



RoT STUDIO
Realization of Things



INDUSTRY SERIES 01

AUTOMOTIVE
2026 EDITION

VIRTUAL REALITY ON THE AUTOMOTIVE LINE

AN EVIDENCE-BASED **VR GUIDE** FOR AUTOMOTIVE PLANT, TRAINING AND ENGINEERING LEADERS

How OEMs and suppliers use VR for model changeover training, EV workforce readiness, ergonomics and design review. What the field studies show, what the plants report, and how to build the business case.

Includes the Ford Otosan Romania case
210 VR assembly training sessions in the first 2.5 months

rotstudio.com
Eindhoven / Istanbul / Ankara

Who this is for, and what it will not do

This guide is written for the people who have to deliver a new model, a new powertrain or a new line with the workforce they actually have.

That means plant and production managers, training and L&D leads, manufacturing and industrial engineers, HSE managers and the engineering directors who own design review. It is not written for investors or technology analysts, so you will find no market-size forecasts here. Headset shipment curves do not help anyone plan a changeover.

What you will find is evidence. Every number is tied to a named source on the last page, with the year it was published and, where it matters, who paid for the study. Where a figure comes from a vendor or a commissioned report, we say so. Where the research base is thin, we say that too.

The structure follows the questions we hear most often from automotive teams: why the training load is rising, what VR has been shown to do, where it fits on the floor, how to build the case, and how to start without a development studio. Read it front to back, or jump to the chapter closest to the problem on your desk this quarter.

01	The workforce problem behind every launch	4
	EV transition, model changeover and the skills gap, in numbers	
02	What the evidence says about VR training	6
	Speed, retention, confidence and cost, with the caveats	
03	Assembly training and model changeover	8
	How plants train before the first physical vehicle exists	
04	Case study: Ford Otosan Romania	10
	Preparing Craiova's assembly lines for electric production	
05	EV readiness and high-voltage safety	12
	Battery assembly, isolation procedures and the hazards you cannot stage	
06	Design review, virtual prototyping and ergonomics	14
	Replacing physical bucks, with the Fiat TOFAŞ motion-capture system	
07	Building the business case	16
	Cost drivers, break-even logic and the KPIs that survive an audit	
08	The 90-day implementation playbook	18
	Station selection, in-house authoring, hardware and measurement	
09	Readiness checklist, about RoT STUDIO, sources	20
	Self-assessment, how to start, and every reference used	

The vehicle is designed in a digital world. Training the people who build it should start there too.

For most of automotive history, training a worker to assemble a new model meant waiting for the model to exist.

A pre-series vehicle arrives, a trainer gathers two or three operators around it, and the rest of the shift waits its turn. When the vehicle moves on to the next station, the previous process cannot be practised again. When a sequence changes, the physical property is already out of date.

This was tolerable when model cycles were long and powertrains were stable. It is not tolerable now. The same plant may run combustion, hybrid and fully electric variants on one line. High-voltage systems have arrived on the assembly floor. Launch windows have shortened, and the labour market is not supplying experienced operators in the numbers the industry needs.

Virtual reality does not solve the labour market. What it does is remove the dependency between training and the physical vehicle. The CAD data that defines the car becomes the environment in which people learn to build it, weeks before the first body reaches the line. Every station can be rehearsed, in any order, by as many people as there are headsets.

We have watched this shift from the inside. RoT STUDIO has been building immersive content for industrial customers for more than two decades, and the automotive sector was among the first to ask for it. This guide collects what the research says and what plants report, including our own work with Ford Otosan Romania and Fiat TOFAŞ, so that you can judge the case on evidence rather than enthusiasm.



I am really happy to say that designing my own training scenarios with only CAD knowledge is exciting! No-code platforms are getting stronger and RoT is one of the best so far with its very realistic environment and 1:1 experience as real-life.

Girlea Alexandru, Virtual Trainer, Ford Otosan Romania

The workforce problem behind every launch

Ask a plant manager what keeps a launch on schedule and the answer is rarely the robots. It is whether the people on the line know the new process before the ramp curve starts.

Three forces are pushing the training load upward at the same time, and each one makes the traditional approach of waiting for a physical vehicle more expensive.

The powertrain transition

More than one million workers are directly involved in manufacturing vehicles and parts in the United States alone, and the shift to battery electric vehicles touches a large share of them.¹ The transition requires new digital, advanced manufacturing and specialised skills, and it affects plants in the traditional hubs as much as the new battery sites.¹ In a 2024 employer survey, 59 percent of automotive manufacturers saw the shift as an opportunity, which is encouraging, but only if the workforce can be moved across in time.¹

European respondents put the problem more bluntly. In the ABB and Automotive Manufacturing Solutions survey, 52 percent identified a stark lack of EV and battery skills as a key reason targets might slip.²

The skills shortage

Labour and skills shortages now rank as the second-biggest challenge in automotive manufacturing. Thirty percent of industry decision-makers in the 2025 AMS and ABB Outlook Survey named growing labour costs and skills shortages as a critical concern, behind only cost pressure.³ Competition from other industries for the same talent was cited by 35 percent.³ Only 19 percent reported expanding employee training and upskilling programmes in response.³

That gap between the size of the problem and the size of the response is where most launch risk now sits.

The changeover itself

Introducing a new model to a running line is a well understood challenge. What is less often quantified is how little training capacity a physical vehicle actually provides. Before Honda's East Liberty plant moved to virtual training for the 2022 Acura MDX, the team typically had one vehicle to train on, and could train only two or three people on it at any one time. On a given shift, more than 400 associates might be working through the assembly process.⁴

One vehicle, three trainees, four hundred people. That ratio, more than any headset specification, is the reason VR arrived on the assembly floor.

30%

of automotive decision-makers name labour cost and skills shortages a critical concern

AMS / ABB Automotive Manufacturing Outlook Survey 2025, 400+ respondents

52%

of European respondents report a stark lack of EV and battery skills

ABB Robotics / AMS industry survey, Europe

19%

report expanding training and upskilling programmes in response

AMS / ABB Outlook Survey 2025

1M+

US workers directly employed in vehicle and parts manufacturing during the BEV transition

World Resources Institute, 2025

2 to 3

operators who can train on a single physical pre-series vehicle at one time

Honda East Liberty Auto Plant, reported 2021

400+

associates working through the assembly process on a single shift at the same plant

Honda East Liberty Auto Plant, reported 2021

Why the old model breaks at exactly the wrong moment

Physical training properties fail in a predictable sequence. They arrive late, because pre-series builds are themselves on the critical path. They are scarce, because every prototype has a queue of engineers waiting for it. They are rigid, because an operator cannot practise suspension fitting until every preceding process has been completed on that body. And they are fragile, because the moment a sequence is revised the property no longer matches the standard.

Jaguar Land Rover's engineers listed the same failure modes when interviewed by the University of Nottingham: the time to produce a physical property is long and slows the review, physical properties are difficult to alter, they take space, and if they are not produced, issues surface late in the development process.⁵ Those were design-side

complaints, but any training lead will recognise them.

The common thread is that the physical vehicle is the bottleneck for both engineering and training, and both functions want it at the same time. Removing that dependency for training frees the prototype for the engineers and lets operators start weeks earlier.

The question this guide answers

Not "is VR impressive", but "does training in a virtual replica of the station transfer to the physical line, at what cost, and how fast can we build it ourselves". The next chapter takes the first part of that question to the research.

What the evidence says about VR training

The research on immersive training is now large enough to separate durable findings from marketing. Four results repeat across independent studies: faster time to competence, higher confidence, better retention, and lower cost at scale.

Speed and confidence

The most cited enterprise study is PwC's 2020 efficacy trial, which trained employees on the same course in a classroom, through e-learning, and in VR. VR learners completed the training up to four times faster than classroom learners, reported being 275 percent more confident in applying what they learned, were 3.75 times more emotionally connected to the content than classroom learners, and were four times more focused than e-learners.

⁶ The course was a soft-skills programme, so the speed figure should not be copied directly onto an assembly task. The confidence and focus effects, however, are precisely the ones a trainer wants before a new operator meets a moving line.

Transfer and retention on real assembly tasks

The automotive-specific evidence is smaller but direct. In a field study at an automotive factory, novice assembly workers were trained on a centre-console installation either in an immersive virtual training environment or conventionally on the

physical car. The VR group showed positive transfer of the acquired procedure to physical assembly, and performance improved over time.⁷

Earlier, the EU-funded VISTRA project tested a virtual training system with real end users at the Opel plant in Rüsselsheim. Virtual training was effective in reducing error during task performance compared with traditional training, and participant opinion was mainly positive.⁸

On retention, the Nottingham group found that for assembly and disassembly tasks, recall after two and four weeks was higher for participants trained in VR than with other systems, and that simulated training lifted task completion from the 50th to the 66th percentile.⁵

Certification and safety outcomes

Forrester's 2025 study records one manufacturing interviewee whose certification pass rates rose from around 50 percent under traditional methods to more than 90 percent with VR.¹⁰ On the safety side, Ford's motion-capture ergonomics programme on the assembly line was associated with a 70 percent drop in employee injuries and a 90 percent reduction in ergonomic issues, as reported in 2015.¹⁵ At Craiova, Ford Otosan Romania's training team reports significantly fewer critical errors in assembly steps and a contribution to fewer on-site injuries after moving assembly training into VR.¹³

Time to competence, as measured in the studies

Relative values, each against its own study's conventional baseline. Studies differ in task, sample and sponsor; they are shown together to indicate direction, not to be averaged.



Sources: PwC VR Soft Skills Efficacy Study 2020 (up to 4x faster); Forrester TEI 2025, composite organisation (12 to 9 business days onboarding) and manufacturing interviewee (8 weeks to 6 weeks).

The cost curve

VR carries fixed costs that classroom training does not: headsets, content and onboarding. PwC modelled the point at which those fixed costs are recovered. Including onboarding time, VR reached cost parity with classroom delivery at only 375 learners. At 3,000 learners VR was 52 percent cheaper than classroom, at 6,000 learners 58 percent cheaper, and at 10,000 learners 64 percent cheaper.⁶ Against e-learning, which has no facilitator, parity arrived later, at 1,950 learners.⁶

For a single automotive plant with a few thousand operators and a changeover every two to three years, those thresholds are crossed inside the first programme.

Forrester's 2025 Total Economic Impact study, commissioned by Meta, built a composite organisation of 10,000 employees with a third training in VR each year. It found a 219 percent return on investment over three years, with onboarding accelerated by 25 percent and task-worker training time reduced by up to 75 percent.¹⁰ One manufacturing interviewee cut crane-operator training from eight weeks to six, and saw certification pass rates rise from around 50 percent under traditional methods to more than 90 percent with VR.¹⁰ The sponsorship is a reason to

treat the headline multiples cautiously, and the plant-level figures as the more useful part.

What the research does not yet prove

Three limits are worth stating plainly, because a training manager will be asked about them.

Sample sizes in automotive field studies are small. A 2026 pilot with eleven operators found a positive user experience but noted that perceived body ownership needed improvement and that results warranted caution.¹¹ Haptics remain incomplete: JLR's engineers reported missing weight, torque and collision feedback, which matters for fitting technique even if it matters less for sequence and location learning.⁵ And trainer practice shapes results as much as the technology does; the Austrian field study concluded with recommendations for trainers, not for headset makers.⁷

The honest summary is this. VR reliably teaches what to do, where, and in what order, faster and with better recall than observation. Learning the physical feel of a fit still happens on the line, but the operator arrives already knowing the process. That is exactly the division of labour the plants in the next chapter describe.

Assembly training and model changeover

The clearest automotive use case is also the oldest. Motorola built a VR system to train assembly line employees in 1995 and concluded it worked at least as well as classical training.⁹ What has changed is that the environment can now be generated from the vehicle's own CAD data, by the plant itself, before any physical body exists.

Honda East Liberty: training before the vehicle arrives

For the 2022 Acura MDX launch, Honda's Ohio plant deployed an interactive 3D virtual training system that recreated every assembly step across four levels of difficulty. Because the vehicle design existed in digital form, the training team could begin far earlier, without a physical vehicle in place. Before mass production started, the plant had trained more than 1,500 associates and logged over 8,000 training cycles.⁴

The operational effects went beyond headcount. Trainers could run sessions at multiple stations with the car in different stages of assembly, something impossible on a single physical body. Associates arrived on the line already knowing the

process steps, so trainers could concentrate on fitting technique. Processes that had historically caused quality issues at launch produced, in the team's words, virtually none. When an associate reported difficulty with a task, the issue was reviewed in the virtual tool after the shift and resolved by the next one, where previously it might have taken a couple of weeks.⁴

There was a design dividend too. During virtual training, associates identified that re-sequencing water hoses would improve the process, and the change was adopted. Engineering also used the tool to simulate assembly impact during the design phase, which led to changes in the vehicle itself.⁴

BMW: VR as standard for a battery plant

By July 2026, BMW Group reported that all production staff at its new high-voltage battery plant in Woodruff, South Carolina complete a VR training programme developed on site, following earlier use of VR in high-voltage battery assembly at the group's pilot plant in Parsdorf.¹² A programme that covers every production employee at a greenfield EV plant is a useful signal of where the practice has settled: not a pilot, but a step in standard onboarding.

Ford Otosan Romania: 210 sessions in 2.5 months

At the Craiova facility, the assembly workforce was prepared for electric variants using VR modules built in the no-code RoT STUDIO Trainer module. Rather than adding more physical training stations, the plant moved its assembly training from physical methods to a faster, more flexible 3D virtual reality environment. In the first two and a half months of deployment, 210 training sessions were delivered, operators reached the actual vehicles already knowing the process, and the plant planned further modules for upcoming models.¹³ The full case is on the next spread.

What these plants have in common

The programmes differ in platform, headset and country, but the operating pattern is the same, and it is the pattern worth copying.

1. **Training starts from design data.** The CAD that defines the product becomes the training

environment, so the calendar no longer waits for a prototype.

2. **Every station is available at once.** The virtual vehicle can be at any stage of assembly for any trainee; throughput is limited by headsets, not by one body.
3. **Content is owned by the plant.** Honda's trainers and Ford Otosan's virtual trainer both built their own modules, with CAD knowledge rather than code. Ownership keeps content in step with revisions.
4. **VR teaches sequence; the line teaches feel.** Operators arrive knowing the process, and time with the physical vehicle goes to technique.
5. **Feedback flows back to engineering.** Operators rehearsing in VR notice sequencing and access issues before production does.

1,500+

**associates trained and
8,000+ cycles logged before
Acura MDX mass
production began**

Honda East Liberty, 2021

100%

**of production staff at
BMW's Woodruff battery
plant complete a VR
programme developed on
site**

BMW Group, July 2026

210

**VR assembly training
sessions delivered in the
first 2.5 months at Craiova**

Ford Otosan Romania and RoT
STUDIO

Honda's system was an interactive touch-screen 3D simulation; BMW and Ford Otosan used headsets. The ramp-up logic is identical. Headsets add spatial memory of where parts, tools and shelves sit relative to the body, which is why most new deployments in the sector are immersive.

Ford Otosan Romania: assembly lines get ready for an electric future

Ford Otosan's Craiova facility plays a key role in Ford's electrification and commercial vehicle growth plans for Europe. It builds Ford's best-selling European passenger and commercial vehicles, and began preparing for all-electric versions in 2024.¹³

The challenge

Introducing a new model to the production line and preparing the workforce to build it are familiar challenges. Craiova needed to transform its assembly training operations to ramp up mass production of the new models in the most effective way, while staying competitive, meeting changing demands and regulations, and maintaining customer interest.¹³

The existing approach shared the constraint every plant knows: one vehicle, a few operators at a time, and no way to rehearse a later station until the earlier ones were done on that body.

The solution

The training team chose the no-code Trainer module of the RoT STUDIO platform. A holistic virtual 3D model of the assembly line was prepared, and every assembly procedure and step was recreated in the module. Operators practise assembling vehicles with the full sequence, parts and tools, following each instruction, and can repeat any fitting action as many times as needed.¹³ Rather than adding more physical training stations, the plant decided to move its assembly training from physical methods to a faster, more flexible 3D virtual reality environment.



The Trainer module presents the vehicle at any assembly state, so a trainee can open the hood, remove a door or start from a bare body without waiting for preceding stations.

At a glance

Industry Automotive manufacturing

Customer Ford Otosan Romania, Craiova facility

Challenge Transform assembly training to ramp up mass production of new models in the most effective way

Solution RoT STUDIO Trainer module, no-code

Result 210 training sessions delivered in the first 2.5 months

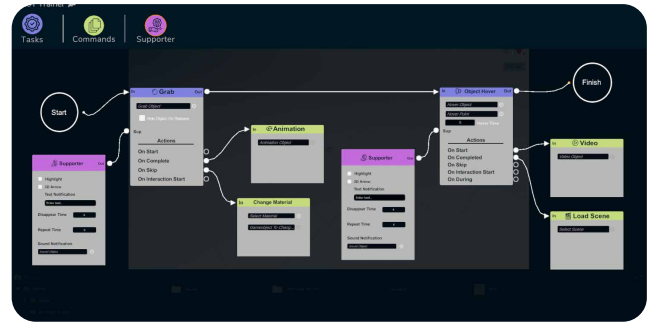
What the Trainer module gives operators

- A three-dimensional space that simulates the real assembly environment
- A step-by-step guide for each operation
- The exact arrangement of machines, shelves, tools and parts along the line
- Unlimited repetition of every assembly and fitting action
- Delivery through VR glasses, so spatial memory of the station is built before the first shift

Results of VR-based assembly training

Two hundred and ten training sessions, developed on the RoT STUDIO platform, were held in the first two and a half months of deployment. The Craiova training team reports a more controlled, effective and safer training environment without any physical vehicle or prototype, operators who already know the process before they reach the actual vehicles, significantly fewer critical errors in assembly steps, and a contribution to reducing on-site injuries.¹³

Beyond session numbers, the programme gave assembly workers practical EV manufacturing skills ahead of electric production, while improving productivity, safety and adaptability on the line. Because the modules are configured rather than coded, the plant plans further modules for upcoming models and versions.¹³



Trainer logic is built from three node types: Task nodes (such as grab and hover), Command nodes (such as animation, video, material change and scene loading) and Supporter nodes (highlights, 3D arrows, text and sound notifications). The Craiova team designed its modules without writing code.

Why no-code mattered here

According to the Craiova training team, the platform allowed them to design assembly line training modules quickly and easily, without writing any code.¹³ Each new model version arrives with new sequences, parts and tools, and the content has to follow on the plant's timeline rather than a supplier's. A module library the training team builds and edits itself, from the 3D data engineering already holds, turns a recurring launch cost into a capability the plant keeps. The team also noted that the RoT team's solution focus during deployment kept the schedule.¹³



Our Craiova facility is improving its assembly line operations through Virtual Reality based trainings, with the support of RoT STUDIO Trainer module. Instead of having one vehicle and training a few assembly operators at once, the RoT STUDIO Trainer module has allowed us to train more operators virtually on any stage of the assembly process. It gives us more flexibility, efficiency and focus, while shortening the time to improve the overall assembly process.

Ford Otosan Romania training team, Craiova facility

EV readiness and high-voltage safety

Electrification adds a category of training that the combustion era never required on the general assembly floor: work on and around systems that can injure or kill through electric shock, arc flash and thermal runaway.

The training problem has two layers. The first is procedural: battery pack handling, module and cell assembly, high-voltage connector sequences, isolation and lockout before intervention, and the personal protective equipment that goes with each step. The second is behavioural: recognising the hazard in a working environment and responding correctly when something deviates from the plan.

Both layers run into the same obstacle. Realistic practice on live high-voltage equipment is slow, expensive to supervise and, by definition, dangerous to get wrong. As one XR business development manager at an automotive manufacturer told Forrester, training on high-voltage products required a great deal of care and oversight per trainee, which limited how many people could train at a given time.¹⁰

What the leading plants are doing

BMW Group used virtual reality in high-voltage battery assembly at its Parsdorf pilot plant, and by mid-2026 every production employee at its Woodruff battery plant completes a VR programme developed on site.¹² At Ford Otosan Romania, the move to VR assembly training was tied directly to the arrival of all-electric versions on the Craiova lines, so that operators gained practical EV

manufacturing skills before electric production began.¹³

The pattern is the same one seen in assembly training. Procedures that are hard to rehearse physically are rehearsed virtually, repeatedly, by everyone, and the physical environment is reserved for supervised confirmation.

Why VR fits high-voltage work specifically

Three properties of immersive training line up with the high-voltage problem unusually well.

Consequence without harm. A trainee who skips an isolation step in VR can be shown the arc, the alarm or the thermal event that would have followed. In a classroom the consequence is a slide. On real equipment it is not available at all.

Procedural fidelity. Lockout-tagout, de-energising, verification and PPE sequences are order-dependent. VR scenarios enforce order and record deviations, which produces the competency evidence auditors ask for. Safety cues live inside the scenario. In the Ford Otosan Romania modules, Supporter nodes deliver prompts such as "Wear your safety glasses" at the exact step where they apply, so your operators meet the rule in context rather than on a poster.¹³

Spatial recognition. Operators learn where the high-voltage components, interlocks and emergency stops are on their own line, because the scenario is built from their line's geometry rather than a generic set.

A scenario map for EV production and service training

Typical modules automotive customers request, grouped by where they sit in the operation. Each row can be built from facility CAD and existing procedures.

Area	Scenario	What the trainee practises
Battery module and pack assembly	Cell-to-module handling, pack sealing, busbar and connector sequence, torque confirmation	Order of operations, tool selection, interlock checks
High-voltage safety	De-energising, isolation, verification of zero voltage, PPE selection and inspection	Lockout-tagout discipline, recognition of live-work boundaries
Emergency response	Thermal runaway indicators, evacuation, fire suppression limits, first response to electric shock	Decision speed under time pressure, escalation
Marriage and final assembly	Pack-to-body marriage, high-voltage harness routing, end-of-line checks	Clearance awareness, sequence, quality gates
Service and dealer networks	EV diagnostics, charging system service, battery management interpretation	Procedures for mixed-fleet technicians
Logistics and storage	Battery storage conditions, damaged-pack handling, transport labelling	Hazard recognition in warehouse context

Where VR stops and physical confirmation starts

VR is not a substitute for a live-work permit, a multimeter in hand, or a supervisor's sign-off. In a well-designed programme it sits before those things. Trainees complete the virtual scenarios, their session data shows which steps were performed correctly and which were repeated, and the supervised physical assessment is shorter because it confirms competence rather than teaching it.

That division also answers the regulatory question. VR session records support internal competency documentation, and in many frameworks they satisfy audit expectations for the knowledge component. Plants under specific compliance scrutiny should confirm scope with the relevant regulator during evaluation, as RoT STUDIO advises its own customers.¹⁴

Related HSE scenarios already in catalogue form

Not every safety module needs to be built from scratch. Lockout-tagout, fire extinguisher use, working at height, industrial fire awareness and hazard hunts are generic enough for ready-made catalogue modules, with plant-specific high-voltage content layered on top. RoT STUDIO's HSE catalogue covers these, and one viewer runs catalogue and custom scenarios on the same headset fleet.¹⁴

Procedures are written down; hazard recognition is not. The value of rehearsing a thermal event or an isolation failure in VR is that the operator has seen it once before, in context, with their own hands. That prior exposure is what changes behaviour in the first seconds of a real incident.

Design review, virtual prototyping and ergonomics

The automotive industry adopted VR for engineering long before it adopted it for training. Volkswagen began investigating the technology in 1994, and BMW was using it to analyse products in the design phase by 1999, finding it could reduce the number of model versions required.⁹

The economic logic has not changed since. Early design decisions can determine up to 70 percent of a product's total cost, and reworking them once physical mock-ups exist is slow and expensive.⁵ Virtual prototypes let those decisions be reviewed, and reversed, before a buck is built.

What the engineers at a global OEM actually use VR for

When the University of Nottingham interviewed eleven engineers at Jaguar Land Rover's Virtual Innovation Centre, the list of day-to-day uses was concrete rather than visionary: experiencing the vehicle architecture, assessing vision, perceiving a surface change, studying access to fluid tanks, calibrating perception before a prototype exists, motion capture of manufacturing tasks, reviewing driving position, and solving issues during

stakeholder reviews.⁵ Virtual properties were used earlier in the process than physical ones, or when no physical property was available.

The interviewees also described what physical properties cost them: not every variant can be built, components are evaluated out of context, electric features wait for driveable vehicles, competitor cars are expensive to obtain, and clay properties are difficult, expensive and secrecy-sensitive to ship.⁵ Volkswagen IT reported to Capgemini one VR proof of concept that replaced a prototype which would otherwise have cost around four million euros.¹⁵

Ergonomics and the human on the line

The same tools that review the car can review the job of building it. Ford used body motion sensors during equipment assembly to capture human movement and re-engineer it to reduce injury risk, a programme associated with a 70 percent drop in employee injuries and a 90 percent reduction in ergonomic issues, as reported in 2015.¹⁵ Virtual assembly also allows a workstation to be evaluated against the full range of body sizes, which ergonomics practice requires and physical bucks rarely accommodate.⁵

Fiat TOFAŞ: perceived quality and ergonomics without a physical prototype

For one of Türkiye's largest vehicle manufacturers, RoT STUDIO implemented a motion-capture VR test system so that engineers could evaluate interior design, ergonomics and perceived quality before physically constructing the vehicle. The system was developed with support from TÜBİTAK, Türkiye's scientific and technological research council, with Fiat TOFAŞ as user and project partner.¹⁶

The installation combines the RoT STUDIO Designer, Connect and Ergonomics modules with an OptiTrack tracking volume: twelve Prime 17W cameras, four active pucks and passive trackers capturing a 6 by 11 metre area, with Vive Pro and XTAL head-mounted displays. A seating buck provides a forward-backward and height-adjustable seat and steering wheel. The user's body is tracked with a suit and finger movements with a glove.¹⁶

Inside the virtual car, engineers walk around the prototype, perform geometric analysis and perceived-quality studies, and compare field of vision, visibility and reachability against a same-class competitor vehicle, without buying that vehicle. An automotive menu defines the H-point for two different vehicles; from that seating reference, visibility through front and side windows and hand reachability are assessed on the virtual prototype.¹⁶

The thread that links design and training

The same CAD model that engineers review in the Designer module becomes the training scenario operators rehearse in the Trainer module. Nothing is rebuilt or re-exported by a studio in between. When the design revises, the training follows on the engineering timeline rather than a vendor's. For

System summary

Modules RoT Designer, Connect, Ergonomics

Tracking 12 OptiTrack Prime 17W cameras, 4 active pucks, passive trackers, 6 x 11 m volume

Displays Vive Pro, XTAL

Buck Adjustable seat and steering wheel, body suit and finger glove

Analyses Geometric, perceived quality, H-point, visibility, reachability, collision checks, assembly procedure simulation

Shared review across sites

More than one engineer can join the same immersive scene and annotate with a brush tool, so a review in Bursa can include colleagues elsewhere. JLR's engineers named travel to the VR facility as one of their main frustrations; networked review is the answer the literature recommends.⁵

a plant this means the design review investment and the training investment share one asset, one licence and one headset fleet.

It also means the Honda effect described in Chapter 3, where operators rehearsing a process found a better hose sequence, becomes systematic rather than lucky. Assembly feedback has a route back to the geometry it came from.

Building the business case

A VR training case that survives a finance review is built on plant numbers, not vendor multiples. The published studies supply the structure and the direction of each effect. Your own data supplies the magnitude.

The cost side

Four cost lines are usually enough. Headsets, at current standalone prices, are the smallest. Content is the largest if it is outsourced to a development studio in four-to-six-month cycles, and much smaller if the plant authors it in-house from existing CAD.¹⁴ Authoring training for in-house staff is typically measured in days. And trainee time, which a classroom case also carries, is the line that VR shortens.

The benefit side

The benefits fall into five groups, each of which has a measured analogue in the evidence base.

Shorter time to competence. PwC measured up to four times faster for a soft-skills course; the

Forrester manufacturing interviewee reported 25 percent for crane operators.^{6,10} Use the lower figure for a conservative case.

Fewer launch-phase defects and line stops. Honda reported virtually no process-driven quality issues at the MDX launch; Ford Otosan Romania reports significantly fewer critical errors in assembly steps.^{4,13} Price this against your own cost of a line stop and your launch-curve scrap and rework budget.

Freed physical prototypes. Every hour a pre-series vehicle is not used for training is an hour available to engineering. The JLR interviews show how scarce that time is.⁵

Fewer injuries during early learning. Ford's motion-capture ergonomics work was associated with a 70 percent drop in injuries; Ford Otosan reports a contribution to fewer on-site injuries.^{15,13} Use your own recordable-incident cost.

Reduced travel and trainer time. Forrester's composite avoided around half of training-related travel expenses.¹⁰ For multi-site groups this is often the easiest line to defend.

A worksheet for the first programme

Fill the right-hand column from plant data. Where you have no figure, use the conservative external value and mark it as an assumption. Inputs are deliberately few; a case with twelve variables is easier to attack than one with six.

Input	Conservative external reference	Your plant
Operators to train in the first programme	PwC parity at 375 learners vs classroom	
Current training days per operator per changeover	Forrester composite: 12 business days onboarding	
Expected reduction in training time	25% (Forrester, crane operators); up to 4x (PwC)	
Loaded cost of one operator training day	Forrester composite: 900 USD per user per day	
Cost of one unplanned line stop	Plant-specific; Ford Otosan reports fewer critical assembly errors	
Launch-curve rework and scrap budget	Plant-specific; Honda reports near-zero process issues	
Scenarios to build, and who builds them	In-house authoring: days; studio: 4 to 6 months	

How the break-even usually falls

With a few thousand operators, PwC's parity threshold of 375 learners is crossed in the first wave of one changeover, after which each additional learner is cheaper than a classroom seat.⁶ Forrester's composite reached payback in under six months, though that organisation was large and the study sponsored.¹⁰

For a plant, the more defensible framing is a per-launch comparison: the current cost of preparing the workforce for one model, including prototype time, trainer hours and launch-phase quality losses, against the same launch trained from the model's CAD. The content library then carries forward, so the second launch bears revision rather than creation.

KPIs that survive an audit

Choose measures that exist already, so the VR programme is compared with a real baseline rather than a memory of one.

- **Time to sign-off per operator per station**, measured the same way before and after
- **First-pass quality and rework during the launch curve**, by station
- **Line stops attributed to operator process error** in the first 90 days of production
- **Recordable incidents and prototype hours released to engineering** during the ramp period
- **Headset session data**: completion, errors per step and repetitions, which point the process team at the steps worth a second look. Classroom training never offered this; it turns training into a diagnostic of the process itself.

The 90-day implementation playbook

The plants that succeed with VR training share a sequence. They start narrow, author in-house, measure against an existing baseline, and only then scale. Here is that sequence as a plan.

Days 1 to 15: pick the station, not the technology

Choose one station or procedure with three properties. It is on the critical path of a coming launch or already causing quality or safety issues. Its CAD and operation standards exist and are current. And its training is constrained today by access to a physical vehicle or live equipment. High-voltage isolation, a marriage station or a complex sub-assembly usually qualify. Record the baseline KPIs from Chapter 7 for that station now.

Days 15 to 45: author the first scenarios

Decide who owns content. The evidence favours the plant. Honda's trainers plugged operation standards into their system themselves. Ford Otosan's team built modules without coding. In a no-code environment such as the RoT Designer and Trainer modules, CAD is imported directly, interactions are assembled from Task nodes (such as grab and hover) and Command nodes (such as animation, video and material change), and

Supporter nodes guide the trainee with highlights, 3D arrows and text or sound notifications. A two-day course brings engineering or training staff to working proficiency.¹⁴ Build two or three scenarios for the chosen station, including at least one error path with a visible consequence.

Days 45 to 60: pilot with the people who will run it

Run the scenarios with a trainee group and the trainers who will own the programme. Capture session data and trainer feedback. The Austrian field study found that trainer practice, not only the environment, determined learning success, so give trainers room to adapt the didactic flow.⁷ Fix the scenarios on the engineering timeline, which with in-house authoring means days.

Days 60 to 90: measure, then decide to scale

Compare the pilot group against the baseline on time to sign-off, first-pass quality and errors per step. If the direction matches the evidence base, extend to adjacent stations and bring the catalogue HSE modules onto the same headset fleet so utilisation rises. If it does not, the session data will usually show which step or which scenario design is responsible.

Three ways to source content, and when each fits

Route	Best for	Cycle time	Keeps pace with CAD revisions
Ready-made catalogue modules	Generic HSE: lockout-tagout, fire, working at height, hazard hunts	Immediate	Not applicable
Custom development by a studio	Flagship or highly specialised scenarios the plant will not edit	Months	Only through a new cycle
In-house no-code authoring from CAD	Station training, changeovers, line-specific HSE, design review	Days to weeks	Yes, on the engineering timeline

Hardware and infrastructure

Standalone headsets such as Meta Quest 3, Quest 3S and PICO 4 are the default for distributed training on the floor; PC-tethered configurations suit fixed high-fidelity stations such as the Fiat TOFAŞ ergonomics buck. The authoring workstation is standard engineering hardware, in the class of an Intel i7 with an RTX 3000-series graphics card or better.¹⁴ Reserve a quiet, clearly marked training area of a few square metres per headset, and treat headset hygiene and charging as part of the training room's standard work.

Mistakes that recur

Starting with a showcase. A beautiful generic scenario impresses visitors and trains nobody. Start with the ugly station that is costing you time.

Outsourcing the content that changes most. Launch and changeover content revises constantly. That is exactly the content a plant should own.

No baseline. Without the current time to sign-off and current launch-curve quality, the pilot cannot prove anything, however well it goes.

Treating trainers as operators of a device. They are the designers of the experience. Involve them from day one and give them the authoring tools.

Expecting VR to teach feel. It teaches sequence, location and recognition. Plan the handover to physical technique deliberately.

What good looks like at day 90

One station trained virtually by every operator who needs it, a measured reduction in time to sign-off against the old baseline, a scenario library the plant can edit, and a short list of process improvements that surfaced during rehearsal. That is a programme, and the second station costs a fraction of the first.

Is your plant ready? A twelve-point self-assessment

Tick what is true today. Eight or more and a first programme can start this quarter. Fewer than five and the preparatory work, usually CAD access and baseline measurement, comes first.

- | | |
|---|---|
| ☐ A launch, changeover or new line is scheduled in the next 18 months
There is a date the training must be ready for. | ☐ High-voltage or other hazardous procedures are entering the line
Where realistic physical practice is limited by safety. |
| ☐ Current vehicle and station CAD is accessible to the training function
Not only to engineering. | ☐ Trainers are willing to author content, not only deliver it
And can be released for a two-day course. |
| ☐ Operation standards exist for the target stations
In a form a trainer can translate into steps. | ☐ An engineering contact owns CAD revisions
So training can follow design changes. |
| ☐ Time to sign-off per operator is recorded today
So a before-and-after comparison is possible. | ☐ A physical training area and headset budget are identifiable
Even if not yet approved. |
| ☐ Launch-curve quality losses are tracked by station
Rework, scrap and line stops attributable to process error. | ☐ HSE wants catalogue modules on the same fleet
Which raises utilisation and spreads the fixed cost. |
| ☐ Training is currently constrained by prototype or equipment access
Operators wait for a vehicle or for live equipment. | ☐ Leadership will accept a 90-day pilot measured on existing KPIs
Rather than a demonstration judged on impression. |

A closing thought for the sceptic

Every study in this guide has a limitation, and we have named each one. What none of them show is a plant that went back to training on a single pre-series vehicle after rehearsing a launch virtually. The open question is not whether, but which station first.



Realization of Things

RoT STUDIO is Türkiye's first local virtual reality and extended reality content and training development platform, working globally for more than 20 years to help customers create their own immersive content in an easy, fast, accurate and collaborative way.

The company operates from Istanbul and Ankara in Türkiye and from its European headquarters at 3EALITY on the High Tech Campus in Eindhoven, the Netherlands. Automotive customers include Ford Otosan Romania and Fiat TOFAŞ; industrial deployments span manufacturing, mining, energy, healthcare and vocational education.

The product family

RoT STUDIO License. The platform for organisations that want to author and maintain immersive content in-house. The **Designer** module

imports CAD and visual 3D models and builds interactive scenes without code; the **Trainer** module turns them into step-by-step procedural training with session-level performance data. Multi-user design review, measurement and sectioning, avatars and voice chat are built in.

HSE Training Catalogue. Ready-made modules including HSE Risk Hunt, Lockout-Tagout, Fire Extinguisher, Working at Height, Industrial Fire Awareness, Earthquake and Information Security scenarios, deployable immediately on the same headset fleet.

Customized VR/XR Services. Scenario development by the RoT team for specialised content, including motion-capture ergonomics systems such as the Fiat TOFAŞ installation.

Scenarios run through the RoT STUDIO Viewer on Meta Quest 3, Quest 3S, PICO 4 and PC-tethered systems. A two-day course brings engineering or training staff to authoring proficiency.

See your own station in VR before you decide

Bring the CAD of one station or procedure and a copy of its operation standard. The RoT STUDIO team will show what a rehearsable version looks like, what it would take to build in-house, and how to measure it against your current baseline. **Book a demo with the RoT STUDIO team at rotstudio.com/contact.**

Eindhoven / The Netherlands: +31 6 1116 0980 · **Ankara / Türkiye:** +90 312 400 07 68 · **Email:** info@rotstudio.com · **Web:** rotstudio.com

Every figure in this guide, with its origin

Where a source is a vendor case study or a sponsored report, it is marked. Figures are reproduced as published; readers should consult the originals before using them in their own business cases.

- 1** World Resources Institute. US Automotive Manufacturing Workers in the Transition to Battery Electric Vehicles: An Assessment of the Impact and Opportunities. 2025. Employer survey conducted 2024.
- 2** ABB Robotics and Automotive Manufacturing Solutions. Annual industry survey, 400+ respondents; European figures on EV and battery skills as reported by AMS and trade press.
- 3** AMS / ABB Automotive Manufacturing Outlook Survey 2025, as analysed in Automotive Manufacturing Solutions, "Talent crisis accelerates as carmakers embrace automation".
- 4** Automotive Manufacturing Solutions. "VR training for assembly operations", Honda East Liberty Auto Plant, interviews with Joey Sippel and Bill Ramsey. Published May 2021, updated July 2025.
- 5** Lawson G., Salanitri D., Waterfield B. The Future of Virtual Reality in the Automotive Industry. University of Nottingham Human Factors Research Group and Jaguar Land Rover Virtual Innovation Centre. Funded by JLR. Includes Gomes de Sá and Zachmann 1999 (70% of cost), Stone 2001 (50th to 66th percentile), Borsci et al. (retention at two and four weeks).
- 6** PwC. The Effectiveness of Virtual Reality Soft Skills Training in the Enterprise: A Study. 2020. Classroom, e-learning and VR cohorts on one course; cost-parity model including onboarding.
- 7** AIT Austrian Institute of Technology. Learning Success in Immersive Virtual Reality Training Environments: Practical Evidence from Automotive Assembly. Field study in an automotive factory, centre-console assembly, between-subject design.
- 8** Establishing the Usability of a Virtual Training System for Assembly Operations within the Automotive Industry. Human Factors and Ergonomics in Manufacturing & Service Industries. VISTRA project (FP7-ICT-285176), end users at the Opel plant, Rüsselsheim.
- 9** Firu A.C., Tapîrdea A.I., Feier A.I., Drăghici G. Virtual reality in the automotive field in Industry 4.0. Materials Today: Proceedings, 2021. Source for the BMW 1999, Motorola 1995 and Volkswagen 1994 references.
- 10** Forrester Consulting. The Total Economic Impact of Meta Quest. July 2025. Commissioned by Meta. Composite organisation of 10,000 employees; manufacturing interviewee figures on crane-operator training and certification pass rates; XR business development manager, automotive manufacturing, on high-voltage training oversight.
- 11** De Vestel C., Zogopoulos V. Virtual Reality Training for Assembly Operators in the Automotive Industry: A Pilot Usability Study. Virtual Worlds, 2026. Eleven operators.
- 12** BMW Group PressClub. Photo captions: "Use of virtual reality in high-voltage battery assembly, BMW Group Pilot Plant Parsdorf" and "All production staff at BMW Group Plant Woodruff complete a VR training program developed on site", July 2026.
- 13** RoT STUDIO. Ford Otosan Romania case study: Assembly Lines Get Ready into "Electric Future" with RoT STUDIO's Virtual Reality Training Solutions. rotstudio.com/case-studies.
- 14** RoT STUDIO. "From CAD to VR Training in Days: How RoT Designer Bridges Engineering and L&D", 2026, and product pages for the RoT STUDIO License, HSE Training Catalogue and Customized VR/XR Services.
- 15** Capgemini Research Institute. Augmented and Virtual Reality in Operations: A guide for investment. 2018. Volkswagen IT prototype example; Ford motion-capture figures citing The Detroit News, July 2015.
- 16** RoT STUDIO. "RoT STUDIO Implements Perceived Quality and Ergonomics Test System with OptiTrack for TOFAŞ". Developed with TÜBİTAK support.

Virtual Reality on the Automotive Line. Industry Series 01, Automotive, 2026 Edition. Published by RoT STUDIO. Ford, Honda, BMW, Jaguar Land Rover, Volkswagen, Opel, Motorola, Fiat, TOFAŞ, Meta Quest, PICO, OptiTrack, Vive and XTAL are trademarks of their respective owners and are referenced for identification only. The Fiat TOFAŞ and Ford Otosan Romania projects are RoT STUDIO deployments; all other company examples are drawn from the published sources listed above.