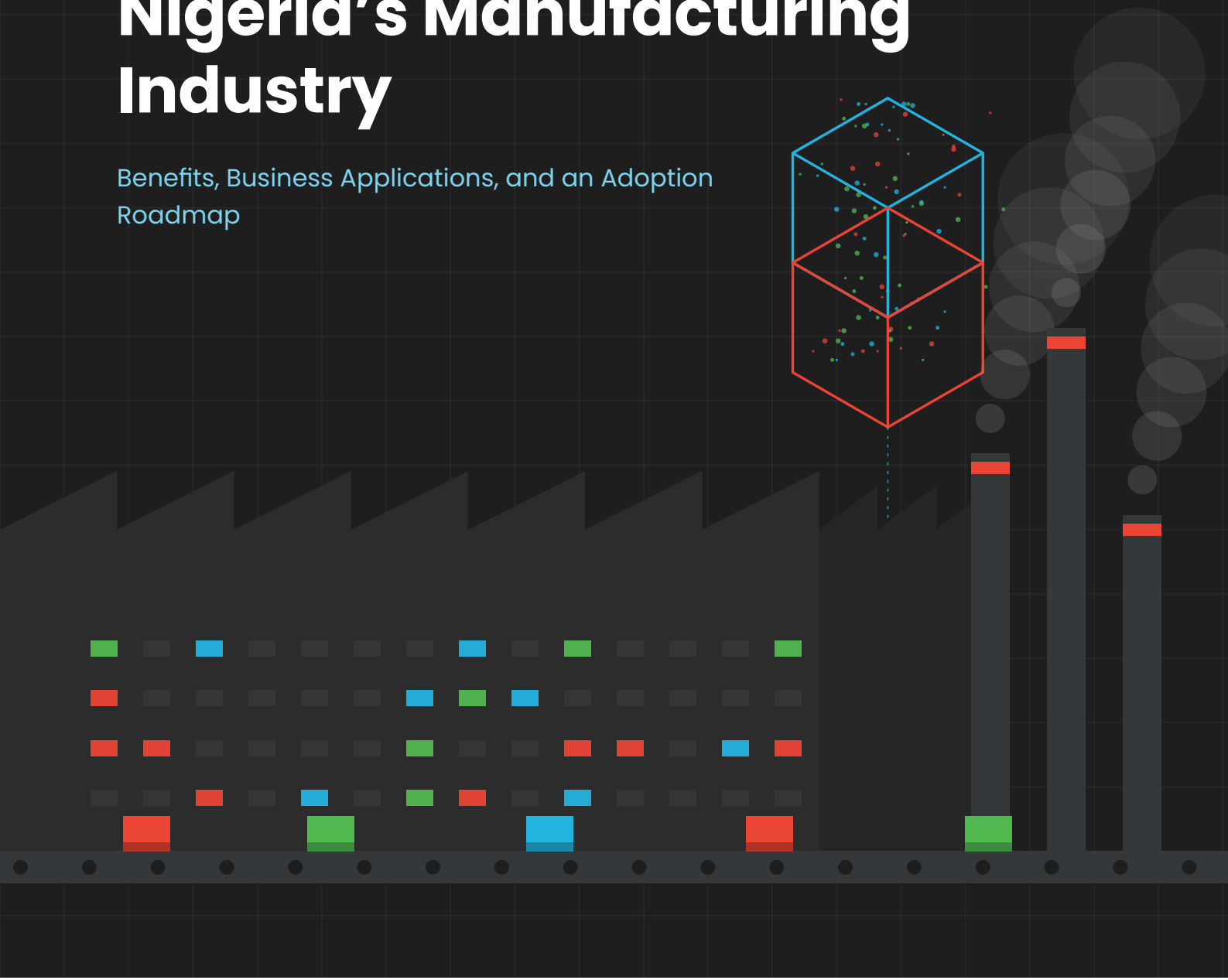
Insightful 3D

WHITE PAPER · NOVEMBER 2026

Extended Reality (XR) in Nigeria's Manufacturing Industry

Benefits, Business Applications, and an Adoption Roadmap



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A guide to the evidence, applications and adoption roadmap for Nigerian manufacturers.

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Executive Summary

Nigeria's manufacturing sector remains a strategic pillar of the economy but continues to operate below its potential. Modest growth, low capacity utilisation, unreliable and costly power, foreign exchange pressures, skills gaps, equipment downtime, and process inconsistencies continue to limit productivity, safety, and competitiveness. However, industrial investments, regional trade integration under the African Continental Free Trade Area (AfCFTA), and growing policy emphasis on technology adoption present opportunities for improvement.

20–50%

reduction in time to competence with XR training compared with traditional approaches

25–40%

shorter task times reported in selected assembly and maintenance operations

200%+

three-year returns on investment reported for some mixed reality programmes

75%

reduction in per-employee training time reported by Boeing with VR assembly training

This white paper examines how Extended Reality (XR), comprising Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), can help Nigerian manufacturers address selected workforce and operational challenges. XR supports immersive training, real-time digital guidance, remote expert assistance, process visualisation, and interaction with digital representations of equipment. While it does not replace investments in infrastructure or basic digital systems, it can improve how workers learn, access information, and execute tasks.

Evidence from global manufacturing deployments points to measurable benefits, including faster workforce training, fewer procedural errors, improved knowledge retention, shorter maintenance times, reduced downtime, and positive returns on investment when applications are properly scoped. These benefits are particularly relevant to Nigerian manufacturers seeking to improve operational efficiency and retain critical technical knowledge.



Figure 1 VR-based safety training lets teams rehearse procedures before they reach the production floor.

Key applications include workforce training and onboarding, health and safety, operations and standard procedures, maintenance and remote assistance, quality assurance, and design and digital twin interaction. The greatest value is often achieved through focused applications that address specific operational problems.

Successful adoption requires a structured approach involving readiness assessment, clear business objectives, carefully selected pilot projects, appropriate solution design, change management, and measurable performance indicators. Challenges such as cost, infrastructure limitations, user adoption, content maintenance, and data governance must also be considered.

As advances in artificial intelligence, spatial computing, wearable devices, and industrial digital twins expand XR capabilities, manufacturers can prepare by strengthening their digital foundations, developing internal competencies, and adopting technology in line with operational priorities.

XR is not a universal solution, but when applied strategically, it can strengthen workforce competence, improve safety, preserve institutional knowledge, reduce downtime, and increase process consistency. This white paper provides the evidence, applications, adoption roadmap, and recommendations to help Nigerian manufacturers evaluate its potential. It encourages decision-makers to identify priority operational challenges and begin with measurable, well-defined pilot projects before considering wider implementation.

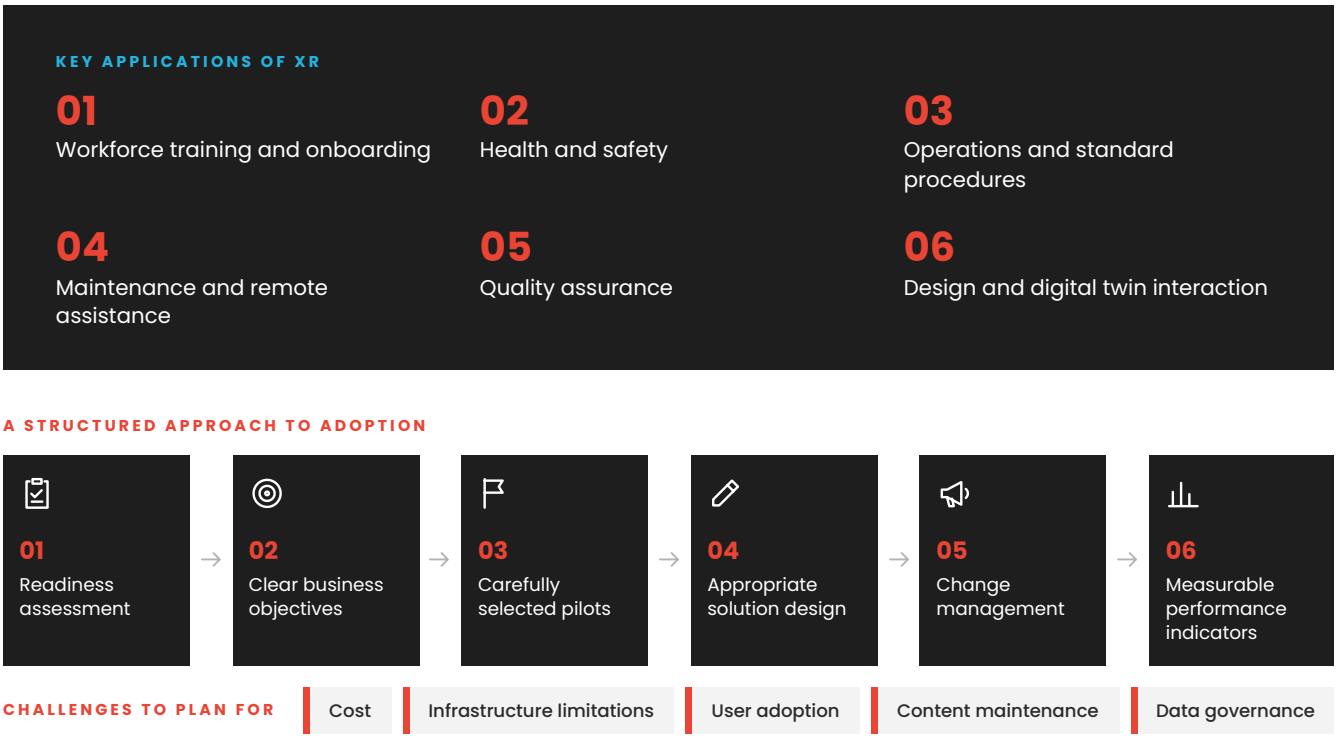


Figure 2 Successful XR adoption follows a structured sequence, with known challenges considered from the start.



01

PART I

Setting the Context

1 Introduction

2 The State of Manufacturing in Nigeria

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1 Introduction

1.1 Purpose of This White Paper

This white paper examines the practical applications and business value of Extended Reality (XR), including Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR), within Nigeria's manufacturing sector.

It explores how XR can address operational challenges, improve workforce training and safety, support knowledge retention and strengthen production processes. Drawing on global industry experience, relevant research and Nigerian market realities, it provides decision makers with practical guidance for identifying suitable applications, assessing business value and planning XR adoption.

Rather than presenting XR as a universal solution, the paper focuses on where the technology can deliver measurable improvements under Nigerian operating conditions.

1.2 Why XR Matters for Nigerian Manufacturers

XR offers Nigerian manufacturers an opportunity to improve how employees learn, access technical information and perform operational tasks. By bringing digital instructions, simulations and 3D models into practical work environments, it makes complex processes easier to understand, practise and execute.

Its applications extend across workforce development, equipment maintenance, production planning, quality assurance and workplace safety. Manufacturers can use XR to simulate procedures before implementation, provide interactive guidance during tasks and preserve technical knowledge for future use.

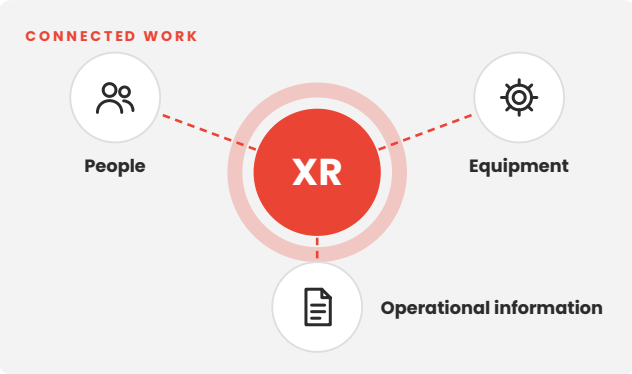


Figure 3 XR connects people, equipment and operational information in more interactive ways.

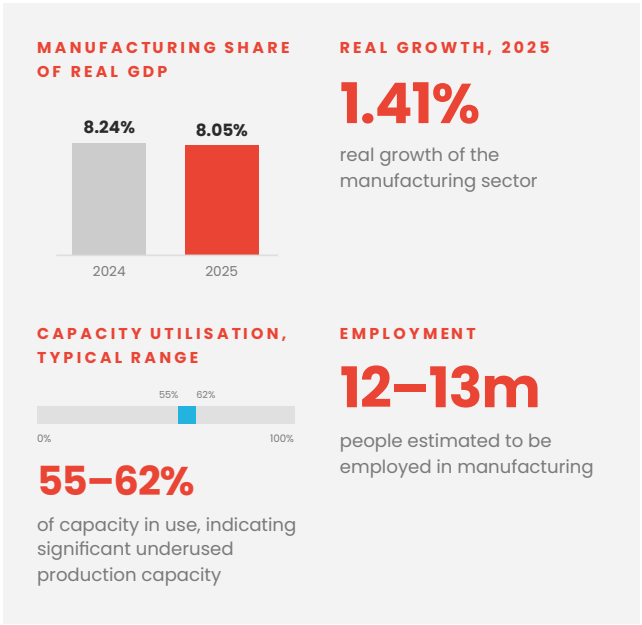
Beyond individual applications, XR supports the wider transition towards digital manufacturing by connecting people, equipment and operational information in more interactive ways. Its value, however, depends on selecting appropriate use cases, integrating the technology into existing processes and measuring its impact on business performance.

2 The State of Manufacturing in Nigeria

2.1 Overview of Nigeria's Manufacturing Sector

Manufacturing remains important to Nigeria's economy, although its contribution to GDP is relatively modest. According to the National Bureau of Statistics, the sector contributed 8.05% of real GDP in 2025, down from 8.24% in 2024, with real growth of 1.41% (NBS, 2025, 2026).

The sector comprises thirteen subsectors, with food, beverages and tobacco accounting for the largest share of output, followed by cement, textiles, chemicals, pharmaceuticals, and basic metals. Capacity utilisation has generally remained between 55% and 62%, indicating significant underused production capacity (MAN, 2025).



Sources: National Bureau of Statistics (2025, 2026); Manufacturers Association of Nigeria (2025).

Figure 4 Nigeria's manufacturing sector at a glance.

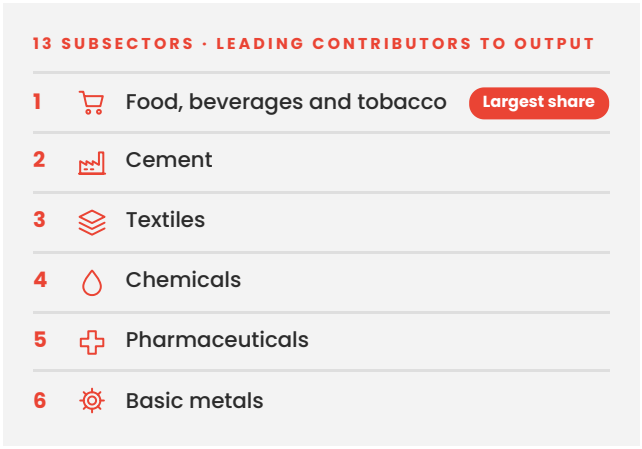


Figure 5 Leading manufacturing subsectors, in order of their share of output.

Manufacturing employs an estimated 12–13 million people. Major investments, including the Dangote Refinery and fertiliser complex, are creating opportunities for downstream industries. However, manufactured goods still account for a relatively small share of Nigeria's exports.



Figure 6 Food, beverages and tobacco account for the largest share of Nigeria's manufacturing output.

2.2 Key Industry Trends

Several developments are shaping the sector:

Import Substitution
Government policies increasingly encourage local production across key industries.

Regional Trade Expansion
AfCFTA offers access to wider markets, although production capacity, quality, and logistics remain challenges.

Digital Adoption
Larger manufacturers are investing in automation, IoT, data analytics, and artificial intelligence, while adoption among SMEs remains limited.

Rising Energy Costs
Unreliable electricity and dependence on alternative power sources continue to increase production costs.

Industrial Policy Support
The Nigeria Industrial Policy 2025–2030 prioritises manufacturing growth, technology adoption, and human capital development.

2.3 The Drive Towards Digital Transformation

Digital transformation is progressing gradually across Nigeria's manufacturing sector. Leading firms are adopting automation, IoT, cloud-based systems, and data analytics to improve productivity, reduce downtime, and strengthen quality control.

However, infrastructure limitations, skills shortages, and high investment costs continue to restrict wider adoption.

Extended Reality (XR) forms part of this broader transformation by improving how workers access operational information, follow procedures, and acquire practical skills. It complements existing industrial systems and becomes increasingly valuable as manufacturers expand their use of digital technologies.

2.4 Opportunities for Growth and Competitiveness

Despite existing constraints, Nigeria's manufacturing sector offers significant growth opportunities through expanding domestic production, major industrial investments, and access to regional markets.

Manufacturers can strengthen competitiveness by improving capacity utilisation, reducing training costs, enhancing workplace safety, retaining institutional knowledge, and maintaining consistent production standards.

Digital technologies, including XR, can support these objectives when applied to clearly defined operational needs. Combining technology adoption with workforce development and process improvement will be important for long-term competitiveness.

2.5 Challenges Facing Nigerian Manufacturers

The sector continues to face interconnected challenges that affect productivity and investment. Unreliable electricity, rising energy costs, foreign exchange volatility, expensive financing, and dependence on imported machinery and raw materials remain significant constraints.

Other difficulties include inefficient logistics, regulatory complexities, weak consumer demand, and underutilised production capacity (MAN, 2025; NESG, 2025/2026).

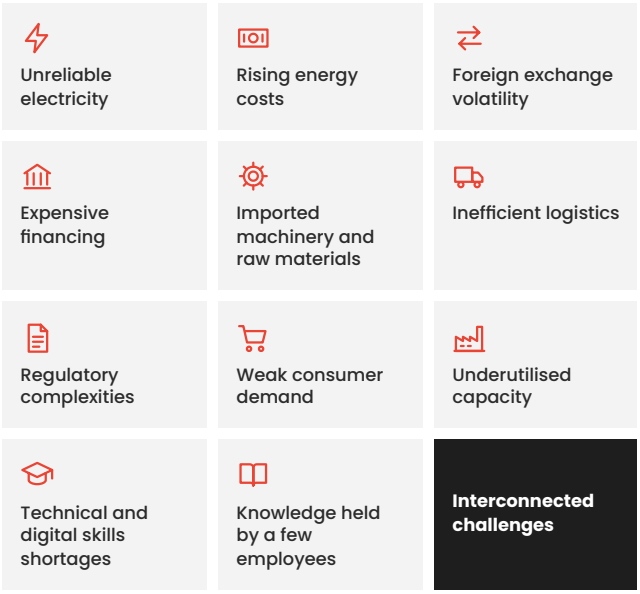
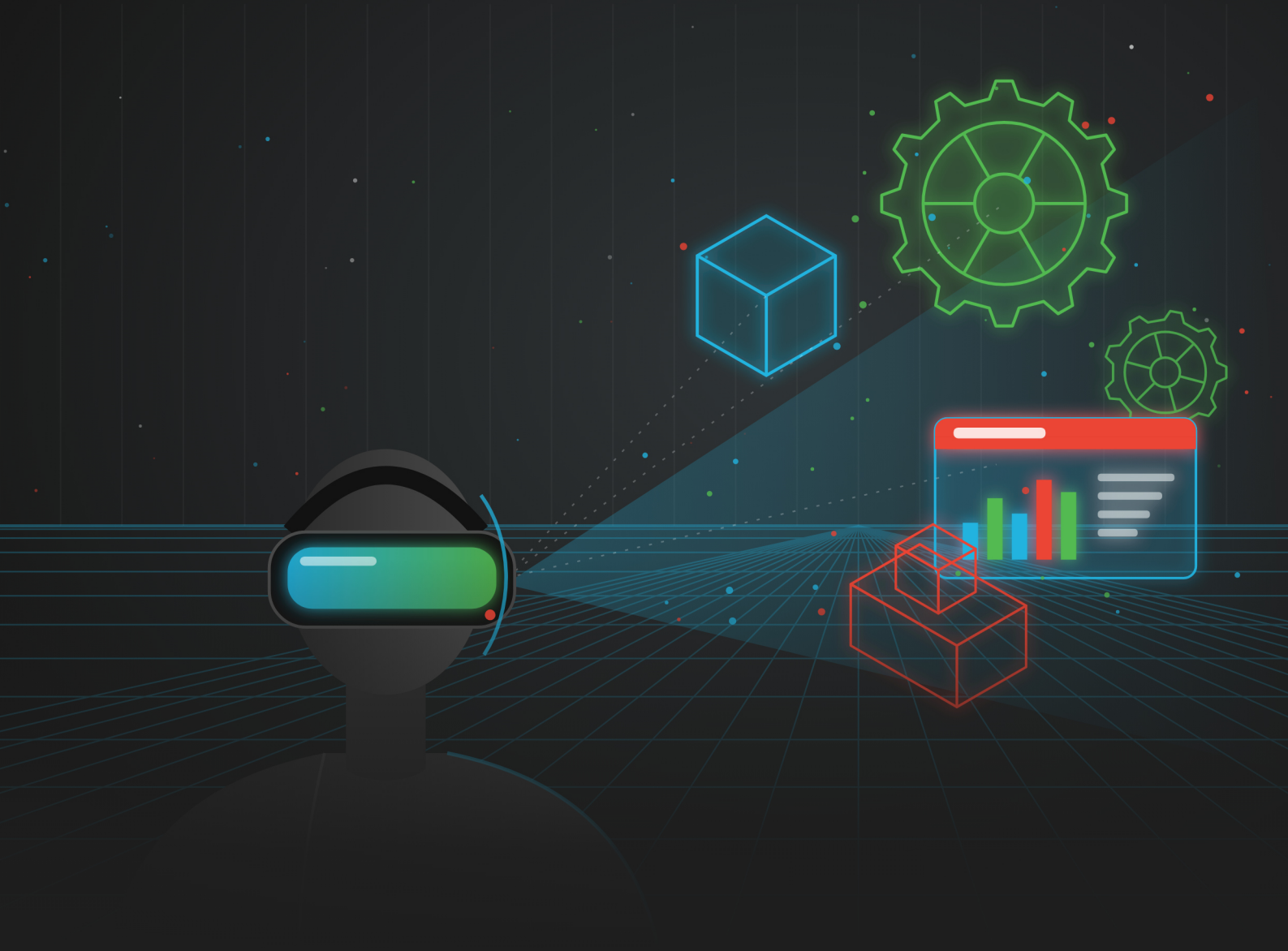


Figure 7 Interconnected constraints that affect productivity and investment (MAN, 2025; NESG, 2025/2026).

Skills shortages, particularly in technical and digital roles, further limit productivity. In many organisations, critical operational knowledge also remains concentrated among experienced employees rather than documented systems.

These challenges highlight the need for strategic technology investments. Solutions such as XR should address specific operational problems, reflect existing infrastructure and workforce capabilities, and deliver measurable business outcomes.



02

PART II

Understanding Extended Reality

3 What is Extended Reality (XR)?

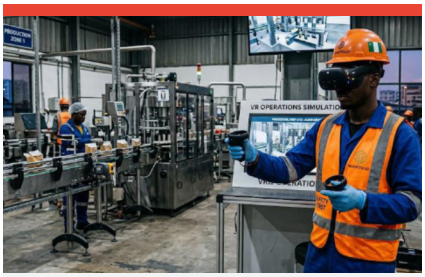
4 Why XR is Gaining Momentum

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3 What is Extended Reality (XR)?

3.1 Defining Extended Reality (XR)

Extended Reality (XR) is an umbrella term for immersive technologies that blend the physical and digital worlds or create fully digital environments. It encompasses Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR), enabling users to interact with digital information in three-dimensional spaces.

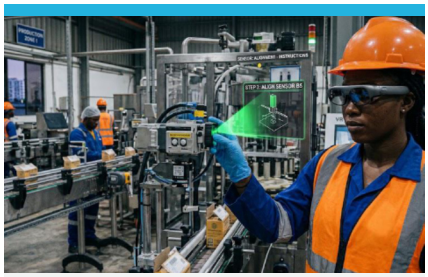


Virtual Reality

A fully digital environment that replaces the user's view of the physical world.

TYPICAL DEVICE

Immersive headset

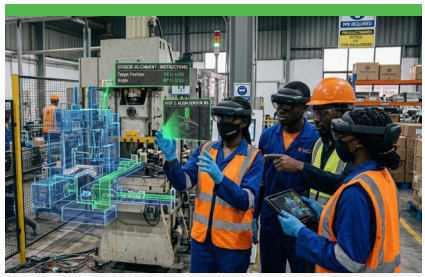


Augmented Reality

Digital information overlaid onto the user's view of the physical environment.

TYPICAL DEVICE

Smartphone, tablet or smart glasses



Mixed Reality

Digital objects that interact with, and stay aligned to, the physical environment.

TYPICAL DEVICE

Advanced headset with spatial tracking

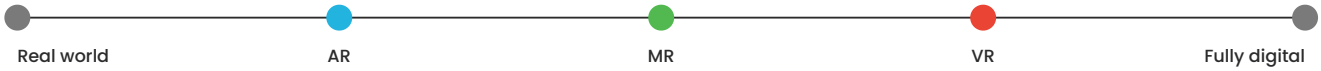


Figure 8 The XR family. Virtual, Augmented and Mixed Reality sit on a spectrum from the real world to fully digital environments.

Unlike traditional digital tools such as desktop applications, videos and paper-based instructions, XR places digital information within the context of the actual task. Workers can follow interactive instructions, practise procedures in simulated environments and receive remote assistance while engaging with equipment and their surroundings.

In manufacturing, XR provides an interactive way for workers to access information, practise procedures, visualise equipment and collaborate remotely. It complements existing industrial systems by making operational information and expertise more accessible at the point of need.

Its value lies in helping workers translate technical instructions into practical actions, supporting more effective training and reducing the potential for operational errors. This is particularly relevant to Nigerian manufacturers dealing with high training costs, limited equipment access and shortages of experienced technical personnel.

3.2 Virtual Reality (VR)

Virtual Reality creates fully digital environments that replace the user's view of the physical world through an immersive headset. In manufacturing, it allows workers to practise procedures and simulate scenarios that may be dangerous, expensive or impractical to replicate on actual production floors.

Key applications include:

Safety and Emergency Training
Simulating hazardous situations without exposing workers to physical danger.

Equipment Training
Practising machine operations without material waste or production downtime.

Factory Layout and Pre-commissioning
Exploring facility designs and equipment arrangements before installation.

VR is particularly useful for training and activities where real-world practice is risky or costly. For example, Boeing reported a 75% reduction in per-employee training time through VR-based assembly training, demonstrating its potential to improve training efficiency.

75%

reduction in per-employee training time reported by Boeing through VR-based assembly training

3.3 Augmented Reality (AR)

Augmented Reality overlays digital information onto the user's view of the physical environment. Through smartphones, tablets or specialised smart glasses, workers can access instructions, 3D models, annotations and safety warnings while interacting with actual equipment.

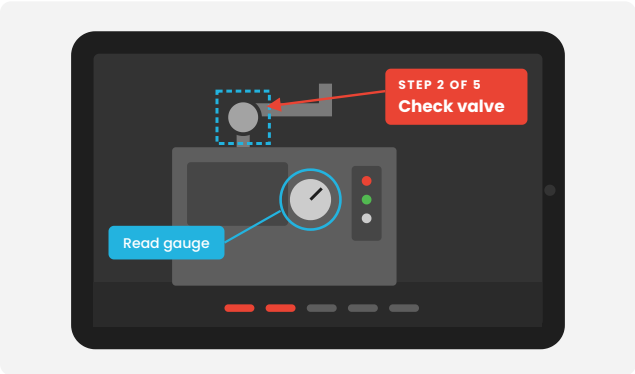


Figure 9 AR places step-by-step instructions, annotations and warnings within the worker's view of the real equipment.

Common manufacturing applications include:

- Step-by-step assembly and maintenance instructions.
- Equipment inspection and quality control.
- Real-time technical guidance and remote assistance.

AR can reduce reliance on paper manuals and separate screens by placing relevant instructions directly within the worker's field of view. It also offers a relatively accessible entry point for manufacturers, as initial applications can use existing mobile devices before progressing to specialised headsets.

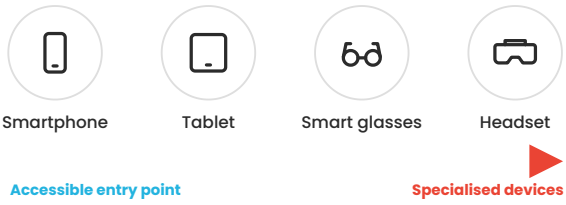


Figure 10 AR can start on existing mobile devices before progressing to specialised headsets.

For manufacturers dealing with technical skills shortages and inconsistent work procedures, AR can help improve task accuracy and standardise operations.

3.4 Mixed Reality (MR)

Mixed Reality combines elements of VR and AR, allowing digital objects to interact with the physical environment. Unlike simple digital overlays, virtual components can be positioned, manipulated and viewed in relation to real-world surfaces and equipment.

MR uses spatial computing technologies, including cameras, sensors and computer vision, to map physical spaces, recognise objects, track movement and position digital content accurately within the environment. This allows digital instructions and 3D models to remain aligned with specific machines and components as workers move around them.

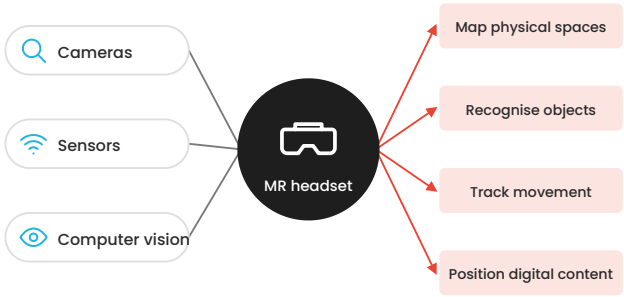


Figure 11 Spatial computing lets MR map the space and keep digital content aligned with real machines as workers move.

In manufacturing, MR supports:

- Visualising proposed factory layouts within existing facilities.
- Examining digital twins alongside physical equipment.
- Remote collaboration with experts using virtual annotations.
- Supporting complex equipment installation and commissioning.

MR typically requires more advanced headsets with spatial tracking and environmental awareness. Improvements in sensors, processors and tracking capabilities have made it increasingly useful for complex design, maintenance and commissioning activities in industrial environments.

4 Why XR is Gaining Momentum

4.1 Global Manufacturing Trends

Manufacturers worldwide face growing pressure to improve productivity, reduce downtime, address skills shortages, and strengthen workplace safety. XR is emerging as a practical tool for improving workforce training, maintenance, knowledge transfer, and remote technical support across industries.

Its growth is closely linked to the Industrial Metaverse, which combines XR, digital twins, AI, and connected industrial systems. These technologies enable manufacturers to simulate production environments, test workflows, and train employees. BMW, for example, uses digital factory simulations to identify potential inefficiencies before implementation.

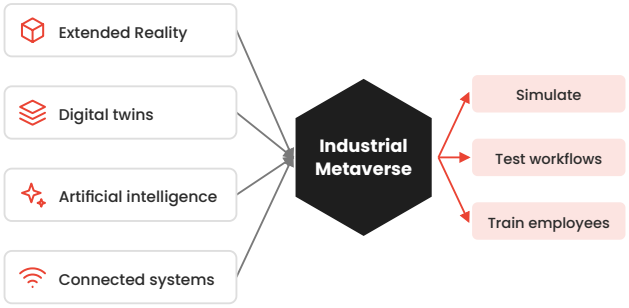


Figure 12 The industrial metaverse brings together XR, digital twins, AI and connected industrial systems.

The World Economic Forum projects that the industrial metaverse could exceed US$100 billion by 2030 (Kobie, 2025), highlighting the growing importance of immersive technologies in manufacturing.

US$100bn+

potential value of the industrial metaverse by 2030, as projected by the World Economic Forum

4.2 Industry 4.0 and Smart Manufacturing

Industry 4.0 integrates digital technologies, automation, connected machines, and data analytics into manufacturing operations. XR complements this transformation by enabling workers to interact with digital information through equipment visualisation, digital twins, and guided instructions.

Manufacturers do not need fully developed Industry 4.0 infrastructure to adopt XR. Targeted applications using existing procedures and digital resources can deliver value while supporting gradual digital transformation.

4.3 Advances in Hardware and Software

Improvements in XR hardware have enhanced display quality, tracking, comfort, and battery performance, while more affordable devices have lowered adoption barriers.

Software developments also allow manufacturers to convert CAD models, technical manuals, and standard operating procedures into interactive experiences. These improvements have made XR more practical for industrial applications, with successful adoption increasingly dependent on selecting appropriate use cases.

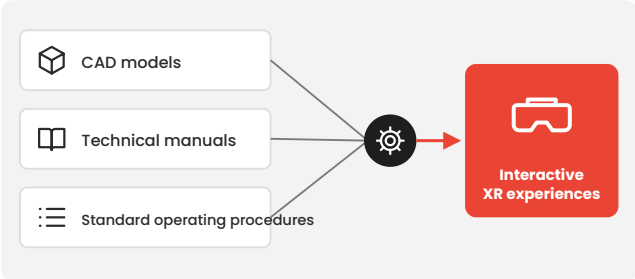


Figure 13 Software developments allow existing engineering and operational content to become interactive XR experiences.

4.4 Artificial Intelligence and XR

Artificial Intelligence (AI) is expanding XR capabilities through interactive training, contextual maintenance guidance, equipment recognition, and personalised learning.

Combining AI with XR also creates opportunities to capture and transfer operational knowledge, particularly as experienced workers retire. This is relevant to Nigerian manufacturers, where critical technical expertise is often concentrated among a limited number of experienced employees.

4.5 Why Now is the Right Time

Several developments make XR increasingly relevant to Nigerian manufacturers:

Technology Maturity

Improved hardware and software have made XR more accessible for industrial applications.

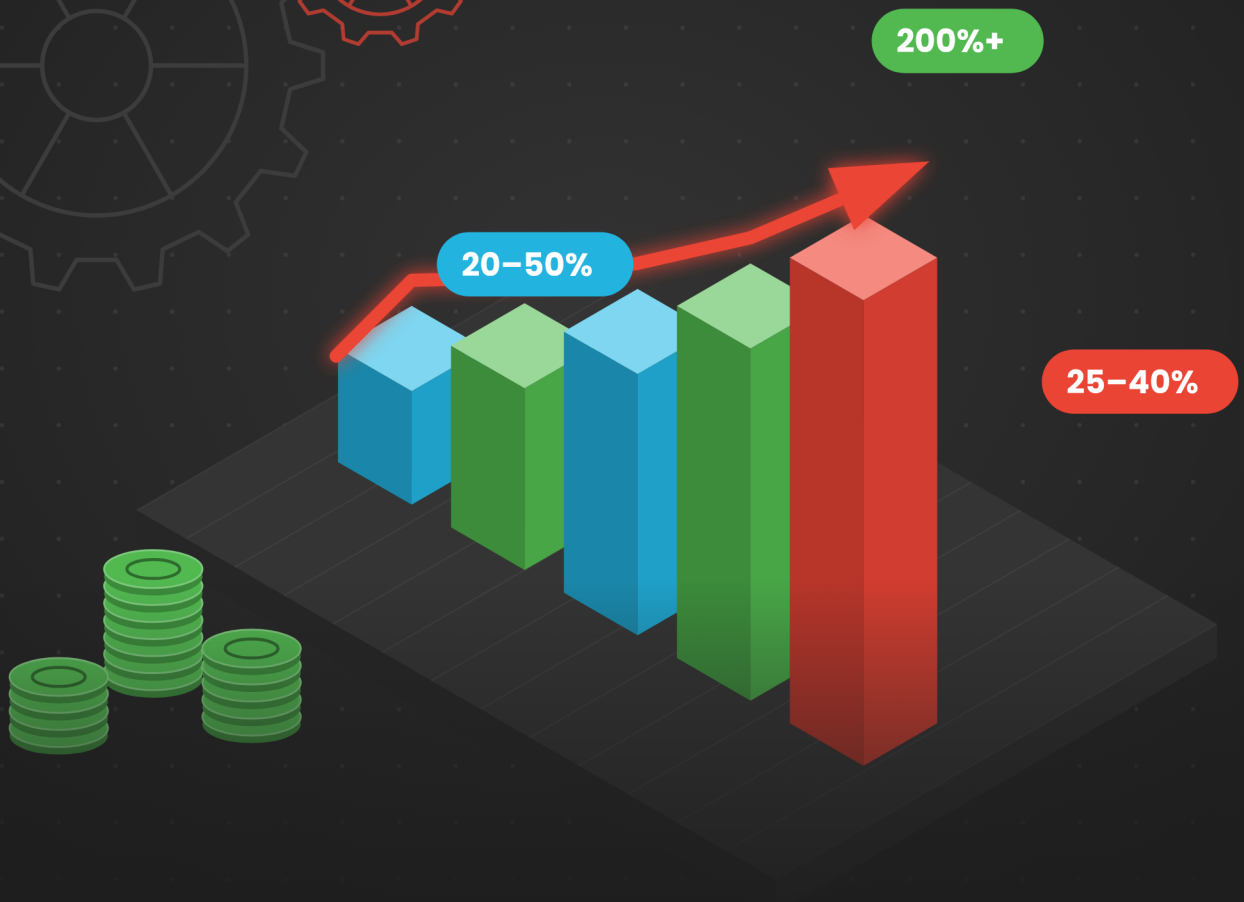
Demonstrated Benefits
Global deployments show potential improvements in training, productivity, and operational efficiency.

Workforce Needs
Skills shortages and safety requirements create opportunities for immersive training.

Digital Adoption
Growing investments in automation and connected systems provide a foundation for XR.

Competitive Pressure
AfCFTA increases the need for stronger productivity, workforce capabilities, and operational reliability.

Manufacturers can begin with focused applications that address specific operational challenges, evaluate their results, and expand adoption where measurable value is demonstrated.



03

PART III

The Business Case for XR

5 Manufacturing Challenges XR Can Address

6 Benefits of XR

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5 Manufacturing Challenges XR Can Address

Nigerian manufacturers face operational challenges that affect productivity, increase costs and limit competitiveness. XR offers practical solutions to several of these challenges, particularly those involving workforce development, safety and operational efficiency.

Workforce Skills Gaps and Rising Training Costs

Limited access to practical technical training slows employee development, while conventional training involves expenses related to instructors, travel, materials and production equipment. XR provides reusable simulations where workers can practise procedures and develop skills without relying entirely on physical equipment or disrupting production.

Safety and Risk Management

Workers face hazards involving machinery, chemicals, high temperatures and confined spaces. VR enables safe emergency simulations, while AR provides guidance during actual operations.

Equipment Downtime and Limited Expert Support

Equipment failures can cause costly production interruptions, particularly when specialist technicians are unavailable. AR-enabled remote assistance connects on-site workers with experts for faster diagnosis, troubleshooting and repairs.

Knowledge Retention

Experienced employees often hold critical operational knowledge that may be lost when they leave or retire. XR helps capture and transfer this expertise through interactive training and digital procedures.

Operational Inefficiencies and Quality Control

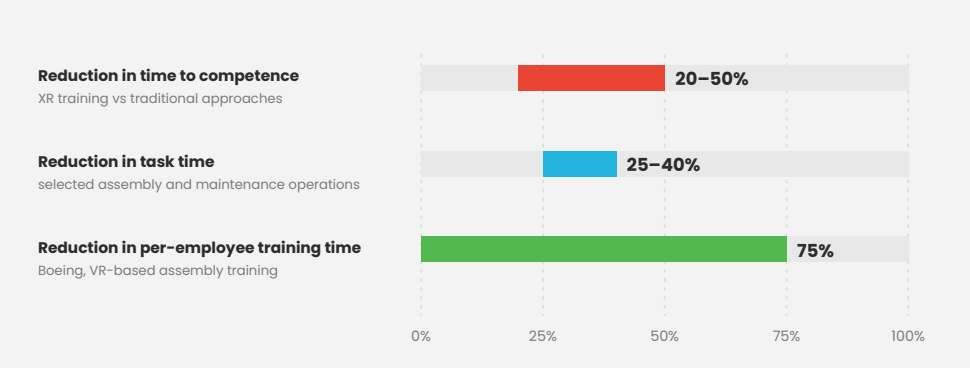
Inconsistent procedures, poorly planned production layouts and inadequate inspection processes can affect productivity and product quality. XR supports process visualisation, virtual layout testing, guided inspections and standardised work instructions.

Limited Access to Specialist Expertise

Manufacturers may struggle to access technical specialists when and where they are needed. XR enables remote experts to provide real-time visual guidance, reducing the need for travel and helping resolve technical issues more quickly.

6 Benefits of XR

When applied to clearly defined operational needs, Extended Reality (XR) can improve workforce training, workplace safety, productivity, maintenance and production planning. Its business value depends on the application, implementation costs and measurable operational outcomes.



200%+

three-year returns on investment reported in some enterprise studies of mixed reality programmes (Microsoft HoloLens Total Economic Impact, 2024)

Figure 14 Reported improvements from XR deployments. Actual results vary by application, implementation costs and operating conditions.

6.1 Improving Workforce Competence and Onboarding

XR allows employees to practise procedures repeatedly in realistic virtual environments before handling actual equipment. This can shorten training periods, improve knowledge retention and reduce reliance on continuous supervision.

Studies and industry reports indicate that XR training can reduce time to competence by 20–50% compared with traditional approaches (Microsoft, 2024).

Tata Steel uses VR to prepare operators for working with expensive and potentially hazardous equipment, while Cementos Argos has applied VR training to improve knowledge retention and workforce readiness (VR Owl, 2025).

6.2 Enhancing Workplace Safety

VR allows workers to practise responding to hazardous situations without physical exposure to danger. AR can also provide safety instructions and guidance during actual operations.

BASF, for example, uses VR for workplace safety training, providing employees across different locations and shifts with consistent and repeatable learning experiences.

6.3 Reducing Operational Costs

XR can reduce costs associated with employee training, production errors, technical support travel, equipment downtime and workplace incidents.

Some enterprise studies have reported three-year returns on investment exceeding 200% for mixed reality programmes (Microsoft HoloLens Total Economic Impact, 2024). Actual returns vary depending on the application, implementation costs and operating conditions.

6.4 Improving Productivity and Operational Consistency

AR-guided workflows provide workers with instructions directly within their working environment, helping them complete tasks more efficiently and consistently. This can reduce interruptions, procedural errors and variations in task execution.

Industrial applications have reported task-time reductions of 25–40% in selected assembly and maintenance operations.

XR also helps standardise technical procedures across employees, shifts and locations. Ford, for example, has used VR to train technicians on electric vehicle systems, including procedures involving potentially hazardous high-voltage components.

6.5 Minimising Equipment Downtime

AR-enabled remote assistance connects on-site technicians with specialists who can provide real-time visual guidance during troubleshooting and repairs. This can reduce delays associated with specialist travel and improve response times.

VR also prepares technicians for complex maintenance tasks before field deployment. Boeing and General Electric, for example, have applied VR training to technical procedures involving aircraft maintenance and wind turbine operations (VR Owl, 2025).

6.6 Supporting Continuous Improvement

XR allows manufacturers to visualise and test production layouts, equipment arrangements and operational changes before implementing them physically. This helps identify potential design or process issues early, reducing the cost and disruption of changes.

Nissan and Siemens have applied VR and digital twin technologies to production simulation, factory planning and process optimisation. Jaguar Land Rover and Ford have also used virtual simulation to evaluate vehicle designs, assembly processes and ergonomics.

Boeing
VR-based assembly training (75% less training time per employee) and aircraft maintenance training

BMW
Digital factory simulations to identify potential inefficiencies before implementation

Tata Steel
VR to prepare operators for expensive and potentially hazardous equipment

Cementos Argos
VR training to improve knowledge retention and workforce readiness

BASF
VR safety training that is consistent across locations and shifts

Ford
VR training on electric vehicle high-voltage systems; virtual simulation of designs and assembly

General Electric
VR training for technical procedures in wind turbine operations

Nissan and Siemens
VR and digital twins for production simulation, factory planning and process optimisation

Jaguar Land Rover
Virtual simulation to evaluate vehicle designs, assembly processes and ergonomics

Figure 15 Global manufacturers referenced in this paper and how they have applied XR.



04

PART IV

Business Applications of XR in Manufacturing

7 Workforce Training and Skills Development
8 Health, Safety and Environment (HSE)
9 Operations and Production
10 Maintenance and Engineering
11 Quality Assurance
12 Design, Engineering and Digital Twins

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7 Workforce Training and Skills Development

XR supports practical workforce development by allowing employees to learn procedures, practise tasks and build technical skills in simulated environments.

7.1 Employee Onboarding

VR allows new employees to explore factory layouts, equipment locations, emergency routes and safety procedures before entering production areas. It also provides introductory equipment and procedural training, reducing the time supervisors spend on basic orientation.



Figure 16 Training systems can track completion time, errors and procedural accuracy as employees practise.

7.2 Technical Skills Training

Employees can use VR to practise machine operation, assembly, welding, process control and equipment changeovers. Tasks can be repeated until workers meet defined proficiency levels, while training systems track completion time, errors and procedural accuracy.

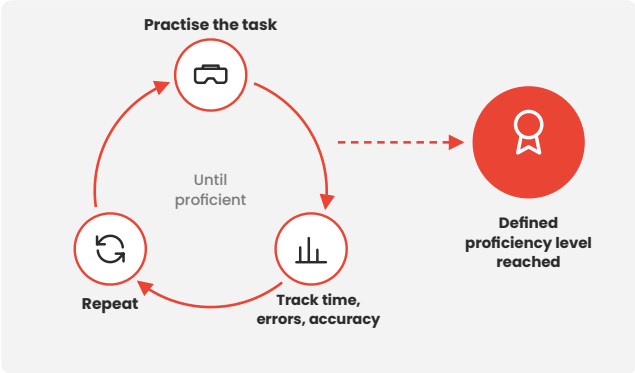


Figure 17 Tasks can be repeated until workers meet defined proficiency levels, with completion time, errors and procedural accuracy tracked.

7.3 Equipment Familiarisation

Virtual replicas of machinery allow workers to understand control locations, operating conditions, warning indicators and basic troubleshooting procedures before handling actual equipment. This is particularly useful for expensive, hazardous or specialised machinery.

7.4 Continuous Learning

XR supports refresher training, procedure updates and cross-training. Digital modules can be updated centrally and accessed across different shifts and locations, allowing employees to maintain and expand their skills.

8 Health, Safety and Environment (HSE)

XR supports safety training through realistic hazard simulations and interactive guidance. VR allows employees to practise emergency responses in controlled environments, while AR can reinforce safety procedures during actual operations.

8.1 Hazard Identification

Virtual environments expose workers to simulated workplace hazards, allowing them to practise identifying risks, assessing their severity and selecting appropriate control measures.

8.2 Emergency Response Training

VR simulates emergencies such as fires, chemical spills, equipment failures and medical incidents. Employees can practise evacuation, emergency shutdown and team coordination procedures before encountering real emergencies.



Figure 18 Emergency scenarios employees can rehearse safely in VR before encountering them for real.

8.3 Fire Safety Simulations

Workers can practise extinguisher selection, fire response, evacuation procedures and assembly point protocols in virtual environments. Site-specific simulations provide repeatable training without the risks and costs of frequent live fire exercises.

8.4 Lockout/Tagout Procedures

VR allows employees to practise equipment isolation, energy verification, tagging and restoration procedures on virtual machinery. This reinforces correct procedures before workers perform actual isolation tasks.

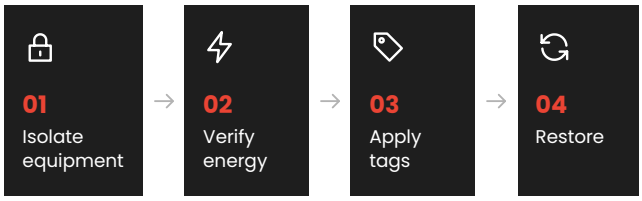


Figure 19 Lockout/tagout sequences can be practised on virtual machinery before workers perform actual isolation tasks.

8.5 Confined Space and Working at Height Training

Immersive simulations allow workers to practise confined space entry, atmospheric testing, permit requirements, fall prevention and rescue procedures. AR can provide contextual reminders during actual work.

9 Operations and Production

XR supports production planning, process visualisation and the consistent execution of operational procedures. It allows manufacturers to evaluate workflows and proposed changes before making physical adjustments.

9.1 Production Process Visualisation

Manufacturers can represent production workflows, material movements and equipment interactions in three-dimensional environments. This helps teams identify bottlenecks, understand process relationships and explore improvements.

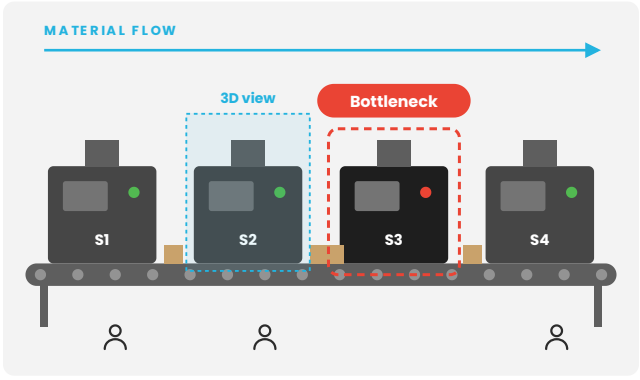


Figure 20 Visualising workflows, material movement and equipment interactions helps teams identify bottlenecks.

9.2 Standard Operating Procedures

Paper-based procedures can be converted into interactive VR training or AR-guided instructions. Workers receive step-by-step guidance on assembly sequences, equipment settings, inspection points and safety requirements.

Digital procedures can also be updated centrally to maintain consistency across shifts and facilities.

9.3 Lean Manufacturing Support

XR supports lean manufacturing practices such as 5S, value stream mapping, standard work and rapid changeovers. Teams can visualise workflows, identify waste and evaluate proposed improvements before implementation.

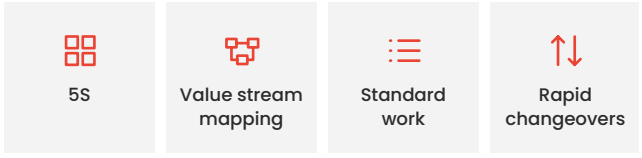


Figure 21 Lean manufacturing practices XR can support.

9.4 Production Line Optimisation and Planning

VR allows manufacturers to simulate production layouts, operator movements, material flows and equipment arrangements before modifying actual facilities. This

helps identify capacity constraints, ergonomic issues and potential safety risks.

10 Maintenance and Engineering

XR supports maintenance training, guided repairs, remote technical assistance and equipment planning.

10.1 Preventive Maintenance and Equipment Simulations

Technicians can practise inspection routines, lubrication, component replacement and troubleshooting on virtual equipment. This builds familiarity with maintenance procedures without using operational machinery for training.

10.2 Digital Work Instructions

AR provides step-by-step maintenance guidance over physical equipment. Technicians can access component locations, torque values, inspection points and safety instructions without constantly referring to separate manuals.



Figure 22 AR work instructions place each maintenance step, such as fastener torque, directly over the equipment.

10.3 Remote Expert Assistance

AR connects on-site technicians with remote specialists who can view equipment through the technician's perspective and provide real-time visual guidance using annotations, arrows and instructions.

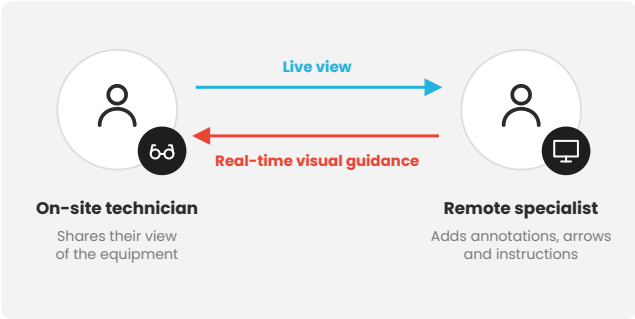


Figure 23 Remote expert assistance: specialists view equipment through the technician's perspective and guide the repair.



Figure 24 Remote experts and on-site teams can troubleshoot together around the same equipment.

10.4 Maintenance Planning and Technician Certification

VR allows maintenance teams to rehearse complex interventions, assess resource requirements and identify potential disruptions before scheduled maintenance. It can also provide a controlled environment for evaluating technician competence before critical maintenance tasks.

11 Quality Assurance

XR supports quality management through inspection training, defect identification and consistent application of quality procedures.

11.1 Inspection Training and Defect Identification

VR provides realistic examples of acceptable and defective products, allowing inspectors and operators to practise identifying defects, including those that occur infrequently.

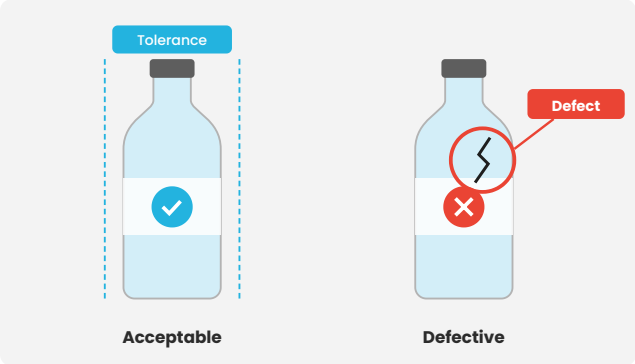


Figure 25 VR provides acceptable and defective examples to practise on; AR can highlight tolerances and critical components during checks.

AR can support physical inspections by displaying tolerances, highlighting critical components and guiding workers through required checks.

11.2 Process Standardisation and Compliance Training

XR can incorporate quality standards, regulatory requirements and internal procedures into interactive training modules and digital work instructions.

Digital content can be updated centrally when requirements change, helping manufacturers maintain consistent practices across facilities.

12 Design, Engineering and Digital Twins

XR supports product development, facility planning and engineering by allowing teams to visualise designs, evaluate proposed changes and collaborate around digital representations of physical assets.

12.1 Factory Layout and Facility Planning

VR allows manufacturers to explore virtual representations of factory floors before making physical changes. Teams can assess equipment placement, production workflows, material movement and safety considerations while identifying potential bottlenecks.

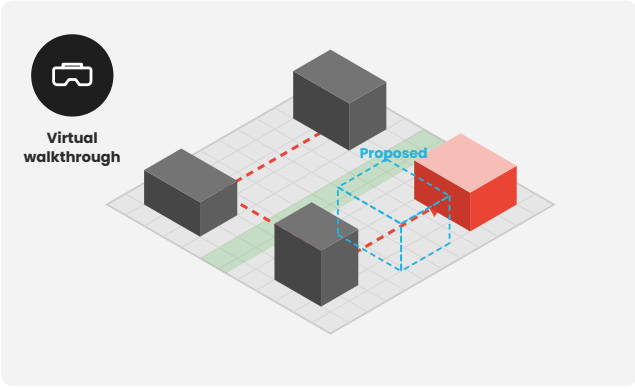


Figure 26 Virtual factory layouts let teams assess equipment placement, workflows and material movement before committing capital.

For Nigerian manufacturers planning facility expansion, new production lines or equipment rearrangement, this provides an opportunity to evaluate decisions before committing capital. Providers such as Emmeatech have demonstrated the application of VR in factory planning and design reviews.

12.2 Product Design Collaboration

Engineering and production teams can examine and interact with three-dimensional product models in shared virtual environments. This supports collaborative design reviews and helps identify assembly, manufacturing and maintenance considerations earlier in product development.

Remote collaboration can also reduce the need for physical meetings and travel.

12.3 Digital Twins

A digital twin is a virtual representation of a physical asset, process or system that uses real-world data to support monitoring, simulation and optimisation.

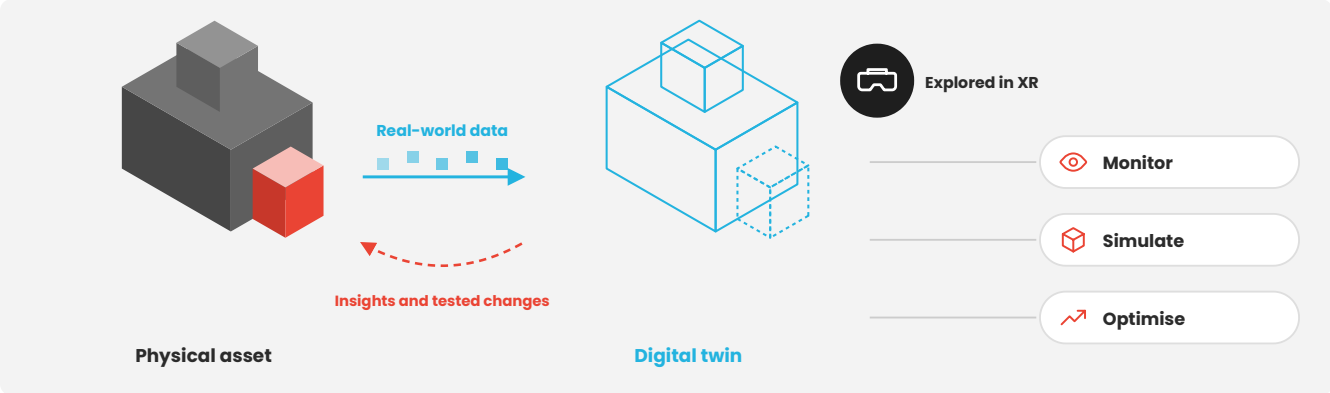


Figure 27 A digital twin uses real-world data to support monitoring, simulation and optimisation. XR makes it explorable in three dimensions.

XR makes digital twins more accessible by allowing engineers and operators to explore virtual equipment, visualise operational data and simulate potential changes in an immersive environment.

Siemens Advanta highlights how combining digital twins, simulation and real-time data supports planning and production decisions.

For Nigerian manufacturers, implementation can begin with selected equipment or production processes, using existing digital models before progressively introducing real-time data and immersive visualisation.

12.4 Commissioning Support

XR supports equipment installation and commissioning by allowing technicians to rehearse procedures in VR before performing them on-site. During commissioning, AR can provide step-by-step guidance, while remote experts assist with technical issues.



05

PART V

Building the Business Case

13 Evaluating XR Opportunities

14 Measuring Return on Investment (ROI)

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13 Evaluating XR Opportunities

Manufacturers should assess XR opportunities based on clearly defined operational needs, expected business value and organisational readiness. This helps ensure investments address measurable problems rather than technology adoption for its own sake (Deloitte, 2025; PwC, 2024).

13.1 Identifying and Prioritising XR Opportunities

XR is most relevant to manufacturing processes involving complex tasks, safety risks, specialised knowledge or costly errors.

Potential applications include:

- Safety-critical procedures, such as lockout/tagout.
- Employee onboarding and technical training.
- Maintenance of critical equipment.
- Quality inspection and production guidance.
- Remote expert assistance and knowledge transfer.

Manufacturers should use existing performance indicators to identify areas for improvement, including:

- Training duration and costs.
- Error and defect rates.
- Equipment downtime and mean time to repair (MTTR).
- Workplace incident frequency.
- Time spent on supervision and technical support.

Prioritisation should consider expected financial and operational benefits, implementation costs, available expertise, infrastructure requirements and potential for expansion. Starting with one or two high-impact applications allows manufacturers to test feasibility and demonstrate value before wider deployment.

13.2 Assessing Organisational Readiness

Before implementation, manufacturers should assess:

Business Needs
Is there a clearly defined operational problem with measurable consequences?

Leadership Support
Is there a senior sponsor to guide the initiative and secure resources?

Infrastructure
Are power, connectivity and suitable physical spaces available?

Skills and Capacity
Can internal teams coordinate implementation, support users and manage change?

Data and Content
Are technical manuals, CAD models and operating procedures available?

Workforce Readiness
Are employees and supervisors prepared to adopt the technology?

The readiness checklist in Appendix B can help identify gaps before implementation.

13.3 Stakeholder Alignment

Successful adoption requires involvement from key departments, including:

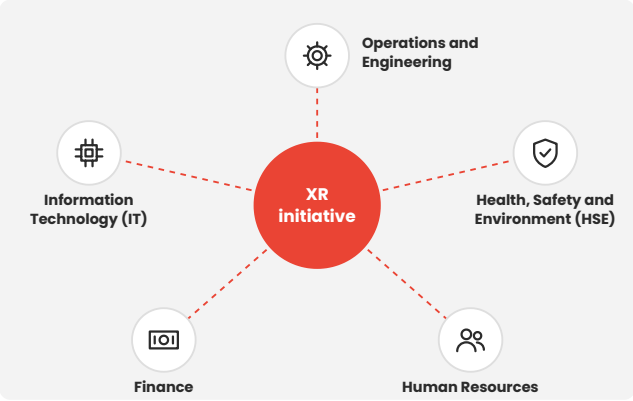


Figure 28 Successful adoption requires involvement from key departments.

Stakeholders should agree on the business problem, project scope, expected benefits, costs and success metrics. Involving frontline supervisors and experienced technicians also helps ensure that solutions address actual operational needs.

Regular progress reviews should guide decisions on whether to refine, expand or discontinue a pilot.

14 Measuring Return on Investment (ROI)

XR investments should be evaluated using measurable financial and operational outcomes. A credible business case requires clear success metrics, baseline data, and realistic estimates of implementation costs and expected benefits.

14.1 Defining Success Metrics

Success metrics should reflect the objectives of each XR application.

Area	Key Performance Indicators
Training	Time to competence, training costs, knowledge retention, completion rates.
Safety	Incident rates, near misses, compliance scores, adherence to safety procedures.
Operations and Maintenance	Repair time, equipment downtime, first-time fix rates, task completion time, rework.
Workforce	Onboarding duration, employee confidence, skills development, staff retention.
Financial	Cost savings, reduced travel, lower overtime, improved production output.

Baseline measurements should be established before implementation to make improvements measurable and credible.

14.2 Financial, Operational and Workforce Benefits

XR can deliver value through several areas:

Financial Benefits

- Reduced training costs.
- Lower equipment downtime and travel expenses.
- Fewer quality defects, scrap, and rework costs.
- Reduced costs associated with workplace incidents.

Operational Benefits

- More consistent task execution.
- Shorter maintenance and production task times.
- Better adherence to standard procedures.
- Faster access to technical expertise.

Workforce Benefits

- Faster skills development and onboarding.
- Improved knowledge retention.
- Reduced dependence on a few experienced employees.
- Greater workforce confidence and preparedness.

Industry studies have reported three-year ROI exceeding 200% in some structured XR training programmes, alongside maintenance task time reductions of 25–40% in selected AR applications. Actual results depend on the use case, implementation quality, and measurement approach (Microsoft HoloLens Total Economic Impact, 2024; industrial AR maintenance studies, 2025–2026).

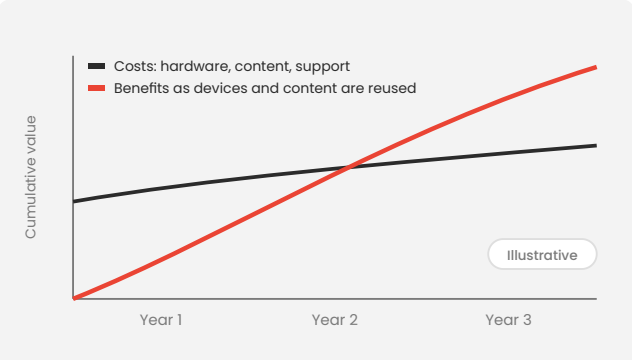


Figure 29 Illustrative only: a multi-year view shows returns as devices and content are reused across employees and applications.

ROI calculations should account for:

- Hardware acquisition and replacement.
- Software licences and content development.
- Internal project and training time.
- Technical support and content maintenance.
- Infrastructure upgrades and partner fees.

A multi-year assessment provides a more realistic picture of returns as devices and content are reused across employees and applications.

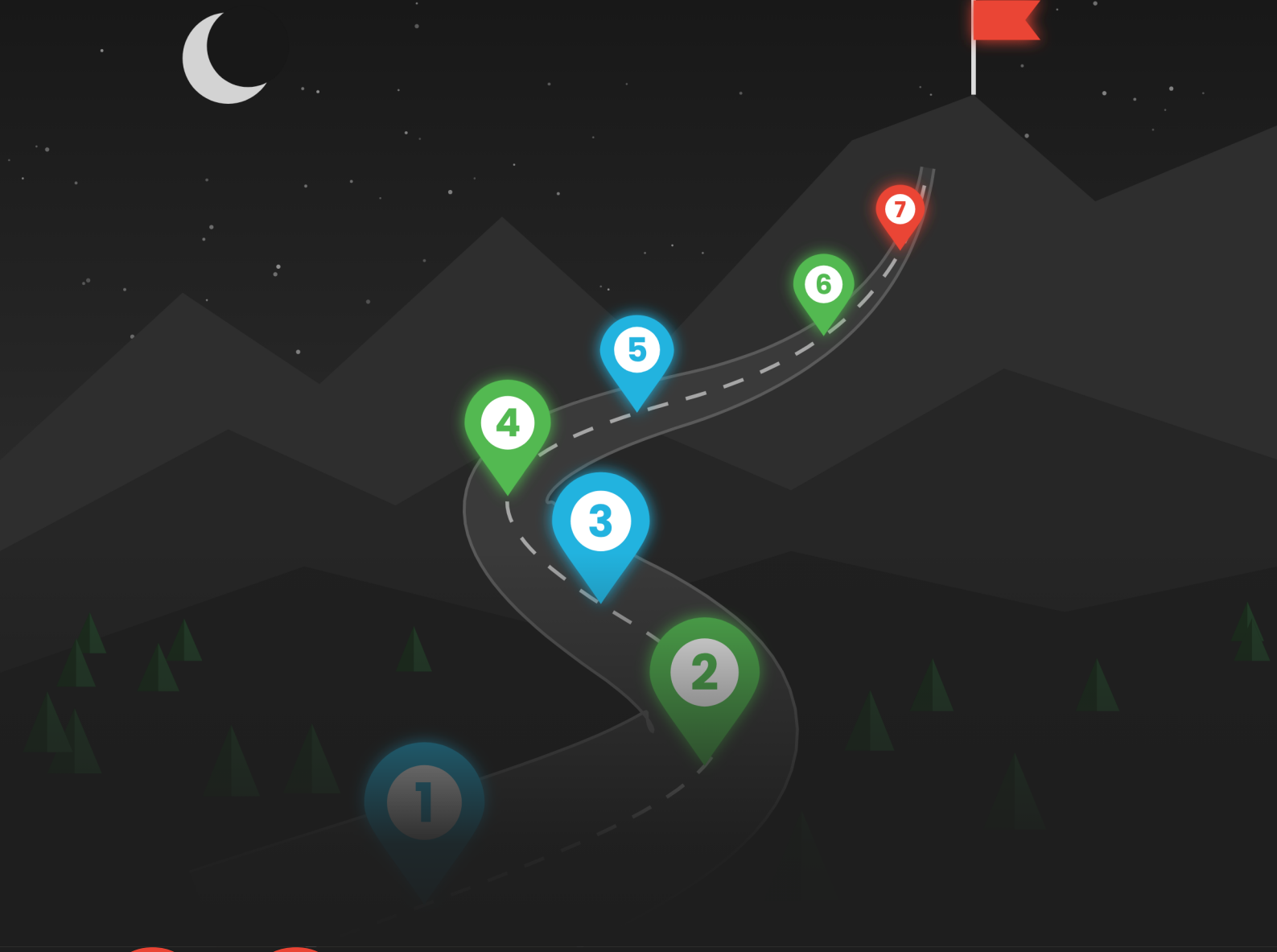
14.3 Long-Term Strategic Value

Beyond immediate financial returns, XR can strengthen organisational capabilities through:

- Better knowledge retention despite staff turnover.
- Consistent training and operational standards across locations.
- Improved readiness for broader digital transformation.
- Stronger technical workforce development.
- Better preparation for customer and regulatory requirements.
- Reduced dependence on individual employees for critical operational knowledge.

These benefits may be difficult to quantify financially but remain important to long-term competitiveness and operational resilience.

A strong XR business case should therefore consider both measurable financial returns and the wider organisational capabilities developed through successful implementation.



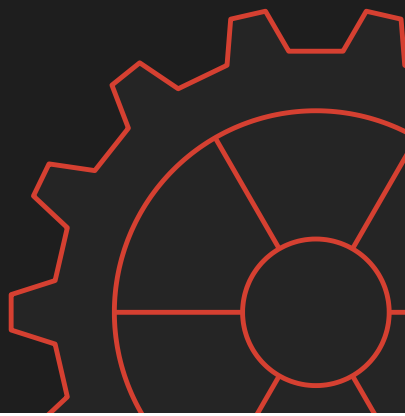
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PART VI

A Practical Adoption Roadmap

15 A Seven-Step XR Adoption Framework

16 Common Challenges and How to Overcome Them



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15 A Seven-Step XR Adoption Framework

Successful XR adoption requires clear objectives, realistic pilots, measurable outcomes and gradual scaling. Nigerian manufacturers should also consider infrastructure limitations, workforce readiness and available resources.

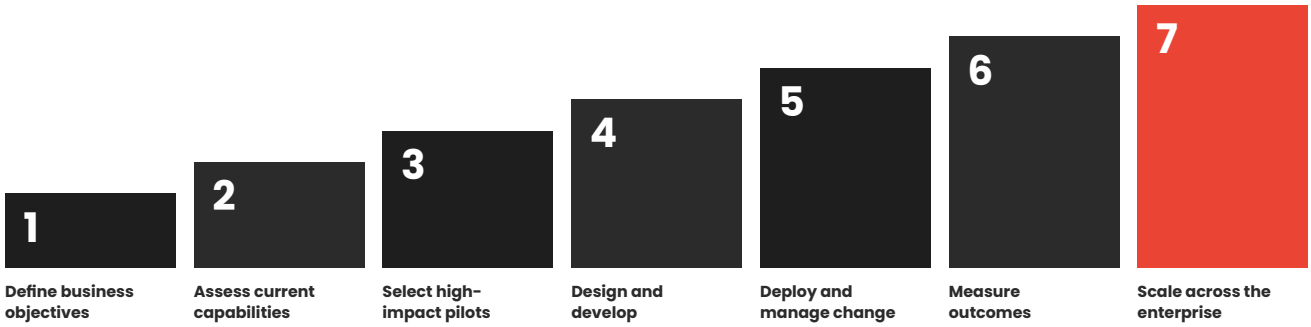


Figure 30 The seven-step XR adoption framework: start with clear objectives and focused pilots, measure, then scale.

01 **Define Business Objectives**

Identify specific operational challenges XR should address, such as reducing training time, improving safety or minimising equipment downtime. Set measurable targets aligned with business priorities.

02 **Assess Current Capabilities**

Evaluate leadership support, power supply, connectivity, workforce skills, content readiness and available resources. Consider offline functionality and device charging where necessary.

03 **Select High-Impact Pilot Projects**

Start with one or two manageable use cases that can demonstrate value within three to six months. Examples include VR safety training, AR-guided maintenance and immersive employee onboarding.

04 **Design and Develop XR Solutions**

Select suitable hardware, software and development partners. Involve subject matter experts and frontline workers to ensure the solution is accurate, practical and suited to local operating conditions.

05 **Deploy and Manage Change**

Train pilot users, communicate expected benefits and appoint internal champions to support adoption. Address practical concerns such as device comfort, charging, hygiene and user resistance.

06 **Measure Outcomes**

Compare results against established baseline metrics, including training time, errors, incidents, downtime and costs. Use employee feedback to identify improvements and determine whether the pilot should proceed.

07 **Scale Across the Enterprise**

Expand successful pilots gradually, prioritising areas with the greatest business value. Standardise deployment, support and measurement processes while building internal capacity to manage future XR applications.

3–6 months

typical window for a focused pilot to demonstrate value

16 Common Challenges and How to Overcome Them

XR adoption can face financial, technical and organisational barriers. Addressing these challenges early improves implementation and long-term value.

Budget Considerations

Initial hardware, development and implementation costs can be significant. Start with small, high-impact pilots and measure returns through reduced downtime, training costs, incidents, scrap and rework. Use phased funding to support gradual expansion.

Change Management and User Adoption

Workers may be unfamiliar with XR or concerned about how it affects their roles. Involve employees early, communicate its purpose clearly, provide practical training and appoint respected internal champions to encourage adoption.

Infrastructure and Hardware Requirements

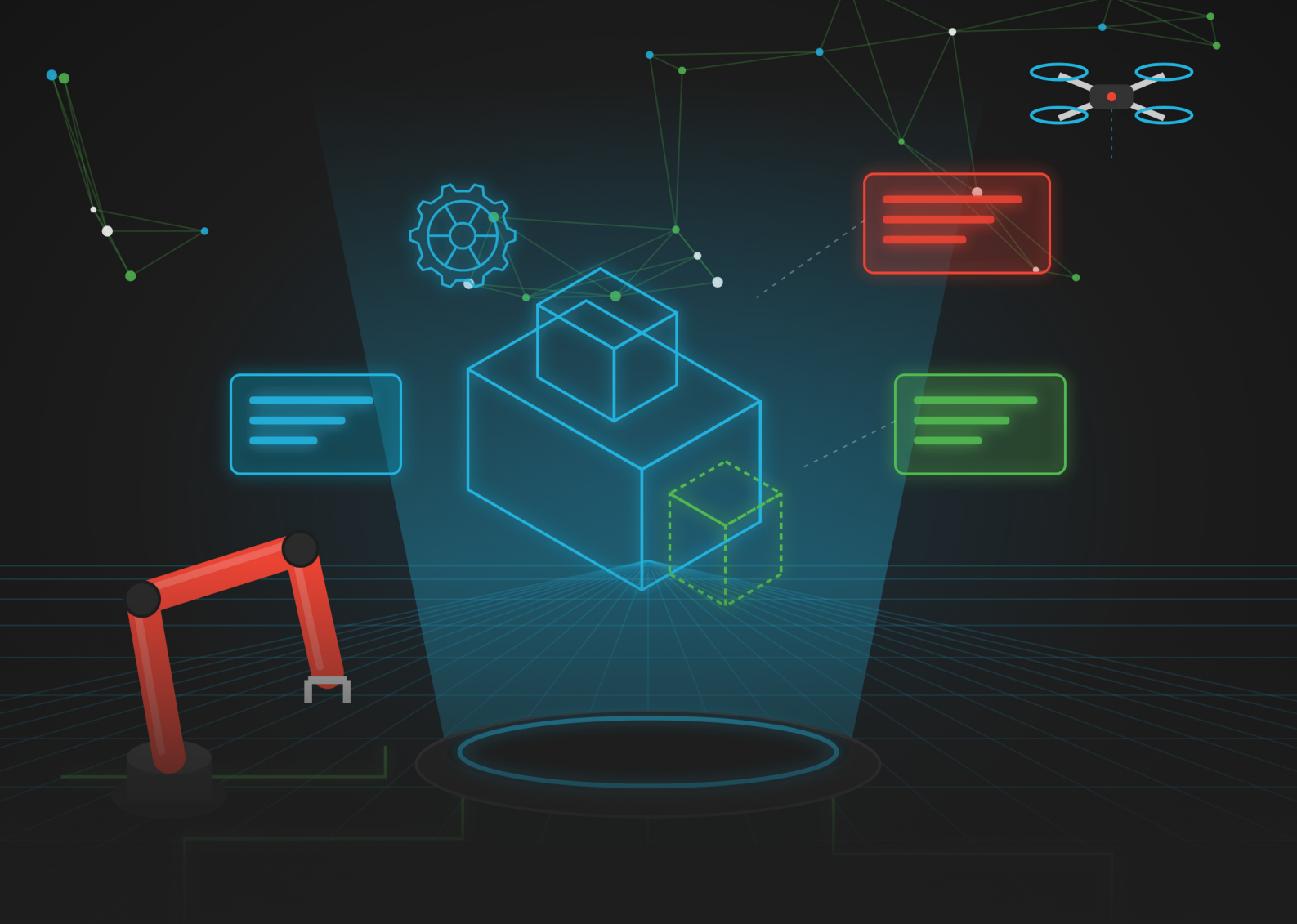
Unreliable power, limited connectivity, heat, dust and storage conditions can affect deployment. Prioritise durable devices, offline-capable applications, adequate battery life and suitable charging and storage arrangements.

Content Maintenance

Changes to equipment, products and procedures can make XR content outdated. Assign responsibility for updates, use version control and design modular content that can be revised without rebuilding entire experiences. Include maintenance costs in the initial budget.

Data Security and Governance

XR systems may collect operational, visual and user data. Establish clear rules for data collection, storage, access, retention and sharing. Apply existing cybersecurity and confidentiality standards, including requirements for external technology providers.



07

PART VII

The Future of Manufacturing

17 Emerging Trends

18 Preparing for the Future

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17 Emerging Trends

Advances in artificial intelligence, spatial computing, connectivity and digital manufacturing are expanding the capabilities of XR. These developments will create new opportunities for manufacturers to improve training, maintenance, collaboration and operational efficiency.

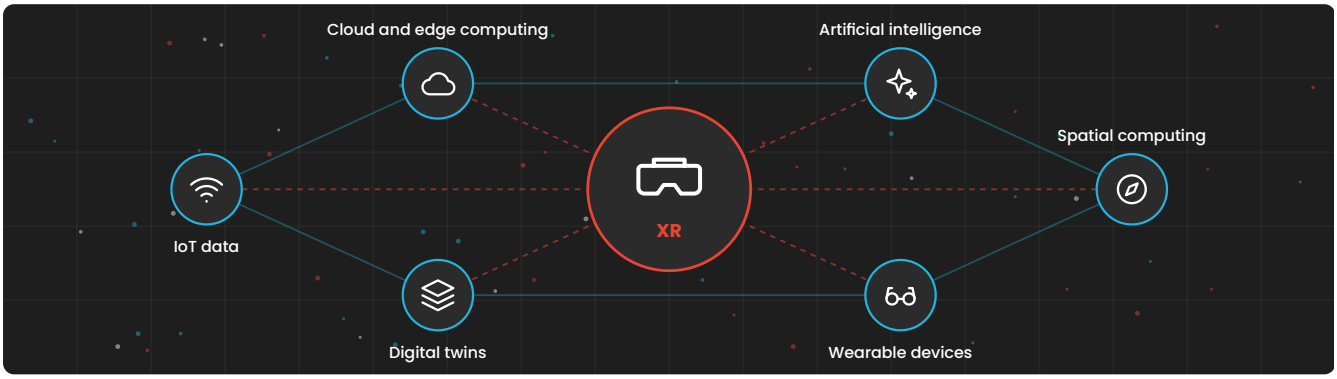


Figure 31 Converging technologies that are expanding the capabilities of XR.

Artificial Intelligence and XR

AI is making XR applications more adaptive and easier to develop. It can convert technical documentation into training content, personalise learning, support equipment recognition and provide step-by-step maintenance guidance. For Nigerian manufacturers, this also offers opportunities to capture experienced workers' knowledge and make it accessible to newer employees.

Spatial Computing and Wearable Technologies

Improvements in spatial mapping, object recognition, tracking and wearable devices are making AR and mixed reality more practical for industrial environments. Lighter, more durable and comfortable headsets and smart glasses could support wider use in maintenance, inspection and routine operational guidance.

Industrial Metaverse and Connected Workforce

The integration of XR, digital twins, IoT data and simulation is enabling shared virtual environments for training, planning, remote collaboration and process optimisation. Although full industrial metaverse adoption may remain a longer-term prospect for many Nigerian manufacturers, individual components such as digital twins and immersive collaboration can be introduced gradually.

Remote Collaboration and Cloud-Based XR

Cloud and edge computing are enabling teams across different locations to share immersive environments for training, design reviews, troubleshooting and commissioning. Centralised content management also makes updates easier across multiple sites. However, connectivity, data security and offline access remain important considerations for Nigerian deployments.

18 Preparing for the Future

Manufacturers should prepare for wider XR adoption by strengthening digital capabilities, encouraging practical experimentation and scaling proven applications. Key priorities include:



Figure 32 A phased path to wider XR adoption.

18.1 Building Digital Capabilities

Develop reliable digital infrastructure, process documentation and staff competencies to support XR adoption. Build internal capacity to manage XR content, support users and measure performance. Partnerships with specialist providers can accelerate implementation while supporting knowledge transfer.

18.2 Encouraging Innovation and Collaboration

Promote a culture of practical experimentation by involving frontline workers in identifying challenges and testing solutions. Use focused pilots with clear objectives and measurable outcomes to build confidence, improve adoption and identify successful applications.

18.3 Scaling Proven Applications

Expand XR deployment gradually, prioritising applications that demonstrate measurable operational value. Standardise content development, device management, user support and performance evaluation to support wider adoption.

For Nigerian manufacturers, a phased approach that considers infrastructure, funding and skills limitations offers a more sustainable path to adoption.



08

PART VIII

Moving Forward

19 Choosing the Right XR Implementation Partner

20 Conclusion

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19 Choosing the Right XR Implementation Partner

Most manufacturers lack all the specialised skills needed to develop, deploy, and maintain XR solutions entirely in-house. Choosing the right implementation partner is therefore essential to achieving practical results, supporting adoption, and building long-term internal capabilities.

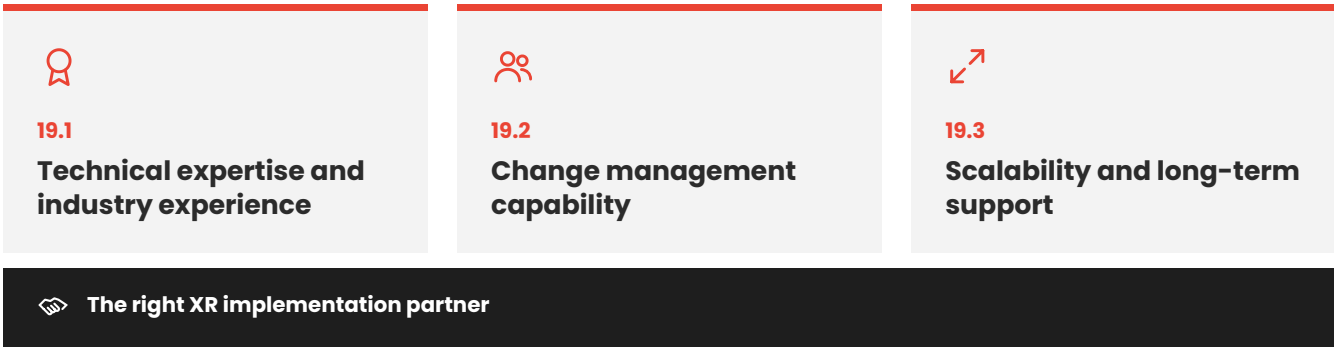


Figure 33 Three areas to assess when choosing an XR implementation partner.

19.1 Technical Expertise and Industry Experience

A suitable partner should demonstrate experience in industrial or manufacturing applications, particularly in training, maintenance, safety, remote assistance, or production guidance.

Key considerations include:

- Proven industrial deployments with measurable outcomes.
- Understanding of factory conditions, including limited connectivity, hardware requirements, and operational constraints.
- Ability to work with CAD models, technical manuals, standard operating procedures, and expert input.
- Focus on practical usability, reliability, and integration with existing workflows.
- Experience delivering solutions that address real operational challenges.

Manufacturers should request relevant case studies, client references, and details of the technologies and development approaches used. Technical expertise should be supported by practical industrial experience.

19.2 Change Management Capability

Successful XR implementation requires more than technical delivery. Partners should support workforce adoption through user involvement, staff training, internal champions, clear communication, and timely resolution of usability challenges.

Manufacturers should assess how potential partners have managed adoption in previous projects, involved employees, addressed resistance, and incorporated user feedback. Effective change management helps ensure that solutions are not only deployed but consistently used.

19.3 Scalability and Long-Term Support

Manufacturers should evaluate whether a partner can support the solution beyond the initial pilot. Important considerations include:

- Ease of updating content as equipment and procedures change.
- Availability of technical support, troubleshooting, and device management.
- Clear knowledge-transfer plans for internal teams.
- Flexible commercial arrangements that support gradual expansion.
- Data security, confidentiality, and intellectual property protection.

- Clear ownership of content, source materials, and future update rights.

Partners should also provide transparent pricing, realistic delivery timelines, and clear exit arrangements. The preferred partner should help manufacturers build internal capabilities and reduce dependence on external support for routine activities over time.

Ultimately, manufacturers should prioritise partners who combine industrial experience, effective change management, and long-term support rather than selecting based solely on impressive demonstrations or initial cost.

20 Conclusion

20.1 Key Takeaways

Extended Reality is a practical set of tools that can help Nigerian manufacturers address persistent challenges in skills development, safety, knowledge retention, equipment uptime, quality consistency, and operational standardisation. When applied to carefully selected use cases, XR has delivered measurable improvements in training speed, error reduction, remote support effectiveness, knowledge transfer, and related cost savings in global manufacturing settings (Microsoft, 2024; enterprise VR and AR analyses, 2025–2026; industrial case evidence summarised throughout this paper).

> **XR is one instrument among others that can contribute to these priorities when selected and managed with care.**

XR does not replace core investments in power reliability, process discipline, basic digital infrastructure, or sound management. It complements them by improving how people learn, access information, execute procedures, and collaborate. The strongest results come from organisations that start with clear business problems, run disciplined pilots with defined metrics, measure outcomes rigorously, manage the human side of adoption, and scale only what proves valuable.

Hardware and software have reached a level of practical maturity that makes industrial application realistic. Artificial intelligence is further reducing content creation barriers and enhancing personalisation and adaptive guidance. At the same time, success still depends more on organisational readiness, use case selection, change management, content quality, and sustained focus on business outcomes than on the sophistication of the technology itself.

For Nigerian manufacturers, the opportunity is real but not automatic. Firms that approach XR with the same operational discipline applied to other improvement initiatives, clear objectives, baseline measurement, controlled experimentation, honest evaluation, and progressive capability building are best placed to capture its benefits. Those that treat it as a technology showcase or a broad digital transformation programme without operational grounding are more likely to experience delayed or diluted returns.

The manufacturing sector faces significant structural constraints. Within those constraints, strengthening workforce competence, retaining critical knowledge, improving safety performance, reducing downtime, and raising process consistency remain high leverage priorities. XR is one instrument among others that can contribute to these priorities when selected and managed with care.

20.2 Recommended Next Steps for Nigerian Manufacturers

Manufacturers ready to explore XR can follow these practical steps:

01 **Identify Priority Problems**
Select one or two operational challenges XR could address, such as lengthy onboarding, safety risks, maintenance delays, or knowledge gaps. Establish their current operational impact.

02 **Assess Readiness**

Evaluate leadership support, power and connectivity, existing documentation, internal capabilities, and workforce readiness. Identify gaps before implementation.

03 **Design a Focused Pilot**

Define the use case, target users, success metrics, and timeframe (typically three to six months). Establish baseline measurements for evaluating results.

04 **Engage Suitable Partners**

Select partners based on industrial experience, technical capability, local understanding, content maintenance, and knowledge transfer.

05 **Manage Implementation**

Involve employees early, appoint internal champions, communicate the purpose clearly, and address adoption challenges throughout the pilot.

06 **Measure Results**

Compare outcomes against baseline measurements, gather user feedback, and determine whether to improve, expand, pause, or discontinue the project.

07 **Scale Proven Solutions**

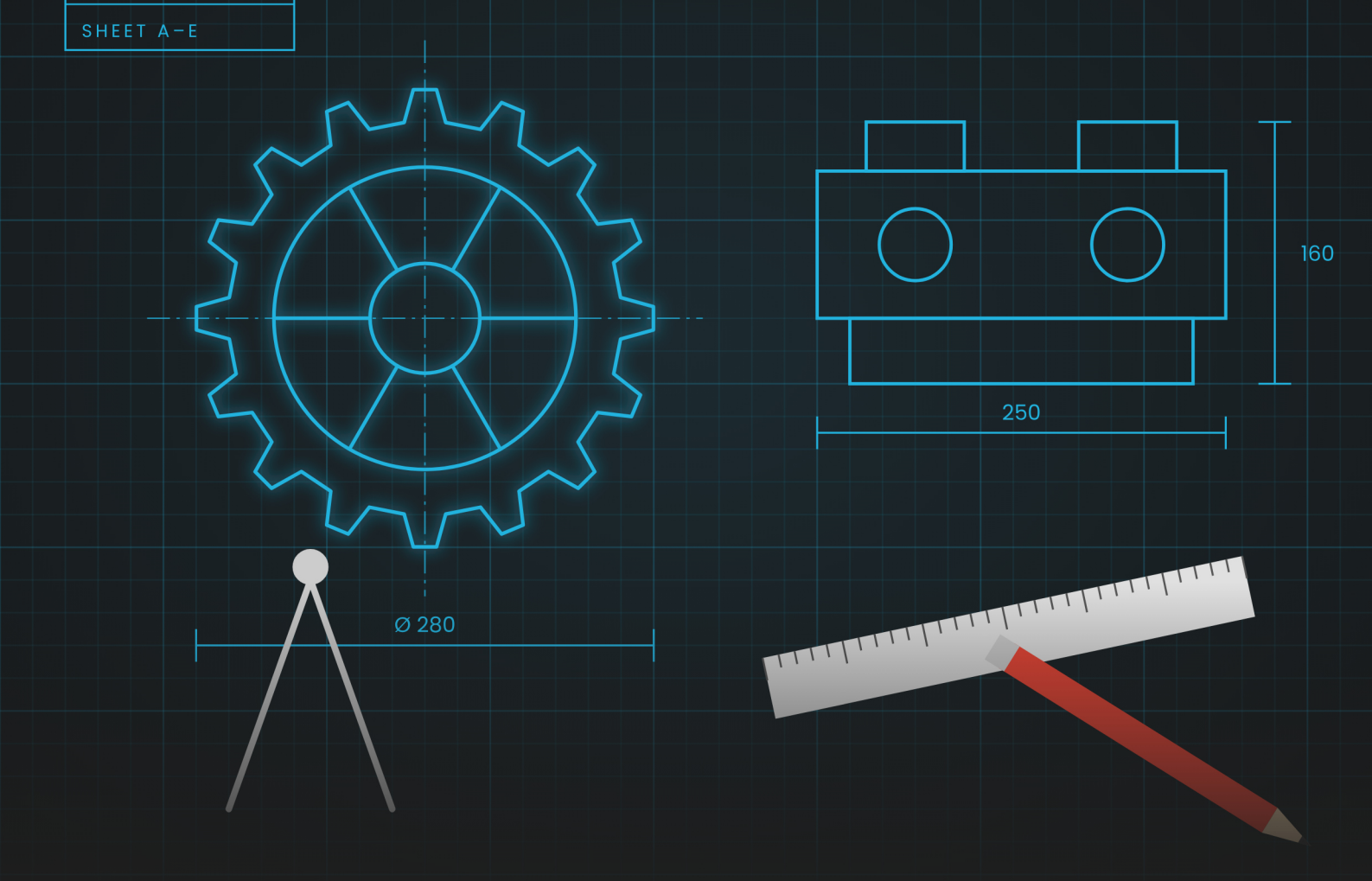
Expand only where measurable value has been demonstrated. Standardise successful approaches and gradually build internal capabilities.

08 **Align with Business Priorities**

Integrate XR initiatives with existing safety, productivity, quality, and workforce development objectives.

Following this approach enables manufacturers to make evidence-based decisions about where and how XR can deliver value. Rather than investing based on technology trends, organisations should focus on clearly defined problems, realistic readiness assessments, and measurable outcomes.

Ultimately, successful XR adoption requires clear objectives, disciplined implementation, and honest evaluation. Manufacturers that adopt this approach will be better positioned to turn XR's potential into lasting operational benefits.



A–E

BACK MATTER

Appendices

A XR Terminology
B XR Readiness Checklist
C Illustrative Manufacturing Use Cases
D ROI and KPI Framework
E References and Further Reading

Insightful 3D

APPENDIX A

XR Terminology

Term	Definition
Augmented Reality (AR)	Digital information such as text, images, instructions or 3D models overlaid on a view of the physical world.
Digital twin	A virtual representation of a physical asset, process or system. It may be connected to real-world data for monitoring, analysis or simulation.
Extended Reality (XR)	Umbrella term covering VR, AR and MR.
Immersive training	Training in which learners interact with simulated environments or contextual digital content.
Mixed Reality (MR)	Digital content integrated with an understanding of the physical environment, allowing virtual objects to interact with real-world spatial features.
Remote expert assistance	A capability that allows a remote specialist to view a local worker's perspective and provide guidance.
Spatial computing	Computing that understands and interacts with three-dimensional space, including users, objects and surfaces.
Virtual Reality (VR)	A computer-generated environment that replaces the user's view of the physical surroundings, typically through a headset.
Digital work instructions	Step-by-step procedural guidance delivered through a digital device, sometimes overlaid on the physical workspace.

APPENDIX B

XR Readiness Checklist

Use this short checklist before committing to an XR pilot.

☐ **Business need**	Is there a clearly defined problem and a measurable outcome?
☐ **Leadership**	Is a business sponsor accountable for the pilot and its results?
☐ **People**	Have end users, supervisors and relevant subject-matter experts been identified?
☐ **Infrastructure**	Are power, connectivity (or offline capability), charging, storage and hygiene arrangements suitable?
☐ **Content**	Are the procedures and technical information available, accurate and approved?
☐ **Delivery and support**	Is there a realistic budget, named project owner and plan for updates and ongoing support?

Readiness decision:	☐ Ready ☐ Ready with actions ☐ Not ready
Critical actions before starting:	_____
	_____
	_____

APPENDIX C

Illustrative Manufacturing Use Cases

Use case	Suitable XR approach	Potential benefit	Example measures
Employee onboarding and facility orientation	VR	More consistent induction	Completion rate, time to productivity, supervisor hours
Lockout/tagout training	VR	Practice of safety-critical sequences	Assessment results, procedural adherence
Confined-space or working-at-height familiarisation	VR	Safe rehearsal of high-risk scenarios	Competence assessment, drill performance
AR-guided maintenance	AR	Contextual instructions at the point of work	Task time, first-time fix rate, MTTR
Remote expert assistance	AR	Faster access to specialist support	Resolution time, travel avoided, downtime
Assembly or changeover instructions	AR	More consistent task execution	Cycle time, error rate, rework
Defect recognition training	VR or AR	Improved inspection practice	Inspection accuracy, escaped defects
Factory layout review	VR or MR	Earlier identification of layout issues	Design changes, issues identified before installation
Emergency response simulation	VR	Rehearsal of response decisions	Drill performance, assessment results
Technician multi-skilling	VR and AR	Broader workforce capability	Multi-skill coverage, time to competence

SELECTION TIP

These examples are starting points, not a recommendation to deploy every use case. Select one or two that address the organisation's most important problems and can be measured.

APPENDIX D

ROI and KPI Framework

1. Establish a baseline

Collect relevant data for a defined period before implementation. Use the same definitions and measurement methods during the pilot.

2. Select relevant measures

Choose only the indicators that relate directly to the project objective. Potential measures include:

- **Training:** time to competence, assessment scores, knowledge retention, cost per learner and supervisor coaching hours.
- **Safety:** procedural adherence, assessment results, drill performance and relevant incident or near-miss trends.
- **Maintenance:** mean time to repair, first-time fix rate, task completion time and downtime.
- **Production and quality:** cycle time, process errors, inspection accuracy, scrap and rework.
- **Workforce:** onboarding duration, multi-skilling coverage and user confidence.
- **Financial:** travel avoided, training costs, downtime value and rework costs.

3. Calculate the financial case

Compare total quantified benefits with total costs over the same period.

ROI (%) = (Total benefits - Total costs) ÷ Total costs × 100

Include hardware, software, content development, integration, internal time, training, support, maintenance and replacement costs. State assumptions and use conservative estimates.

4. Record qualitative outcomes

Capture user and supervisor feedback, ease of use, consistency of procedure execution, content-update effort and internal capability gained.

5. Review results

- **During the pilot:** regular operational check-ins.
- **At pilot completion:** formal review against the baseline.
- **After scaling:** periodic benefit tracking, such as quarterly or semi-annually.

APPENDIX E

References and Further Reading

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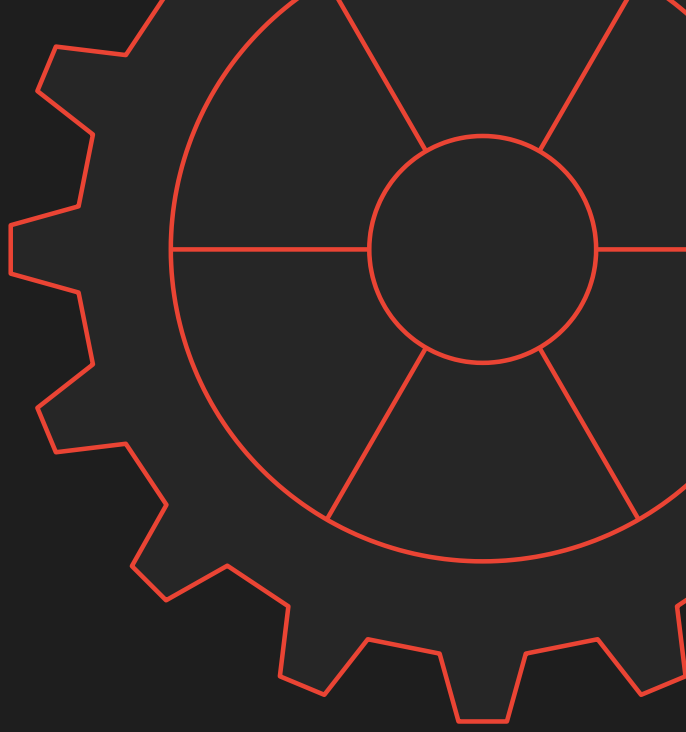
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The decision to explore XR does not require a leap of faith.

It requires clarity about problems, realism about readiness, discipline in execution, and honesty in evaluation.

ABOUT INSIGHTFUL3D

Insightful3D is a Lagos based immersive technology company delivering Extended Reality (XR) solutions and industrial 3D scanning services. This white paper is part of our work to help decision makers evaluate immersive technology with clarity and operational discipline.

Email	info@insightful3d.com
Phone	+234 906 000 6378
Web	www.insightful3d.com
Lagos	8a Oje Imianvan Street, Julie Estate, Oregun, Ikeja

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