-03,** other test evaluations at the NTSB behest several follow-up trials took place. Initial pilots in the 1990s proved concept feasibility but revealed reliability and driver acceptance issues. More recent programs- especially the FRA's V2I-based RCVW- demonstrated robust performance and strong promise for enhanced rail warning systems.

3.1 1997–2000: Illinois Pilot of Advisory On-Board Warning

- **Pilot Study in Illinois (1997):** Trackside transmitters sent K-band signals to 300 in-vehicle systems across 5 crossing- mainly on buses and emergency fleets- alerting drivers (IVWS) when a train was approaching or on the crossing.
- **Performance evaluation (2002):** Found the off-the-shelf system had low reliability, with many false alerts or missed warnings. Although human factors issues were identified and early In- vehicle Response (IVR) hardware improvements helped, the system didn't meet expectations
- **Federal Railroad Administration**: A 2000 field test on the Gary- Chicago- Milwaukee corridor used GPS-based detection and In-vehicle warnings from March to December. It was effective at alerting drivers, but behavioural impact data wasn't conclusive.

3.2 Late 1990s: Multi-State ITS Grade-Crossing Projects.

A cross-cutting study of seven ITS projects (late 1990s) included (IVWS) In-Vehicle Warning Systems in Minnesota and Illinois pilots. The Minnesota pilot (30 drivers) was too small for firm conclusions, but the Illinois test (~300 drivers) revealed participants found the system helpful in raising awareness of approaching trains.

3.3 2016–2021: U.S. DOT FRA's V2I-Based RCVW.

- The Rail Crossing Violation Warning (RCVW) program, developed by FRA (Federal Railroad Administration) with support from the Volpe Centre and Battelle, tested V2I- equipped vehicles communicating with roadside infrastructure in pilot settings.
- Phase II (2018-2021) integrated advanced GNSS RTK (Real Time Kinematic), DSRC (Dedicated Short Ragne Communications), vehicle CAN-bus data, and human factors- designed audio / visual alerts. Results indicated V2I-enabled IVWS alerts can significantly enhance crossing safety.

3.4 Academia & Emerging Tech (~2019-2021)

- DSRC-based warning system pilots (2021) measured millisecond-level latency (<5 ms) and warning windows (~25–30 s) for crossings in the U.S., affirming technical viability for speeds up to ~35 mph.
- Other DSRC prototype tests assessed antenna configurations and reliability for early-warning detection.

3.5 Evaluation Takeaways.

Era	System Type	Results
Late 1990s	K-band / GPS IVWS pilots	Technically feasible, but low reliability and inconsistent behavioural effects
Late 1990s	Multi-state ITS cross-study	Drivers valued alerts, but scale was small
2016–2021	V2I-enabled RCVW (DSRC, RTK GNSS)	Strong evidence that connected-vehicle alerts improve driver awareness and safety
2019–2021	Academic DSRC prototypes	Technically robust warning latency and coverage even at moderate speeds

4. SUMMARY & CONCLUSIONS: EFFECTIVENESS OF IVWS VS ITS- HUMAN FACTORS.

Over nearly three decades, extensive research and trials have consistently demonstrated the potential of In-Vehicle Warning Systems (IVWS) and Intelligent Transport Systems (ITS) to mitigate human factor related collisions at railway level crossings.

From early trials in the 1990s to modern V2I-based systems (e.g. RCVW), the evidence indicates that IVWS and ITS technologies can significantly improve driver awareness, reduce risky behaviours, and enhance decision-making at passive and active rail crossings.

4.1 Key Conclusions.

- **Human Error Is Persistent:** Across all studies, driver behaviour- such as distraction, overconfidence, complacency, and risk-taking- were identified as a dominant cause of level crossing incidents.
- **Technology Enhances Safety:** GPS, DSRC, auditory alerts, and V2I systems have been shown to reduce vehicle speed, improve driver response times, and enhance compliance, especially in high-risk conditions or for heavy vehicles.
- **User Trust & Alert Design Are Critical:** Success is highly dependent on system reliability, low false alarm rates, intuitive alert interfaces, and selective warning logic.

- **Early Systems Had Limitations:** Initial pilots (e.g. 1997–2000 K-band and GPS alerts) were hindered by technical reliability and user acceptance issues, which delayed adoption.
- **Modern Systems Show Strong Promise:** Advanced V2I systems (e.g. FRA's RCVW, 2016–2021) demonstrated robust performance, real-time response capabilities, and positive behavioural impact- signalling readiness for broader deployment.
- **Cost-effective & Scalable:** Technologies such as auditory- only alerts or GPS (GNNS) based IVWS are shown to be low-cost and scalable, making them ideal for widespread implementation.

4.2 Overall Conclusion.

Whilst early ITS and IVWS trials faced technical and behavioural challenges, modern systems have matured to a point where they offer proven, cost-effective mitigation of human-factor risks at level crossings.

Integration into vehicles and transport networks- supported by inter-agency cooperation and regulatory endorsement- can significantly reduce fatalities and incidents caused by human error. Wide-scale deployment is both justified and urgently needed.

5. IVWS VS ITS- A BRIEF COMPARISON.

Aspect	ITS (Intelligent Transportation Systems)	IVWS (In-Vehicle Warning Systems)
System Complexity	High- requires integration of roadside infrastructure (sensors, signals, communication networks, central management systems).	Low- self-contained in the vehicle; uses GPS / GNNS and Geofencing to alert drivers at specific hazard locations.
Infrastructure Needs	Extensive- must be deployed network-wide to be effective (crossings, intersections, traffic signals, etc.).	Minimal- relies primarily on GPS/ GNSS data; no external infrastructure required.
Cost per Site / Vehicle	High- installation and maintenance at each location is costly; costs can reach hundreds of thousands per site.	Low- estimated ~$100 per vehicle (LSM Technologies), especially feasible at scale or via government mandate.
Rollout Timeframe	Slow- constrained by civil works, logistics, and coordination across jurisdictions.	Fast- easily retrofitted to existing vehicles; scalable across fleet and public vehicles.
Human Factors	High cognitive load- presents multiple alerts for diverse hazards (traffic, speed zones, weather, etc.), leading to driver distraction, alert fatigue, or missed warnings.	Focused- targeted alerts for specific threats like rail crossings (overhead impacts) reduce cognitive load and improve driver response.
Suitability for Autonomy	Optimally designed for use with Autonomous Vehicles (AVs), which can process multiple inputs simultaneously without distraction.	Designed for human- driven vehicles; supports human situational awareness and response.
Technology Readiness	Long-term-- full ITS benefit requires widespread adoption of connected or autonomous vehicles- dedicated roads with no human driven vehicles.	Immediate- available now and effective in current vehicle fleets.

ITS is a broad, long-term vision for traffic safety and efficiency, intended to provide drivers (non- driver vehicles) with comprehensive information about road conditions.

However, **its reliance on driver interpretation** introduces **human factors issues-** such as distraction, **alert fatigue**, and **compliance failure**, particularly when multiple alerts are presented simultaneously.

Such complexity makes ITS more compatible with a future of **fully autonomous vehicles**, which can process and react to a wide range of inputs without distraction.

But with **autonomous vehicles still decades away from wide adoption**, IVWS offers a **practical, focused, and immediately deployable** solution to address specific high-risk scenarios like passive level crossing collisions- **without overloading the driver** or relying on external infrastructure.

6. IVWS (IN- VEHICLE WARNING SYSTEMS)- PUSHBACK.

Based on the analysis of the *2024 March ATSB Transport Rail Crossing Safety Report RS-2021-001*, there are references that **support** and those that **challenge** the use of IVWS warning technology for level crossing safety.

6.1 Support for In-Vehicle Warning Technology.

- **Potential Safety Benefits and International Trials:** The report acknowledges that IVWS can improve drivers ability to notice and respond to level crossing warnings. A referenced study (Grégoire Larue et al. (2019) involving a GPS- based system trialled at a passive crossing in Victoria showed a significant increase in driver response time and reduced failure- to-stop incidents "*The drivers who received warnings had a significantly lower rate of failure to stop... suggesting that auditory and visual in-vehicle warnings can positively influence driver behaviour."*
- **Technological Readiness:** the report notes that: *"Many new vehicles already include navigation systems and connected vehicle infrastructure... enabling feasible integration of real-time in-vehicle alerts at crossings."*
- **Alignment with Broader ITS Objectives:** In-vehicle warnings are discussed as part of a broader ITS (Intelligent Transport Systems) solution space that could complement existing passive and active control measures, especially at higher-risk rural crossings.

6.2 Limitations with In-Vehicle Warning Technology.

- **Reliance on Voluntary Uptake and Market Penetration:** The report flags a significant concern around the limited short-term effectiveness due to slow market penetration: "The effectiveness of IVWS will remain limited until such systems are widespread across the fleet, which may take decades."
- **User Distraction and Information Overload:** There is concern that such systems could lead to distraction or message fatigue: *"Excessive or poorly timed alerts may lead to drivers ignoring or disabling warning systems, reducing their long-term effectiveness."*
- **Integration and Standardisation Challenges**: The report also highlights complexity in ensuring consistent integration, especially given differences in OEM platforms and lack of national policy: "*Without a national mandate or standardised implementation, voluntary adoption by manufacturers will remain patchy and inconsistent."*

6.3 Summary.

The report supports IVWS as **promising safety tools**, especially for mitigating human error at passive level crossings. However, it pushes back on their near-term utility (short- term usefulness), citing **low uptake**, **driver distraction risks**, and **integration hurdles**.

7. IVWS (IN- VEHICLE WARNING SYSTEMS)- COUNTERPOINT.

Considering the specific functions of **IVWS** namely, real-time detection of train approach (optional- suggested by the writer for active crossings with boom gates **only**), driver inattention mitigation, non-reliance on GPS maps, autonomous in-cabin alerts (visual / auditory), and integration with existing vehicle systems- a IVWS offers **distinct advantages** that directly overcome the **pushbacks** outlined in the ATSB report.

■ Discussion: IVWS+Conventional+RASX Rail Crossing Protection Systems

7.1 “Limited Market Penetration”.

- **Advantage with IVWS:** IVWS is **immediately deployable** as a **retrofittable safety device** across existing heavy vehicle fleets (and passenger **vehicles**).
- **Future-proofed**: With an **Australian Design Rule (ADR) mandate**, IVWS can be **seamlessly integrated during vehicle manufacture**, providing **native compatibility** in new trucks and heavy vehicles while preserving retrofit options for legacy fleets and all new vehicles manufactured with the IVWS integrated into the vehicles systems..

7.2 “Over-alerting / Driver Distraction”.

- **Advantage of IVWS:** The system can utilise real-time radar (external and vehicle) and sensor data from external infrastructure- rather than relying on map-based predictions- to issue alerts only when a train is genuinely approaching (the writer supports this approach exclusively for active protected crossings with **boom gates**).
- **Distraction**: This method ensures a high **signal-to-noise ratio**, minimising unnecessary alerts, reducing driver annoyance, and fostering ongoing driver engagement and trust.

7.3 “No National Mandate or Policy”.

- **Advantage with IVWS:** IVWS is a self**- sufficient safety mitigation solution** that does not depend on external infrastructure or legislative change to function. However, if **nationally mandated**, either through policy (retrofit) or via an **ADR inclusion**, rollout would be both **technically simple** and **financially viable**.
- **Cost Recovery Option**: With an estimated **unit cost of ~$100**, the full national cost can be **easily offset** by a **minor annual increase in vehicle registration fees** (e.g., under $15 per year), creating a **cost-neutral public safety benefit**.

7.4 “Technical Complexity and Integration Barriers”.

- **Advantage with IVWS:** As a **plug-and-play retrofit**, IVWS avoids complex integrations with other telematics, ECUs, or third-party infrastructure.
- **ADR Pathway:** When adopted under an **ADR pathway**, it can be **factory-fitted**, simplifying compliance and ensuring interoperability across all OEM platforms.

7.5 “Inconsistent user Interfaces Across OEMs”.

- **Advantage with IVWS:** IVWS employs a **standardised visual and auditory alert system**, delivering a **consistent user experience** regardless of vehicle make, model, or cabin configuration- critical for fleet managers and multi-driver operations.

7.6 Pushback: “Driver Non- compliance or Inattentiveness”.

- **Advantage with IVWS:** It does not depend on the driver's alertness, memory, or visibility conditions. By autonomously warning of train approach, it **bypasses human fallibility**, especially important at **passive level crossings**, where traditional signs may be overlooked.

7.7 Strategic & Economic Advantages.

- **Low-cost safety impact:** At ~AU$100/unit, IVWS is far more cost-effective than boom gates or overpass construction.
- **Retrofit now, integrate later**: Dual implementation strategy supports immediate aftermarket deployment and future OEM integration under ADR mandates.
- **Public cost neutrality:** A minor registration levy could fund national deployment without burdening operators or taxpayers.
- **Alignment with ATSB findings:** Directly addresses the need for fail- safe engineering controls that reduce reliance on human perception.

7.8 Summary Table.

ATSB Pushback	IVWS® Counter- point / Advantage
Limited uptake	Retrofits existing fleet today; ADR pathway enables OEM integration tomorrow
Alert fatigue / distraction	Radar-based, real-time alerts only when needed
Lack of mandate	Fully autonomous, but ready for ADR-backed national adoption
Integration complexity	Plug-and-play now; streamlined OEM integration later
Interface inconsistency	Standardised visual / auditory alerts for consistent user experience
Driver error / human fallibility	Delivers warnings based on vehicle position and known crossing hazards- independent of driver behaviour or visibility conditions- not reliant on detecting train presence
High cost of traditional infrastructure	Not required: ~AU$100/unit; scalable and recoverable via registration fees

8. CONVENTIONAL VS RASX VS IVWS TECHNOLOGIES.

To enhance protection at passive level crossings, one option is to install conventional active systems such as flashing lights, bells, and boom gates. However, these are often impractical on high-speed or high-volume roadways due to cost, space, and traffic disruption.

Alternatively, newer technologies like **Rail Active Signage Crossing** (RASX)- which primarily rely on visual and audible signals offer a more streamlined solution but still depend on roadside infrastructure and driver compliance.

A third approach involves In-Vehicle Warning Systems (IVWS), which provide direct alerts to drivers inside the vehicle, independent of external visibility conditions or infrastructure limitations.

Below is a comparative analysis of these three system types to assess their effectiveness, cost, and deployment feasibility.

8.1 Features Comparison.

Feature	IVWS	Conventional	RASX
Warning Delivery	In-cab alert (visual / auditory)	External signs/lights/bells/gates at crossing	Roadside LED signage activated by train detection
Activation Method	GPS/geofence or digital wireless (e.g., DSRC)	Track circuit or axle counters	Train detection (e.g., radar, AI camera, or track)
Integration with Vehicle Systems	Yes (when fitted)	No	No
Infrastructure Dependency	Low (vehicle-based system)	High (civil/trackside infrastructure)	Moderate (roadside signs and detection systems)
Human Factors Addressed	Fatigue, distraction, habituation, limited visibility	Limited (relies on visual/auditory stimuli)	Some (visibility, location-specific context)

8.2 Benefits Comparison.

Criteria	IVWS	Conventional	RASX
Cost per Unit	Low (~$100/vehicle)	Very high (~AU$300k-$1M+/crossing)	Moderate (~AU$30k-AU$100k /crossing)
Scalability / Deployment Speed	High- can be rapidly retrofitted	Very slow – civil works, permits, utilities	Faster than conventional, but slower than IVWS
Coverage	Covers all passive crossings if geofenced	Only at equipped crossings	Limited to equipped crossings
Effectiveness in Poor Visibility	High- alerts delivered directly to driver	Poor- visual signals may be missed	Moderate – enhanced signage but still external
Upgrade Potential	High- can integrate with other vehicle ADAS	Low	Moderate
Maintenance Cost	Very low (eg software updates)	High- electrical systems, mechanical parts	Moderate- sensors, power, communications

8.3 Disadvantages Comparison.

Criteria	IVWS	Conventional	RASX
Driver Alert Fatigue	Risk of over-alerting (if poorly calibrated)	N/A	Less dynamic than IVWS
Technology Compatibility	Requires vehicle hardware or app integration	Independent of vehicle	Independent of vehicle
Dependence on Digital Accuracy	Relies on GPS or data mapping	N/A	Relies on detection and signage logic
No Visual Deterrent to Crossing	No physical barrier to stop vehicles	Boom gates are physical deterrents	No physical deterrent- relies on driver compliance
Coverage Limitations	Must be installed in each vehicle	Requires major investment per site	Still requires hardware at each crossing

8.4 Summary.

- **IVWS:** is cost-effective, rapidly deployable, and directly mitigates human error- particularly valuable for passive crossing coverage across large fleets.
- **Conventional systems:** are most effective for high-risk (high volume train traffic / urban) crossings, but costly, slow to install, and hard to scale.
- **RASX systems:** visible and active at the roadside, cheaper than conventional setups, but still reliant on driver response and infrastructure- does not resolve human and environmental factors.

9. CONVENTIONAL VS RASX- COST ANALYSIS.

The estimated costs for a **RASX (Rail Active Signage Crossing)** system versus a **Conventional Active Rail Crossing system** (e.g. with gates, bells, flashing lights) differ significantly due to complexity, installation, power, and maintenance requirements.

Let's consider the Callaghans Lane crossing near Quirindi (NSW) which is the first RASX installation in NSW, funded with a total of AU$1.2 million- AU$715K from NSW Government and AU$500K from the Australian Government's Regional Australia Level Crossing Safety Program.

This trial converts a **passive** crossing into a (semi) **active** site with flashing lights, bells, and wireless train detection, running through to mid- 2026.

9.1 Cost Insights.

Making some assumptions based upon available information:

Total Trial Cost: AU$1.2 million

- Covers **one crossing**, including local road and track works, full system installation, testing, and trials

Per- Crossing Cost Estimate.

- If fully rolled out, RASX is expected to cost roughly **one-third** of a traditional active crossing.
- Since conventional active crossings in Australia often range between **AU$600K- AU$900K**, a RASX deployment would likely be around **AU$200– AU$300 K** per crossing.

Cost Comparison

System Type	Conventional Cost	Estimated RASX Cost
Active Crossing	~AU$600K–900K	~AU$600K–1.2M (total)
RASX (trial base)	—	~AU$200–300K (estimated)

9.2 Cost Drivers- Why RASX Is Less Expensive.

- **Modular & wireless:** design eliminates trenching and cabling costs.
- **Solar-powered:** units and jack-hammered steel footings reduce civil works.
- **Remote diagnostics & fail-safe operation:** lower maintenance and lifecycle costs.

9.3 Real-World Rollouts.

- Queensland Rail has already installed RASX at **Oakey** and **Thallon**, with trials ongoing and a second Queensland deployment confirmed.
- NSW, now joining, could roll out **up to three crossings** for the same cost as one traditional crossing.

9.4 Summary.

- **Trial cost**: AU$1.2 million for one crossing (complete package).
- **Projected cost per crossing (mass production):** ~AU$200–300K (~⅓ of conventional).
- **Benefits:** Rapid deployment, reduced capex, lower maintenance, high safety integrity (SIL 3 certified).

10. LIFECYCLE MAINTENANCE COSTS.

Here's a detailed lifecycle and maintenance cost breakdown for the **RASX (**Rail Active Signage Crossing) and **Conventional** (Traditional) systems in Australia.

10.1 Maintenance Schedule – Callaghans Lane (NSW Trial).

The RASX maintenance plan for Callaghans Lane (Quirindi) trial is structured as follows:

- **Commissioning- Month 2**: Maintenance every **14 days** to fine-tune setup and address early issues.
- **Month 3- Mid-2026 (trial remainder)**: Maintenance shifts to **every 28 days**, covering:
  - Lights, bells, structural integrity checks
  - Antenna, solar panels, battery inspections
  - Clearing vegetation, checking wireless/shutter systems
  - Diagnostics via Remote Crossing Management System (RCMS)

This monthly cycle ensures consistent performance whilst minimising Labor and site disruptions.

10.2 Maintenance Cost Drivers.

- **Self-powered & wireless configuration:** node-specific solar panels and batteries eliminate trenching and mains power infrastructure.
- **Fail-safe shutter system:** avoids emergency manual intervention; faulty units revert to passive mode for safe operation.
- **Remote diagnostics (RCMS):** Remote Controlled Monitoring Systems enable centralised fault tracking and proactive maintenance scheduling, reducing site visits.
- **Simplified civil works ("Surefoot" foundations):** reduce long-term structural maintenance.

10.3 Comparative Maintenance Cost Outlook.

- **Conventional active crossings** in Australia incur high component maintenance (track circuits, cabling, power supply), with recurring costs for mains power upkeep and hardware replacements.
- **RASX** cuts maintenance costs significantly:
  - **No cabling or mains power:** means less civil wear-and-tear and electrical failures.
  - **Solar panel upkeep and battery replacements:** are the main consumable costs.
  - **Monthly node inspections (plus 28-day maintenance)** keep operational reliability without high labour intensity.

While exact cost figures aren't publicly published, industry comparisons suggest **RASX lifecycle costs are 20- 40% lower** than conventional systems- driven by modular design, remote monitoring, and reduced hardware complexity.

Discussion: IVWS+Conventional+RASX Rail Crossing Protection Systems

10.4 Strategic Cost Summary.

Cost Category	Conventional	RASX
Installation	AU$600- AU$900K	AU$200- AU$300K (1/3)
Maintenance Frequency	Daily / weekly for power & track	Monthly: 14-day then 28-day cycle
Key Costs	Track alarm hardware, mains power repairs, cabling	Solar battery upkeep, vegetation clean-up, diagnostics
Remote Monitoring	Minimal remote capabilities	RCMS logs, alerts reduce site costs
Estimated Lifecycle Cost	High (civil + power + hardware)	~20–40% lower due to system simplicity

10.5 Summary.

- **RASX lifecycle costs** in Australia are significantly **lower than traditional systems**, mainly due to:
  - Elimination of cabling and mains power.
  - Remote maintenance enabled by RCMS.
  - Reduced structural wear through self-powered modular units.
- **Maintenance cycles** are streamlined: 14-day visits during commissioning; transitioning to 28- day cycles post– initial period.
- **Consumable costs** mainly solar panels and batteries; remote diagnostics reduce emergency interventions.

10.6 Estimate Total Cost for RASX Fit out.

To estimate the total cost of fitting out Australia's passive level crossings with the **RASX system**, let's break it down.

10.7 Key Assumptions.

- **Total level crossings in Australia**: ~23,000
- **Passive crossings (no active protection)**: ~80% ⇒ **18,400 crossings**
- **RASX cost per crossing** (based on trial + projected full rollout):
  - **Low estimate**: AU$200,000
  - **High estimate**: AU$300,000

10.8 Estimated National Rollout Cost.

Scenario	RASX Per-Crossing Cost	Total (18,400 passive crossings)
Low Estimate	AU$200,000	AU$3.68 billion
High Estimate	AU$300,000	AU$5.52 billion

10.9 Additional Notes.

- These figures include hardware, solar power, installation, foundations, and commissioning.
- Does not include annual maintenance, RCMS connectivity, or potential bulk procurement discounts.
- Lifecycle savings (compared to conventional systems) would be significant over 10+ years.

10.10 Strategic Implication:

Replacing all passive crossings with RASX at a cost of **~AU$3.7- AU$5.5 billion** is:

- **Far more economical:** than installing conventional active systems (which would cost **AU$11- AU$17 billion** for 18,400 crossings at AU$600K-900K each).
- **Faster and logistically simpler:** due to RASX's modular, solar-powered, and wireless design.

Below is based on available Australian trial data (e.g. Callaghans Lane RASX trial) and conservative engineering estimates. A breakdown of **annual maintenance costs** for the **RASX (Rail Active Signage Crossing)** per crossing and nationally:

11. RASX MAINTENANCE STRUCTURE.

11.1 Maintenance Tasks (Monthly).

- Inspection of lights, audible devices, mast / footings.
- Solar panel and battery check.
- Vegetation clearing.
- Visual & functional check of wireless detection units.
- Remote diagnostics via RCMS (Rail Crossing Monitoring System).

11.2 Replacement Intervals.

- Batteries: ~5-7 years.
- Solar panels: ~15- 20 years.
- Electronics/hardware: typically 10- 15 years.
- Firmware **updates & remote system calibration-** as / if needed.

11.3 Estimated Annual Maintenance Cost.

Component	Estimated Annual Cost (AUD)
Site inspection (12 x / year)	AU$3,500–$3,800
Minor parts / consumables	AU$300–$500
Battery amortisation (5- 7 yrs)	AU$200–$300
Remote diagnostics (RCMS access)	AU$200–$400
Total per crossing	**AU$4,200- $5,000**

Note: Using an **average of AU$5,000 / year per crossing**.

11.4 National Maintenance Cost Estimate.

For 18,400 passive crossings converted to RASX:

Annual Cost / Crossing	Total Annual Maintenance
AU$3,500 (low average)	AU$64.4 million
AU$4,000 (median estimate)	AU$73.6 million
AU$5,000 (upper bound)	AU$92.0 million

11.5 Comparisons & Efficiency.

- **Conventional systems** can cost **AU$7,000- $15,000+** per year (esp. with wired power, signal cables, and controllers).
- RASX offers **~50-70% savings** in lifecycle maintenance due to:
  - Solar / wireless setup (no mains trenching repairs).
  - Remote diagnostics (fewer site visits).
  - Modular components (easy swap/replace).

11.6 Summary.

- **Annual maintenance per RASX crossing**: ~AU$4,200- $5,000.
- **National total (18,400 crossings):** ~AU$77- 92 million / year.
- **Savings vs conventional active systems:** substantial (~50–70% lower).

12. RASX VS CONVENTIONAL ACTIVE SYSTEM- COMPARED.

Feature	RASX	Conventional
Detection	Wireless (radar, magnetometer)	Track circuits / axle counters
Power	Solar-powered	Mains electricity (AC)
Activation	Lights, bells, optional shutter gate	Lights, bells
Monitoring	Remote (RCMS)	Often manual / periodic

12.1 Capital Cost Comparison.

Cost Element	RASX	Conventional System
Equipment & Install	AU$200K- AU$300K	AU$600K- AU$900K
Civil works	Minimal (precast footing, solar)	Significant (trenching, conduit, signal cabling)
Signalling integration	Minimal	High (requires signalling authority, safe working)
Total CapEx per site	**AU$250K (avg)**	**AU$750K (avg)**

12.2 Annual Maintenance Cost Comparison

Maintenance Element	RASX	Conventional System
Site inspections	Monthly (28-day cycle)	Monthly or weekly
Power maintenance	Battery replacement (~5-7 yrs)	Electrical faults, surge protection, wiring
Detection hardware	Low (modular wireless)	High (track-based detection maintenance)
Vegetation, clearance	Similar	Similar
Diagnostics	Remote (RCMS)	Often manual
Annual cost / crossing	**AU$4,200–AU$5,000**	**AU$7,000–AU$15,000**

12.3 10-Year Cost Comparison (Per Crossing).

Item	RASX (est.)	Conventional (est.)
Capital cost	AU$250,000	AU$750,000
10-year maintenance	AU$42,000- AU$50,000	AU$100,000- AU$150,000
Total (10 years)	**AU$292- AU$300K**	**AU$850K- AU$900K**

12.4 National Scale Comparison (18,400 Crossings).

Metric	RASX	Conventional Active
Total Capital (18,400)	AU$4.6 billion	AU$13.8 billion
Annual Maintenance Total	AU$78- AU$92 million	AU$129–276 million
10-Year Combined Estimate	**~AU$5.4- AU$5.52 billion**	**~AU$16–18 billion**

12.5 Conclusion

- **RASX costs ~1/3 the** capital **cost** and **~1/2 or less the maintenance cost** of conventional active crossings.
- Over 10 years, **RASX could save over AU$10 billion** nationally compared to upgrading passive crossings with traditional systems.
- **Deployment is faster** with less civil work, and the **modular / solar design** offers significant lifecycle and safety monitoring advantages.

13. IVWS VS RASX: COST AND EFFECTIVENESS.

Background: Australia has over 23,500 level crossings (2024 data), of which ~79% (~18,400) are *passive* (only Stop/Give Way signs). These passive sites see many incidents-e.g. ATSB- RS-2021-001 (March 2024) reports 283 level crossing collisions with vehicles between 1 July 2014 and 30 June 2022. Of these, 220 were collisions with light passenger vehicles, with 44 collisions involving heavy freight vehicles.

13.1 Registered Vehicles in Australia.

With ~21.7 million registered vehicles in Australia, improving safety can involve either upgrading crossings (infrastructure) or warning vehicles (in-cabin systems).

Vehicle Type	Estimated Registrations	Percent of Total (≈21.74 m)
Passenger vehicles (PV)	15,700,000	72.2 %
Light commercial vehicles (LCV)	4,080,000	18.8 %
Rigid trucks	630,000	~2.9 %
Articulated trucks	124,300	~0.6 %

13.2 In-Vehicle Warning System (IVWS).

- **Description:** Uses GPS / GNSS Rail Crossing Data (on- board), optional integration to external infrastructure (signs, transmitters, sensors- eg boom gates- train approach) to warn drivers. It provides **audible / visual alerts** and can even trigger deceleration and automatic braking if the driver does not respond. It targets **human factors / error** and driver attention at crossings.
- **Cost:** An estimate of **"under $100 per in-cabin device per vehicle"** (LSM Technologies) as a retro fit device.
- **Coverage- Vehicles / Heavy:** Initially it would be proposed that an IVWS is fitted firstly to heavy and commercial vehicles only as these seem to be the largest offenders (and costs) of Train collisions. Subsequently fitting ~5,000,000 registered heavy and light trucks would calculate at a cost of about AU$500 million.
- **Coverage- Passenger Vehicles:** With ~15.7 million passenger vehicles, the retrofitting cost would be ~AU1.57 billion but this would be reduced if a plan to retrofit say 1.5 million vehicles / annum with new vehicles being fitted (at no cost) through vehicle attrition / replacement process over 10 years.
- **New Vehicle Life Cycles:** The plan would be to ensure that the IVWS is installed in vehicles at manufacture and so at a nil cost to the road user- thereafter.
- **Maintenance:** No routine maintenance is required.
- **Cost Recovery**: Importantly, **no extra roadside infrastructure or ongoing maintenance** is required and roll- out costs could be **recouped via vehicle registration fees** for **retrofitted vehicles.** With an **ADR** then the **costs** would eventuate to **zero** as the IVWS technology would be **fitted to vehicles at manufacture.**
- **Retro Fit Lifecycle:** The device has a possibility for a 10 year lifespan.
- **Emphases / Effect:** is that IVWS **"minimises human error, behavioural issues"** from inside the vehicle cabin. An IVWS is provided for every vehicle and so is effective at all Rail Crossing whether Active or Passive.

Discussion: IVWS+Conventional+RASX Rail Crossing Protection Systems

13.3 RASX (Rail Active Crossing System).

- **Description:** A solar-powered upgrade for *passive* crossings. RASX installs wireless train detectors plus flashing LED signs (both at the crossing and advance warning signs). When a train approaches, the signs flash and alert road users (simulating an active crossing).
- **Cost (Capital):** Industry estimates suggest **~AU$250,000 per crossing** on average (modular, wireless design). Converting all ~18,400 passive sites at $250k each is ~AU$4.6 billion in upfront capital. (Note: NSW's first RASX trial is budgeted at $1.2 million for *one* crossing, implying RASX units cost in the mid-six-figures.) The RASX design "dramatically cuts installation costs… (over 50% cost saving)" vs conventional booms / lighting.
- **Maintenance:** RASX is mostly self-contained (solar power, wireless), but still needs periodic servicing. Rail Safety Systems notes **"1–2 service visits [per crossing] are required per year"** (for battery checks, cleaning, etc).
- **Cost Recovery**: If one assumes ~$5,000 per site visit / year, that's roughly ~$50k per crossing per 10 years, totalling ~$92 million over 10 years) for all 18,400 sites.
- **Retro Fit Lifecycle:** The RASX has a possibility for a 10 year lifespan and may require complete **replacement** or at the least **refurbishment** of major components every 10 years thereafter.
- **Emphases / Effect:** A RASX system will not significantly negate **human error, behavioural and environmental issues**. If the system fails, it automatically defaults to a STOP sign (passive mode). RASX is aimed specifically at rural / regional passive crossings and not active crossings

13.4 Cost Comparison (10-year and 20 years).

Cost Item	IVWS	RASX
Capital (Year 0)	**AU$500 M**	**AU$4.6 B** (18,400×$250k)
Capital (Year 10) Remaining Passenger 15.7 million vehicles / 10 roll out on attrition / new registrations	~**AU$863 million**	**≈$0**
Lifecycle Replacement	Design for >10 years	Designed for >10 yr life
Maintenance (0–10 years)	**≈AU$0**	**≈AU$920 M** (assumed (assumed $5k/site / year×18,400))
10 year cost	**≈AUD$1.363 B**	**≈AU$5.55 B**
20 year cost	**≈AU$0** (all vehicles fitted as standard at manufacture)	**≈ AU$2.2 B** (based on(≈AU$70k / ×18,400 for major components- not full replacement) + 10 year Maintenance costs
Total	**≈AU$1.363 B**	**≈AU$7.75 B**

■ Discussion: IVWS+Conventional+RASX Rail Crossing Protection Systems

13.5 Summary.

- **10-Year Horizon:** Retrofitting an initial 5 million heavy vehicles in Year 1 would cost approximately **AUD 500 million**.
- **20-Year Horizon:** If the remaining 15.7 million vehicles were fitted progressively through new registrations at a rate of 1.5 million per year, it would take an additional **10 years** and cost around **AUD 863 million**. With available resources (vehicle workshops= ~30,000) retrofitting can be dramatically shortened.
- **Total 20-Year Cost:** With no ongoing costs beyond the initial rollout- assuming the IVWS technology incurs **no maintenance expenses-** the total investment over 20 years would remain approximately **AUD 1.36 billion**, with **zero additional expenditure** beyond that period.

13.6 Remote Active Signage Systems (RASX).

- **10-Year Cost:** Estimated at approximately **AU$5.5 billion**, with additional maintenance costs ranging from **AU$78 million to AU$920 million** over the period.
- **20-Year Lifecycle:** Including major component replacements such as solar units, batteries, detection modules, and lights, the total 20-year lifecycle cost is projected at around **AU$7.75 billion**. Note that on- going maintenance / repair costs will occur moving forwards as well as refurbishment / replacement costs each 5-10 years.
- In comparison, the capital costs of **IVWS** (In-Vehicle Warning Systems) remain significantly lower, with a total 20-year investment estimated at just **AU$1.37 billion-** highlighting a substantial cost advantage. And after 20 years there will be **nil on- going costs.**

13.7 Safety and Effectiveness Trade-offs.

- **Human Error vs Infrastructure:** IVWS directly addresses driver error. It alerts even in poor visibility and can actively brake, tackling “behavioural issues”. RASX, on the other hand, changes the crossing environment (flashing signs) to catch attention- a more **passive** mitigation (it still relies on drivers seeing and obeying signals). Both systems aim to eliminate the split-second risk at crossings. As LSM technologies notes, collisions often come from drivers doing “the wrong thing… through error or deliberate”. IVWS can warn a distracted driver eg, similar to **DDM- Driver Distraction and Fatigue Monitoring** technology now **commonly** used in heavy vehicles and being delivered with **new passenger vehicles**.
- **Risk Reduction:** No official data exist yet for RASX crash reduction. However, emphasise is that this technology will have **limited effectiveness** mitigating human / environmental factors.

13.8 Coverage and Incident Avoidance / Cost per Collision.

The **ATSB Report RS-2021-001** (March 2024) records **283 level crossing collisions** involving vehicles between **1 July 2014 and 30 June 2022**. Of these, **238 involved motor vehicles**:

- **44** collisions with heavy freight vehicles.
- 194 with **light passenger vehicles.**
- The ARTC- Australian Rail Track Corporation: *Safety Around Level Crossings* report that there are between 500- 1,000 near missies each year requiring harsh braking- a **“near miss can be considered as a connect”.**

Recapping the cost for both mitigation strategies are considered for preventing level crossing collisions:

Technology	Type	Coverage	Total Estimated Cost
IVWS	Vehicle-based	All equipped vehicles	**AU$1.36 billion**
RASX	Infrastructure-based	All road users at crossing	**AU$5.5 billion**

Assuming each system could prevent (100%) **all 238 motor vehicle collisions** recorded over the 8-year period:

- **IVWS:** AU$1.36B ÷ 238 collisions = **~AU$5.71 million per collision avoided**
- **RASX:** AU$5.5B ÷ 238 collisions = **~AU$23.11 million per collision avoided**

These estimates illustrate that, on a per-incident basis, **IVWS is approximately four times more cost-effective** than RASX- assuming **full fleet penetration** (IVWS)**.** Also RASX and IVWS need to provide equal safety mitigation effectiveness against **human / environmental factors.**

13.9 Summary.

- **Capital outlay:** IVWS is extremely low ($1.36B vs ~$7.75B).
- **Ongoing costs:** IVWS zero.
- **Coverage:** Quicker and easier roll- out of IVWS.
- **Effectiveness:** Both aim to prevent collisions, but by different means. IVWS directly mitigates human error in the cabin; RASX upgrades infrastructure to catch drivers' attention.
- **Cost per incident avoided:** Rough estimates suggest IVWS yields a lower cost per collision prevented for the subset of crashes involving equipped vehicles.

14. ROLLOUT- RASX VS IVWS.

Here is the full side-by-side comparison analysis of the rollout characteristics for **IVWS** and **RASX** systems across Australia.

This table highlights differences in installation speed, cost, required resources, disruption to traffic, and the type of safety coverage each system provides.

Here's a detailed comparison of **crew size requirements** for RASX installations vs. IVWS fitments:

14.1 RASX (Rail Active Signage Crossing) System.

Typical Crew Composition per Site:

Based on industry practice and modular infrastructure installs, each RASX installation crew would include:

Role	Count per Crew
Team Leader / Supervisor	1
Civil Technician (mounting)	1–2
Electrical/Signal Technician	1–2
Safety & Traffic Controller	1–2
Crane/Boom Operator (if used)	Optional (1)
Total per Crew	**4 to 6 persons**

RASX installations typically involve 4–6 people on-site for 2–5 days depending on weather, location, and access.

14.2 IVWSystem.

Technician Requirement:

- 1 x technician per install.
- Install time: ~1 hour per vehicle.
- Simple wiring to vehicle power + mounting display or interface module.
- Can be done during regular servicing, inspections, or by mobile installers..

14.3 Comparison Table.

Attribute	IVWS	RASX
Crew size	1 x technician	4- 6 personnel
Time per install	~1 hour	~1 week per crossing
Site-based or mobile	Mobile / workshops	Fixed roadside location
Special equipment required	Minimal	Mounting rigs, boom lifts
Disruption to public	None	Yes (traffic control needed)

14.4 Summary.

- **IVWS requires 1 person per vehicle install**, enabling large-scale deployment with minimal resources and no road impact.
- **RASX needs 4- 6 people per crossing**, including specialists and safety staff, making it more labour- and coordination-intensive.

Factor	IVWS	RASX
Target Installations	5M vehicles initially + 1.5M vehicles /y ear	18,400 passive level crossings
Install Time per Unit	~1 hour	~1 week per site (~40 labour-hours)
Technicians Required	1 per vehicle	5–6 per crossing (per crew)
Total Labour-Hours Required	~5 million hours (initial 5M rollout)	~3.7–4.4 million hours (all crossings)
FTEs for 1-Year Rollout	~3,125 full-time installers	~2,500–2,750 technician-years
Workforce Availability	~60,000+ auto technicians nationwide	Limited — severe shortage of rail-signalling electricians
Installation Locations	Mobile / at service workshops (~31,000 locations)	Fixed road / rail sites with traffic access constraints
Traffic Disruption	None	Yes- 1 to 5 days per site (lane closures, control teams)
Workforce Scalability	High- accessible through fleets, OEMs, workshops	Low- reliant on RIW-certified rail crews, slow to scale
Deployment Time Estimate	<1 year (initial) + annual flow easily manageable	3.5-18 years depending on number of install crews
Skill Shortage Risk	Low- general technician shortage, but manageable	High – chronic signalling/electrical workforce shortage
Training Lead Time	Short – plug-and-play installation	Long – years to certify new rail signal electricians
Supply / Availability / Delivery	Rapid scalability due to readily available components, mass production capability, and access to common manufacturing facilities worldwide, enabling quick and cost-effective deployment	Longer lead times and higher costs due to complex supply chains, limited manufacturing facilities, and the need for large-scale specialised equipment and assembly processes and number off / specialised skilled personnel

14.5 Strategic Insight.

Capability	IWVS-Advantage	RASX- Disadvantage
Speed of rollout	✅ IVWS	Long lead times due to complex supply chains and specialised installation
Logistics & access simplicity	✅ IVWS	Heavy, complex equipment with limited transport and site-access flexibility
Infrastructure independence	✅ IVWS	Requires dedicated roadside infrastructure and power sources
Long-term maintainability (at site)	✅ IVWS	On-site maintenance costly and labour-intensive
National workforce readiness	✅ IVWS	On-site maintenance costly and labour-intensive; prone to environmental wear

14.6 Summary Conclusion.

- An **IVWS** is highly scalable, fast to install, and supported by a broad technician base (~31,000 service locations and tens of thousands of automotive staff). It could complete a national retrofit of 5M vehicles in under a year and sustain 1.5M / year without straining capacity for the proceeding 10 years.
- **RASX**, is limited by workforce shortages in rail signalling, traffic management needs, and complex site-based logistics. Even with 100 full crews, rollout would realistically take > 10 year.
- **An IVWS is best suited for fast national deployment.**

15. TECHOLOGY ROLL-OUT / DELIVERY / MANUFACTURE.

To get such technologies to the market and implemented in a timely fashion, key factors like production complexity, sourcing, capacity, logistics, and deployment need to be considered.

To estimate supply chain delays and delivery timelines for mass-scale production of:

- **RASX**: 18,400 units.
- **IVWS**: 5.0 million units (initially).

15.1 RASX Systems – 18,400 Units.

- **Complexity:** High (infrastructure-based system with barriers, sensors, lights, communication modules, civil works, regulatory approvals).
- **Deployment model:** Installed at individual level crossings.

15.1.1 Supply Chain Estimate.

Component	Delay Risk	Notes
Electromechanical hardware	Medium	Custom; depends on local vs imported sourcing
Control and telemetry systems	Medium	Complex logic controls and integration
Civil works & foundations	High	Requires permits, engineering teams
Logistics & delivery	Medium	Site-specific delivery and installation coordination

15.1.2 Estimated Timeframes.

- **Manufacturing lead time:** 12–18 months (with batch rollout).
- **Installation time:** ~2–3 days per site (parallel crews).
- **Supply chain delay buffer:** ~3–6 months due to regulatory approvals, parts, etc.
- **Total estimated rollout time**:~9-18 years for 18,400 units (at 2,000-1,000 crossings installed / annum nationally, with multiple parallel teams).

15.2 IVWS Systems – 5.0 Million Units.

- **Complexity:** Medium-Low (in-cabin electronic unit, likely embedded with GPS, alerts, CAN integration or retrofit OBD-II port).
- **Deployment model:** Mass-produced units distributed via auto OEMs and retrofit channels.

15.2.1 Supply Chain Estimate.

Component	Delay Risk	Notes
Circuit boards & chips	**High**	**Semiconductor shortages may apply**
Plastic casings / enclosures	**Low**	**Easily sourced / moulded**
Software integration	**Medium**	**If tailored to vehicles, adds time**
Distribution	**Medium**	**Needs national logistics scale**
Vehicle installation	**Low-Medium**	**Can be user-installed or done at rego inspections**

15.2.2 Estimated Timeframes.

- **Initial manufacturing scale-up:** 6–12 months (tooling, ramp-up, compliance)
- **Production rate:** ~200,000–500,000 units / month (post scale-up)
- **Supply chain delay buffer:** ~3–5 months (semiconductors, OEM lead times)
- **Total estimated rollout time:**~2–4 years to produce and install 5 million units (faster if integrated into new vehicles at factory level).

15.3 Summary Table.

System	Total Units	Rollout Time Estimate	Supply Chain Risks	Key Bottlenecks
RASX	**18,400**	**9-18 years**	**Civil works, approvals, telemetry equipment**	**Site-specific work, infrastructure scope**
IVWS	**5.0 million**	**1- 2 years**	**Chips, logistics, vehicle integration**	**Chip shortages, installation at scale**

16. SUMMARY OF CORE FINDINGS.

16.1 IVWS (LSM TrainSense®) – In-Vehicle Warning Systems.

- **Purpose:** Alerts drivers inside the vehicle (via GPS/GNSS or optional sensor input) of upcoming railway crossings, with visual/auditory warnings—and optionally deceleration or AEB activation.

- **Cost:** ~AUD $100 per vehicle. Initial rollout (5 million vehicles) costs ~$500 million; total 20-year national cost (including future retrofits): **~$1.36 billion**.
- **Effectiveness:** Directly mitigates human error- e.g., distraction, fatigue, low visibility- and performs consistently in all weather and environmental conditions.
- **Deployment Speed:** Rapid (1 technician per vehicle, ~1 hour install). Existing workforce (~60k technicians) can support national rollout in under 1 year.
- **Maintenance:** Virtually none. No roadside infrastructure or civil works required.
- **Scalability:** High. Retrofittable for current fleets; manufacturable as standard in future vehicles via ADR.

16.2 RASX – Rail Active Signage Crossing) Systems.

- **Purpose:** Roadside infrastructure (e.g. LED signs, bells, sensors) warns drivers of train approach at passive crossings.
- **Cost:** ~$250k per crossing. 18,400 crossings = **~$4.6-5.5 billion**. Including lifecycle / maintenance: **~$7.75 billion over 20 years**.
- **Effectiveness:** Improves driver visibility and environmental awareness but still relies on human behaviour and visual cues.
- **Deployment Speed:** Slow. Requires rail-certified crews, civil works, traffic control. National rollout = **9- 18 years**.
- **Maintenance:** ~AU$5,000/year per site = ~$920 million over 10 years.
- **Scalability:** Limited due to site-specific installs, workforce bottlenecks, and access constraints.

16.3 Comparative Effectiveness.

Factor	IVWS	RASX
Cost (20 years)	~AU$1.36 billion	~AU$7.75 billion
Install Time	~1 hr / vehicle	~1 week / crossing
Labour Resources	1 tech per install	4-6 person crew
Coverage	All road types; in-vehicle	Only at equipped crossings
Weather/Visibility	Unaffected (in-cabin alert)	Potentially ineffective in fog, rain, sun glare
Human Error Mitigation	Strong- alerts driver directly	Weak- depends on driver compliance
Scalability	High	Low
Maintenance	Negligible	AU$78- AU$ 92M annually
Autonomy Compatibility	Current driver-focused, ADR-ready	Infrastructure-dependent
Cost per Collision Prevented	~AU$5.71M	~AU$23.11M

16.4 Supporting Evidence from 30+ Years of Trials.

The document synthesises decades of technical studies, including:

- **NTSB (1998)**: Identified human error (familiarity, misjudgement) as the leading cause of passive crossing incidents.
- **Beanland (2018), Larue (2015), Nadri (2023)**: Found IVWS significantly improves driver awareness, reduces speed, improves compliance- especially in rural, low-visibility settings.
- **ATSB (2024)**: Strong endorsement for IVWS, especially for heavy vehicles, but noted policy gaps and lack of mandate as challenges.
- **U.S. DOT FRA RCVW Trials (2016–2021)**: Demonstrated high technical viability and behavioural benefit of V2I-connected in-vehicle systems.

16.5 Human and Environmental Factor Mitigation.

- **IVWS (TrainSense®)** directly targets:
  - **Driver fatigue, distraction, overconfidence, cognitive overload.**
  - **Environmental constraints** like rain, sun glare, fog, foliage, and night visibility.
  - **Works in all conditions**- without needing to "see" an external signal.
- **RASX**, while improving external cues, **still relies on drivers seeing and obeying** road signals- making it vulnerable to:
  - **Distraction or inattention.**
  - **Environmental obscurants.**
  - **Deliberate risk-taking.**

16.6 Strategic Rollout & Policy Implications.

- **IVWS**:
  - Immediate retrofit capability.
  - Simple ADR adoption can embed it into new vehicles- zero marginal cost long term.
  - Cost- neutral public policy option- rollout costs recoverable via a nominal annual registration fee (<$15/vehicle).
- **RASX:**
  - Significant logistics, cost, and skilled labour challenges.
  - Installation requires road closures, civil works, and rail safety staff.
  - Long-term public infrastructure burden.

16.7 Integration with Modern Vehicle Safety Systems.

Modern heavy vehicles are increasingly manufactured with **radar-based proximity detection and AEB (Automatic Emergency Braking)** systems, supported by mandated regulations such as:

- **ADR 97/00**: High-speed rear-end crash avoidance.
- **ADR 108/00**: Reversing safety—superseding older audible/visual-only alerts due to human factors limitations
- Additionally, **passenger vehicles now commonly include similar technologies**, such as active cruise control, lane assist, and emergency braking. The **United States has mandated AEB for all new light vehicles from 2029- s**etting a global precedent.
- Given these developments, **IVWS (e.g., LSM TrainSense®)** is ideally positioned to **interface with these electronic safety systems**, enabling dynamic vehicle control where appropriate:
- **Reducing vehicle speed** when approaching a passive crossing

- **Initiating braking or full stop** at an active crossing (e.g., when boom gates are down or warning is triggered)
- This capability significantly enhances the safety function of IVWS beyond basic driver alerting—supporting **active collision mitigation**, especially where human error or distraction may delay response

16.8 Overall Conclusion.

- **IVWS**- offers a significantly more effective, scalable, and affordable solution for mitigating rail level crossing collisions than **RASX** or traditional infrastructure upgrades.
- It delivers targeted, real-time alerts directly to the driver, bypassing the behavioural limitations and environmental vulnerabilities inherent to roadside systems. Backed by 30 years of global trials and recent technological maturity, **IVWS** stands out as the most promising pathway to rapid, nationwide safety improvement, with an investment return up to 4 x greater than **RASX** on a per-collision basis.
- While IVWS offers a comprehensive, vehicle-based solution that can function independently of roadside infrastructure, it is also designed to interface with **external sensors, transmitters, and infrastructure systems**, including **RASX** installations- where required.
- This interoperability allows for **strategic integration at high-priority or high-risk crossings**, where both in-cabin and roadside alerts can operate in tandem. The result is a **layered, fail-safe mitigation strategy** that enhances driver awareness, reduces human error, and maintains system effectiveness under varying environmental conditions.
- IVWS

16.9 Final Recommendation.

- **IVWS should be prioritised as a national safety strategy, supported by ADR mandates and rapid fleet retrofitting.** It addresses the root cause- human error- at a fraction of the cost and with vastly greater scalability and speed than infrastructure-based alternatives like RASX.
- This recommendation is further supported by the IVWS system's alignment with existing and emerging regulatory pathways, including **ADR 97/00** (rear-end collision avoidance) and **ADR 108/00** (reversing safety). The technology is **technically feasible for immediate integration** with current vehicle safety platforms and is **compatible with electronic braking and proximity detection systems** now standard in modern heavy and passenger vehicles.
- As global regulations evolve—such as the **U.S. mandate for AEB on all new vehicles by 2029-** IVWS stands out as a **future-proof solution**. It can deliver not only driver warnings but also **dynamic vehicle control actions**, such as slowing on approach to passive crossings or automatically stopping at active crossings.
- Furthermore, IVWS is inherently **compatible with future Intelligent Transport Systems (ITS)** and will be capable of interfacing with **fully autonomous vehicle platforms** as they are gradually introduced. This ensures the technology remains relevant and scalable in both the short term and long term, supporting a **cost-effective, policy-aligned national safety strategy** through ADR mandates and staged rollout programs.

Reference Material

1. **NTSB Study SS-98-02 (1998)"** *"Safety at Passive Grade Crossings"* National Transportation Safety Board
https://www.ntsb.gov/safety/safety-studies/Documents/SS9802.pdf

2. **NTSB Study SS-98-03 (1998)** *"Highway-Rail Grade Crossing Active Warning Device Issues"*
https://www.ntsb.gov/safety/safety-studies/Documents/SS9803.pdf

3. **La Trobe University Trial (2013)** *Trial of DSRC-based In-Vehicle Warning System in Victoria*
(No public direct URL found; contact La Trobe Centre for Technology Infusion or VicRoads)- but see video: https://www.youtube.com/watch?v=H_7dlr-MwGY

4. **Beanland, V. et al. (2018)** *"Evaluation of In-Vehicle Warning Systems for Railway Level Crossings"* Australasian College of Road Safety Journal
https://www.sciencedirect.com/science/article/abs/pii/S0925753517310986

5. **Larue, G. et al. (2015)** *"The Potential for In-Vehicle Warnings to Improve Safety at Passive Rail Crossings"* Centre for Accident Research & Road Safety – Queensland (CARRS-Q), QUT
https://research.qut.edu.au/carrsq/

6. **Nadri, M. et al. (2023)** *"Improving Safety at Highway-Rail Grade Crossings Using In-Vehicle Auditory Alerts"* published in: Accident Analysis & Prevention
https://pubmed.ncbi.nlm.nih.gov/36179543/

7. **ATSB Report RS-2021-001 (2024)** *"Level crossing collisions involving trains and heavy road vehicles"* Australian Transport Safety Bureau
https://www.atsb.gov.au/sites/default/files/2024-04/RS-2021-001%20Final%20v1.2.pdf

8. **FRA Rail Crossing Violation Warning (RCVW) Program (2016–2021)** U.S. Federal Railroad Administration
https://railroads.dot.gov/sites/fra.dot.gov/files/2022-02/RCVW%20Phase%20II%20Project%20Report.pdf

9. **U.S. DOT ITS Evaluation: Illinois On-Board Advisory Warning Pilot (1997–2002)** Referenced in: *ITS Benefits and Costs Report, U.S. DOT Volpe Center*
https://www.ideals.illinois.edu/items/46357

10. **Callaghans Lane RASX Trial (NSW)**
NSW Government & ARTC (part of Regional Australia Level Crossing Safety Program)
https://www.artc.com.au/artc-news/new-level-crossing-technology-trial-underway/ and

11. **Queensland RASX Trials – Oakey & Thallon**
Queensland Rail / TMR
https://www.railsafetysystems.com.au/wp-content/uploads/2023/01/RAXS-feature-RailwayDigestAugust2022.pdf and https://www.tmr.qld.gov.au/safety/rail-safety/level-crossing-safety

12. **Australian Design Rules (ADR) – Heavy Vehicle Safety Standards** Department of Infrastructure, Transport, Regional Development, Communications and the Arts
https://data.gov.au/data/dataset/road-vehicles-australia-january-2024 and
https://www.bitre.gov.au/sites/default/files/documents/bitre-road-vehicles-australia--january2024.pdf

13. **Bureau of Infrastructure and Transport Research Economics (BITRE)** *Vehicle Registration Statistics – Australia (2023–2024)*
➤ https://www.bitre.gov.au/publications/2023/motor-vehicle-census-2023

■ Discussion: IVWS+Conventional+RASX Rail Crossing Protection Systems

14. **LSM Technologies- LSM TrainSense® / BridgeSense®** Product Info + Case Studies
TrainSense: https://go.lsm.com.au/TSense
BridgeSense: https://go.lsm.com.au/BSense

15. **ARTC- Australian Rail Track Corporation:** *Safety Around Level Crossings*
https://www.artc.com.au/community/safety-around-level-crossings

16. **ADR 97/00: Advanced Emergency Braking for Omnibuses and Medium/Heavy Goods Vehicles: Mandates AEB systems on new model buses from 1 November 2023, all buses from 1 November 2024, and all heavy goods vehicles > 3.5 t GVM from 1 February 2025.**
https://www.legislation.gov.au/F2022L00211

17. **ADR 108/00 – Reversing Safety: Mandates reversing safety systems addressing human factor limitations of visual/audible-only alerts; implemented via Australian Design Rule standards.**
https://www.legislation.gov.au/F2023L01006

18. **U.S. Mandate – AEB standard on all new passenger vehicles by September 2029: NHTSA finalized FMVSS-127 requiring AEB- including pedestrian detection—on all cars and light trucks by September 2029. Estimated to save ~360 lives and prevent 24,000 injuries annually.**
https://www.nhtsa.gov/press-releases/nhtsa-fmvss-127-automatic-emergency-braking-reduce-crashes