A Forrester Total Economic Impact™
Study Commissioned By PTC
July 2019

The Total Economic Impact™ Of PTC Vuforia

Cost Savings And Business Benefits Enabled By Industrial Augmented Reality

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ABOUT FORRESTER CONSULTING

Forrester Consulting provides independent and objective research-based consulting to help leaders succeed in their organizations. Ranging in scope from a short strategy session to custom projects, Forrester's Consulting services connect you directly with research analysts who apply expert insight to your specific business challenges. For more information, visit forrester.com/consulting.

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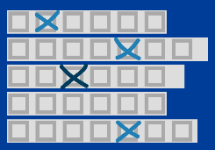
Benefits

Improved knowledge transfer:
50% reduction in new hire training

Improved field service quality and productivity:
10% to 12% reduction in overtime spend

Improved documentation:
60% faster creation of technical documents



Reduction in spoilage, rework, and waste:
5% to 10% reduction

Executive Summary

Forrester defines augmented reality (AR) as "the virtual overlay of contextual digital information that a computer generates on a physical-world object and that a user sees in the display of a mobile device as its camera captures it in real time."[1] AR has become a powerful tool for a variety of employee-oriented enterprise scenarios and has found a home in industrial, manufacturing, and field service-oriented verticals.[2] This adoption has increased as the complexity of workers' jobs across manufacturing, maintenance, and technical service sectors increases in direct proportion to the complexity of the products they make and maintain.[3]

PTC provides an industrial augmented reality product suite that plays a key part in its customers' transformation to Industry 4.0. With the Vuforia family of products, organizations can rapidly create and deploy AR experiences to enrich their operations, training, and sales processes.

PTC commissioned Forrester Consulting to conduct a Total Economic Impact™ (TEI) study and examine the potential return on investment (ROI) enterprises may realize by deploying Vuforia. The purpose of this study is to provide readers with a framework to evaluate the potential financial impact of AR products from Vuforia on their organizations.

To better understand the benefits, costs, and risks associated with this investment, Forrester interviewed four customers with years of experience using Vuforia and surveyed 150 US manufacturing firms that are interested in adopting AR.

Prior to using Vuforia, interviewed customers used traditional operations, training, and sales processes. Training was performed in classroom-based sessions, with manual examination and evaluation. Sales teams would visit jobsites and marketing events with physical, and oftentimes cumbersome, equipment. Operations workers relied on rudimentary tools and paper documentation to complete their job functions. Nevertheless, organizations discerned that an aging workforce and changing customer expectations would become a barrier for growth in the not too distant future — and their current state of operations would not be sufficient to overcome these obstacles.

With Vuforia, organizations can modernize operations across business functions: creating immersive training environments, streamlining the creation of technical documents, augmenting service and line workers, arming their sales teams with powerful tools, and differentiating their products in competitive markets.

Key Findings

Quantified benefits. The following risk-adjusted present value (PV) quantified benefits are representative of those experienced by the companies interviewed:

- **Vuforia improved knowledge transfer, and reduced training time by 50%.** The transition of conventional training processes — classroom instructions, hands-on training, and paper manuals — to digital AR experiences facilitated a reduction in the amount of time and investment required to train new employees while improving the quality of outcomes. Organizations experienced a 50% decrease, on average, in time-to-productivity for their new workers trained with Vuforia AR experiences.

> "Value is being created in four levels. One is documentation, second is training, third is operations, and fourth is analytics. These four levels of the pyramid are how we are transforming our business."
>
> *Global head of innovation, semiconductor manufacturing*

- **Vuforia improved field service quality and productivity, reducing overtime spend by 10% to 12%.** Vuforia AR products improved first-time fix rates for field service workers and enabled them to do more jobs during shifts. Organizations with more productive field service workforces saw a reduction in overtime hours and the corresponding payroll burden.
- **Vuforia reduced time in creating new technical documents, reducing effort by 60%.** Organizations needed to create complex and detailed technical documents to accompany their products and internal processes. PTC Vuforia allowed organizations to create experiences for end users of their products, providing an interactive alternative to traditional paper or PDF manuals. Furthermore, organizations with elaborate internal manufacturing processes used Vuforia Expert Capture to quickly and effectively create visual documentation.
- **Vuforia facilitated better production processes, reducing waste, spoilage, and rework.** With more robust training and real-time work assistance, organizations improved production processes. Manufacturing operations experienced less waste, spoilage, and fewer reworks when workers can leverage Vuforia AR products to accomplish their day-to-day tasks.
- **Vuforia reduced selling expenses.** The ability to bring AR experiences to trade shows and sales meetings eliminated sizable shipping and sales expenses for organizations that normally bring large machinery to remote sites.

Unquantified benefits. The interviewed organizations experienced the following benefits, which are not quantified for this study:

- **Improved customer satisfaction.** Organizations used Vuforia experiences to enrich customers' interactions with their products. Customers used experiences to self-assemble and service products or were aided by service agents through interactive AR interfaces. In the latter case, customers experienced better service — improved quality of installations and increased first-time fix rates — which improved their overall satisfaction.
- **Improved visibility into channel sales and product usage.** Organizations selling their products through channel partners gained insight into their end users' product usage with paired AR applications. Organizations could track and better understand how their customers interacted with products, creating a feedback loop for improving their offerings.
- **Differentiated product and service offerings.** Organizations differentiated their products from similar offerings on the market by pairing them with AR experiences. Organizations also used AR at trade shows and on jobsites to create unique and immersive product experiences for potential customers. Furthermore, organizations that provide service techs with AR tools improved the quality of service provided and rose above their competitors.
- **Reduced contact center costs.** The ability to visually assist customers using Vuforia Chalk or provide them with self-help experiences using Vuforia Expert Capture and Vuforia Studio reduced the frequency and length of customer contacts and lowered contact center costs.
- **Enriched sales leads and improved sales environment.** Organizations used AR experiences to showcase their offerings at trade shows, increasing traffic to their booths and subsequent leads.

ROI
172%

Benefits PV
$12.6 million

NPV
$7.9 million

Payback
<6 months

Furthermore, the ability to demonstrate industrial products in an office setting instead of in loud factories created a more comfortable environment for customers and sales teams.

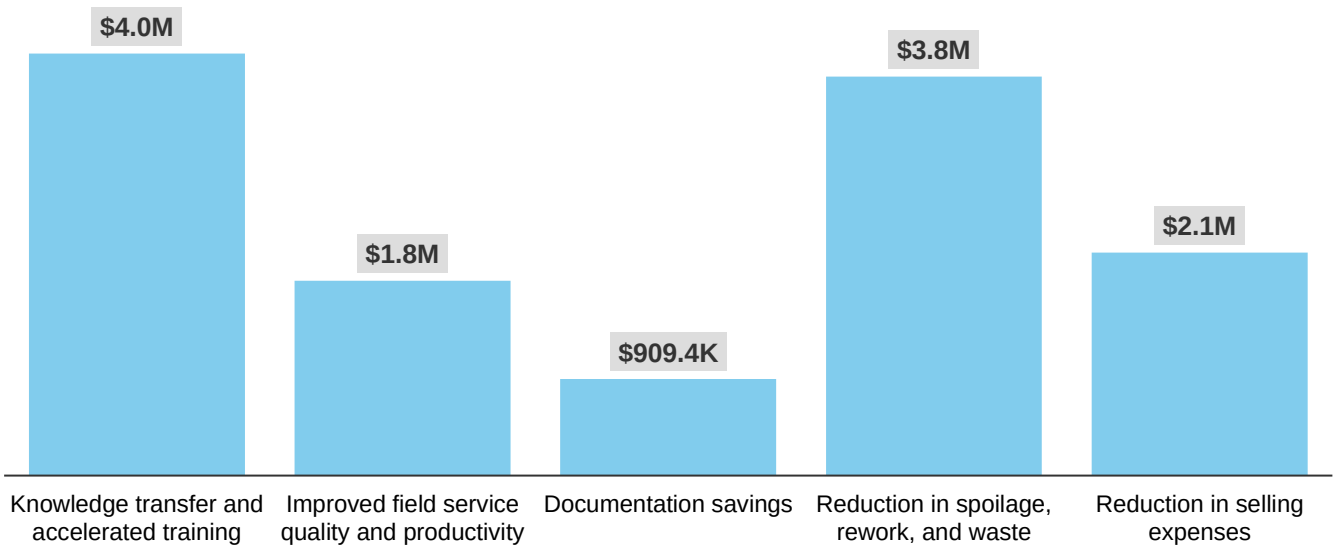
- **Improved safety and working conditions.** Providing real-time assistance to workers and highlighting operation hazards with AR overlays reduced the likelihood of accident and improved overall safety. Additionally, instructing employees on virtual versions of tools rather than physical machinery provided a safer training environment.

Costs. The interviewed organizations experienced the following risk-adjusted PV costs:

- **Vuforia license costs.** Organizations paid PTC annual license fees for use of the Vuforia suite of products.
- **Internal planning and development expenses.** Organizations maintained innovation teams, tasked with developing internal use cases and planning deployments of AR experiences.
- **Purchases of AR devices.** Organizations purchased tablets and head-mounted devices for use with AR applications. Furthermore, organizations refunded their employees for bring-your-own-device (BYOD) smartphones used to access AR applications.

Forrester's interviews with four existing customers and subsequent financial analysis found that an organization based on these interviewed organizations experienced benefits of $12,578,069 over three years versus costs of $4,627,354, adding up to a net present value (NPV) of $7,950,650 and an ROI of 172%.

Benefits (Three-Year)



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TEI Framework And Methodology

From the information provided in the interviews, Forrester has constructed a Total Economic Impact™ (TEI) framework for those organizations considering implementing PTC Vuforia.

The objective of the framework is to identify the cost, benefit, flexibility, and risk factors that affect the investment decision. Forrester took a multistep approach to evaluate the impact that PTC Vuforia can have on an organization:

The TEI methodology helps companies demonstrate, justify, and realize the tangible value of IT initiatives to both senior management and other key business stakeholders.

DUE DILIGENCE
Interviewed PTC stakeholders and Forrester analysts to gather data relative to Vuforia.

CUSTOMER INTERVIEWS
Interviewed four organizations using Vuforia to obtain data with respect to costs, benefits, and risks.

COMPOSITE ORGANIZATION
Designed a composite organization based on characteristics of the interviewed organizations.

FINANCIAL MODEL FRAMEWORK
Constructed a financial model representative of the interviews using the TEI methodology and risk-adjusted the financial model based on issues and concerns of the interviewed organizations.

CASE STUDY
Employed four fundamental elements of TEI in modeling PTC Vuforia's impact: benefits, costs, flexibility, and risks. Given the increasing sophistication that enterprises have regarding ROI analyses related to IT investments, Forrester's TEI methodology serves to provide a complete picture of the total economic impact of purchase decisions. Please see Appendix A for additional information on the TEI methodology.

DISCLOSURES

Readers should be aware of the following:

This study is commissioned by PTC and delivered by Forrester Consulting. It is not meant to be used as a competitive analysis.

Forrester makes no assumptions as to the potential ROI that other organizations will receive. Forrester strongly advises that readers use their own estimates within the framework provided in the report to determine the appropriateness of an investment in PTC Vuforia.

PTC reviewed and provided feedback to Forrester, but Forrester maintains editorial control over the study and its findings and does not accept changes to the study that contradict Forrester's findings or obscure the meaning of the study.

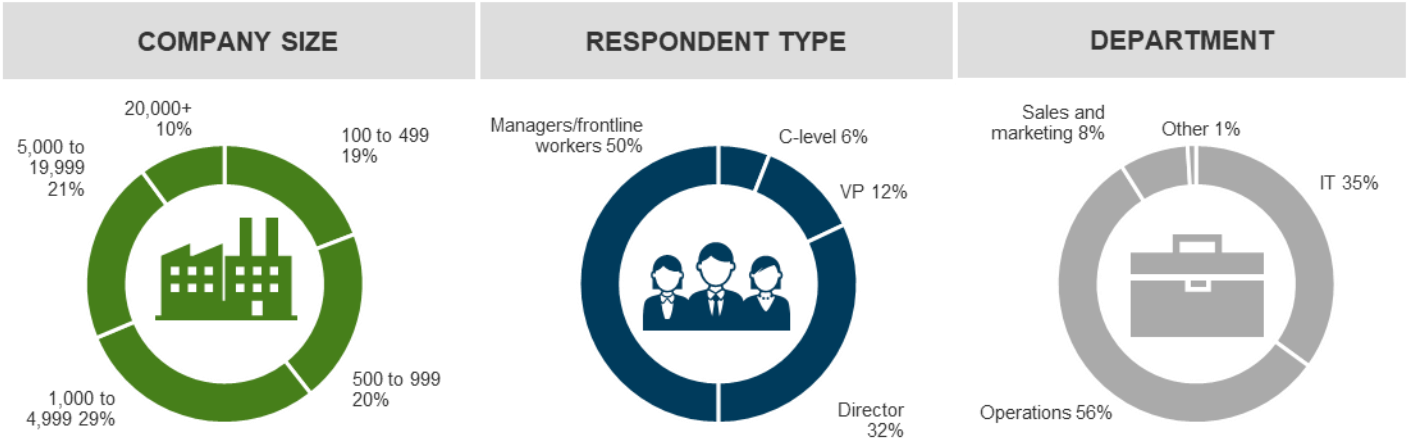
PTC provided the customer names for the interviews but did not participate in the interviews.

The Vuforia Customer Journey

BEFORE AND AFTER THE VUFORIA INVESTMENT

Surveyed Organizations

Forrester conducted an online survey of 150 respondents at manufacturing firms in the United States with 100 or more employees. The survey evaluated interest in AR and how it could be applied to critical organizational objectives.



Base: 150 US manufacturers
Note: Percentages may not total 100 because of rounding
Source: A commissioned study conducted by Forrester Consulting on behalf of PTC, March 2019

Interviewed Organizations

For this study, Forrester conducted four interviews with PTC Vuforia customers. Interviewed customers include the following:

INDUSTRY	REGION	REVENUE	DEPLOYMENT
Medical equipment	United States	$10.5 billion	Smartphones Tablets
Semiconductor manufacturing	United States	$5.5 billion	Head-mounted devices Smartphones Tablets
Industrial machinery	United States	$3.5 billion	Head-mounted devices Smartphones Tablets
Sports manufacturing	United States	Est. $200 million	Smartphones

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Key Challenges

Prior to implementing PTC Vuforia, interviewees shared several common challenges and pain points in their operations:

- **The drive to improve operational efficiencies.** A critical objective for organizations was to improve operational efficiencies, through training and improved worker productivity. Of the 150 manufacturers surveyed, 74% stated that improved operational efficiency was the top business priority driving their interest and investment in AR.
- **Aging workforces and inability to retain knowledge.** Interviewees expressed concerns that their organizations' current workforces had a high average age, and as such, they projected a significant turnover in the coming years. Furthermore, many organizations had postponed documentation of work in pursuit of increased output, putting them at risk of losing knowledge with workers as they retired. Interviewees needed a way to capture and document work during the course of operations, without impeding production. The global head of innovation for a semiconductor manufacturing firm said: "The documentation is never where we need it to be. Shipping product will always take precedence over doing the documentation, so there is always a gap between where we need to be and where we are in terms of standard operation procedure. Documentation is not a sexy job; it's not something you can do immediately — it takes time."
- **A need to revamp existing training processes.** Interviewed organizations wanted to create enriched learning environments that would accelerate training times and use new technologies to attract younger talent. A senior manager of IT product service at a medical equipment firm said: "We know we're going to lose a significant amount of talent in the next 10 years because of retirements. In order to engage younger, early-career professionals, we need to do something that can enable remaining senior technicians to help less senior technicians — but do it in a way that is going to entice people who have grown up with computers their whole lives."
- **Competitive markets with little product differentiation.** An engineering manager at a sports manufacturing firm stated: "Fifteen years ago, there were a lot of competitors, and you could stand as a brand just by making a quality product. At this point, everyone makes a good and reliable product, so differentiation is always a problem. Everyone knows what everyone else is doing — and builds features and prices to match. Differentiation within the product is very difficult for us, and we're always looking for new ways to do it. AR was something we could add to our offering, without changing the product itself, and still offer a very different experience than our competitors."
- **An organizational mandate to transition to Industry 4.0.** Organizations shared a larger goal of accelerating digital transformation and evolving their enterprises to Industry 4.0. Departments had mandates in place for increased innovation within operations to compete in the manufacturing market of the future.

> "I think in two years, every product is going to have some form of interactive experience. But right now, there is a window over the next couple of years where the fast movers will receive undo advantage. That means more sales and or market share."
>
> *VP of digital growth, industrial manufacturing*

> "Our old training was highly manual. It was done in classroom-based sessions, through written work and manual documents. As people are getting up to speed, the measurement and assessments are done on paper and reviewed by a trainer. It was very time-intensive; the cost and the time-to-productivity were criteria we looked to cut down."
>
> *Senior manager of IT product service, medical equipment*

"What are the top business priorities/drivers for your organization?"
(Select all that apply)

Base: 150 US manufacturers
Source: A commissioned study conducted by Forrester Consulting on behalf of PTC, March 2019

"PTC's view is, 'Be hardware-agnostic.' We really like that because it gives us the flexibility to use what we have or experiment with new devices of our choice."

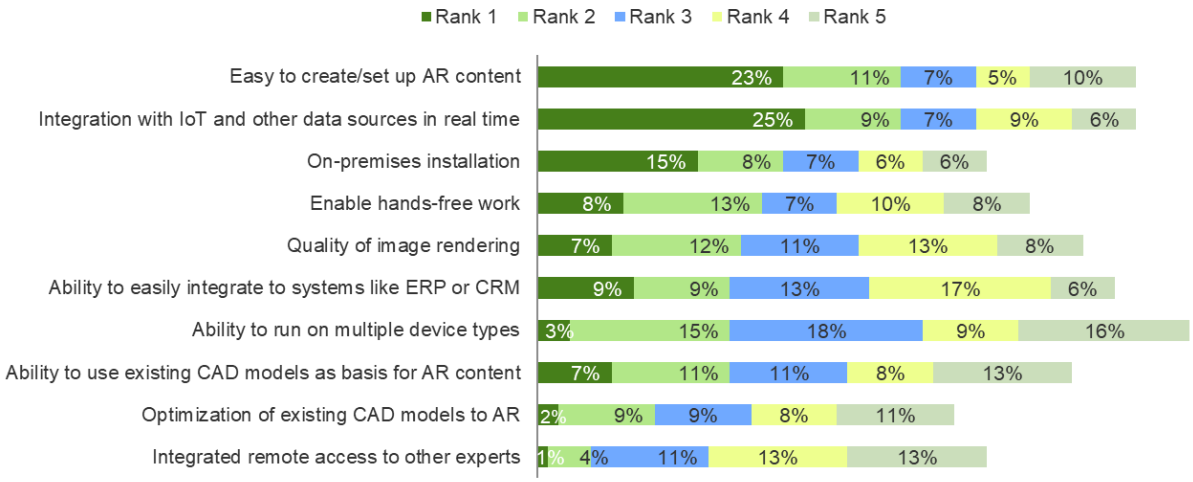
Global head of innovation, semiconductor manufacturing

Solution Requirements

The interviewed organizations searched for a solution that could:

- Easily deploy using existing internal assets.
- Improve training quality while reducing time and costs.
- Easily document products and processes.
- Deploy on peripherals of choice.

"What are the most important features/qualities of an augmented reality solution?"



Base: 150 US manufacturers
Source: A commissioned study conducted by Forrester Consulting on behalf of PTC, March 2019

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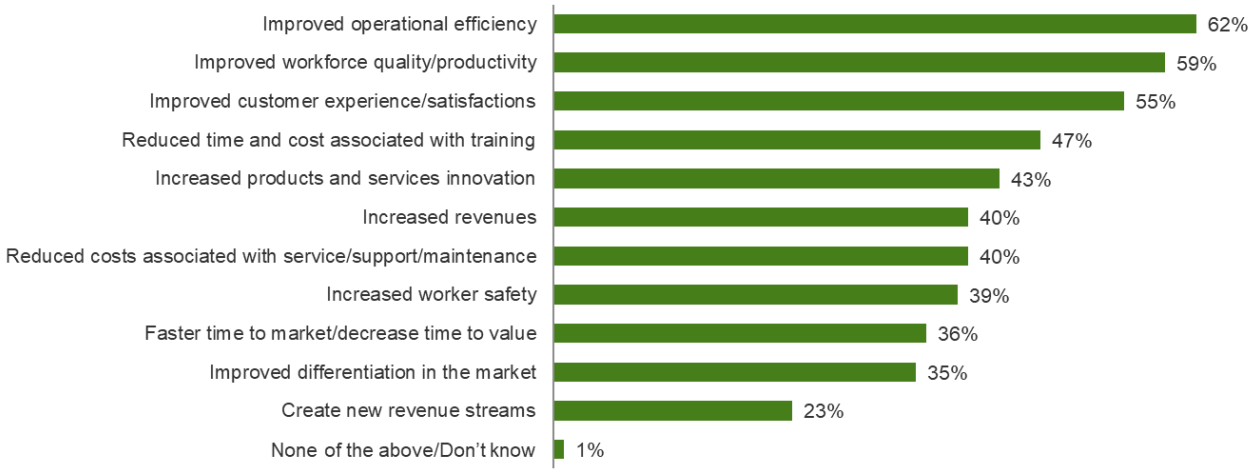
Key Results

The interviews revealed that key results from the Vuforia investment include:

- **Drastic reduction in training times and costs.** Organizations saw an average reduction of 50% in the time required to train employees on complex industrial tasks. Interviewees transformed classroom- and paper-based instructional courses into highly interactive AR experiences. Trainees going through the AR course were able to better understand the tools they would be working with and could do so at a more accelerated pace than in the traditional training processes.
- **Improved field service productivity.** Field technicians installing and servicing equipment were aided by remote assist, allowing them to complete jobs faster and with improved accuracy. Organizations using Chalk saw a 10% to 12% reduction in overtime spend allocated to field service teams due to their ability to complete more jobs during normal shifts.
- **Reduced effort to create technical documents.** Using Expert Capture, employees could easily document their work during operations. This reduced the effort required to fulfill documentation duties and encouraged workers to do so in a timely manner. The global head of innovation at a semiconductor manufacturer said: "With PTC's Expert Capture coming in, we have created more than 30 use cases in our plant. By the end of the year, we plan to have 500."
- **Reduction in spoilage, rework, and waste.** Improved workforce training had a downstream effect of increased work quality, leading to less waste. Additionally, organizations provided workers with AR assistance to aid them in making real-time operational decisions, which further improved the quality of their work.
- **Reduction in selling expenses.** Organizations supplanted traditional trade show installations and jobsite demonstrations with Vuforia Studio AR experiences for potential customers to view their products. The ability to visually overlay large equipment at a jobsite without transporting and assembling it physically provided a substantial financial benefit to companies.

> "PTC has been giving us the absolute best they are capable of. It's probably the best collaboration I've seen. Anytime I request help, they've sent 15 people over within two weeks. Every deadline we've had has been possible due to their support."
>
> *Global head of innovation, semiconductor manufacturing*

"What business benefits have you seen/do you expect to see by adopting AR solutions?"
(Select all that apply)



Base: 107 US manufacturers with plans to adopt or implement AR
Source: A commissioned study conducted by Forrester Consulting on behalf of PTC, March 2019

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Composite Organization

Based on the interviews, Forrester constructed a TEI framework, a composite company, and an associated ROI analysis that illustrates the areas financially affected. The composite organization is representative of the four companies that Forrester interviewed and is used to present the aggregate financial analysis in the next section. The composite organization that Forrester synthesized from the customer interviews has the following characteristics:

- The organization is a US-based, Fortune 500 company with global operations. The organization manufactures industrial equipment and replacement parts and performs service and repairs for end users. It has an annual revenue of $6 billion, with average growth of 5%.
- The organization operates five factories, with 7,500 total manufacturing employees. It employs 250 field service technicians who perform installations and repairs for customers. Annual turnover rates for the organization are 5%.
- Using Vuforia Expert Capture, Studio, and Chalk, the organization deploys on a mix of BYOD smartphones, tablets, and head-mounted devices. The organization primarily uses tablets and phones but transitions factory workers to head-mounted devices by Year 3.

Key assumptions

5 factories
250 field service technicians
7,500 factory workers
$6 billion annual revenue
Using Vuforia Expert Capture, Studio, and Chalk

Analysis Of Benefits

QUANTIFIED BENEFIT DATA AS APPLIED TO THE COMPOSITE

Total Benefits

REF.	BENEFIT	YEAR 1	YEAR 2	YEAR 3	TOTAL	PRESENT VALUE
Atr	Knowledge transfer and improved training	$421,875	$1,534,500	$3,091,500	$5,047,875	$3,974,394
Btr	Improved field service quality and productivity	$675,000	$742,500	$810,000	$2,227,500	$1,835,838
Ctr	Documentation savings	$348,300	$366,876	$385,452	$1,100,628	$909,435
Dtr	Reduction in spoilage, rework, and waste	$972,000	$1,530,900	$2,143,260	$4,646,160	$3,759,106
Etr	Reduction in selling expenses	$675,000	$850,500	$1,041,863	$2,567,363	$2,099,296
	Total benefits (risk-adjusted)	$3,092,175	$5,025,276	$7,472,075	$15,589,526	$12,578,069

The table above shows the total of all benefits across the areas listed below, as well as present values (PVs) discounted at 10%. Over three years, the composite organization expects risk-adjusted total benefits to be a PV of more than $12.6 million.

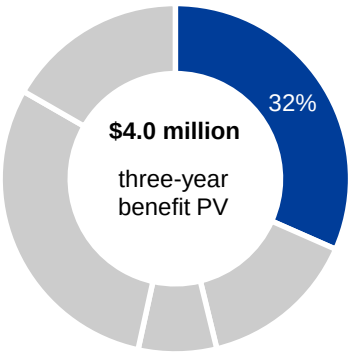
Knowledge Transfer And Improved Training

Interviewees detailed the factors driving improved training processes:

- Organizations traditionally funneled new hires through a series of classroom learnings and paper examinations before they could practice using machinery.
- Interviewees noted that the machines used within their factories were complicated and expensive and that taking them offline for trainees to use could potentially limit throughput.
- Factory floors posed an issue for training: Loud machinery inhibited instructors' ability to communicate with trainees, and new hires could potentially be injured.

Interviewees highlighted the impact of supplementing their training processes with Vuforia AR:

- Interviewed organizations took their traditional training programs and converted them to AR experiences. Trainees could follow along with instructors on virtual machines, overlaid within the classroom to understand how they worked — without the risk of injury, risk of damaging equipment, or a slowdown in operations.
- Instructors could quickly assess trainees' understanding of the equipment they would use and address any gaps in knowledge early in the training process.
- The global head of innovation at a semiconductor manufacturer told Forrester: "The training now occurs virtually. We can bring the tool into the classroom using AR, give them an orientation so they know what to expect. Then we have them on the factory floor, and the instructor just needs to show them how to put on the headset and overlay the CAD (computer-aided design) on the tool. The trainee then drives the process — no more instructor yelling over machinery. The trainee controls what they see; they can backtrack or go forward at their pace, and the expert is just there in case they need assistance. We've seen



Knowledge transfer and improved training: **32%** of total benefits

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our training times condense quite a bit since introducing this new method."

For the composite analysis, Forrester assumes:

- AR training is initially deployed in a single factory, rolling out to all five factories by Year 3. Each factory has 1,500 employees.
- Annual turnover is 5%, which accelerates to 6.1% by Year 3. As the workforce ages, turnover increases with retirements.
- Prior to deploying Vuforia, the organization required 400 hours of training to get a worker into full production. This decreases by 50% in Year 1 when the organization introduces AR, and it accelerates to 60% by Year 3.
- The average fully burdened hourly wage for factory workers is $31.25.

This benefit will vary based on the following risk factors:

- Ability to obtain and convert equipment manufacturers' CAD documents.
- Organizational agility and speed of deployment expansion.
- Complexity of factory work and baseline training hours required for new employees.
- Prevailing labor market rates.

To account for these risks, Forrester adjusted this benefit downward by 10%, yielding a three-year risk-adjusted total PV of $3,974,394.

50%
Reduction in average training times.

Impact risk is the risk that the business or technology needs of the organization may not be met by the investment, resulting in lower overall total benefits. The greater the uncertainty, the wider the potential range of outcomes for benefit estimates.

Knowledge Transfer And Improved Training: Calculation Table

REF.	METRIC	CALC.	YEAR 1	YEAR 2	YEAR 3
A1	Factories using Vuforia		1	3	5
A2	Employees impacted	A1*1,500	1,500	4,500	7,500
A3	Annual turnover		5.0%	5.5%	6.1%
A4	New employees trained annually	A2*A3	75	248	458
A5	Training time without Vuforia	A4*400	30,000	99,200	183,200
A6	Training time reduction with Vuforia		50%	55%	60%
A7	Training time savings with Vuforia		15,000	54,560	109,920
A8	Average fully burdened hourly rate		$31.25	$31.25	$31.25
At	Knowledge transfer and improved training	A7*A8	$468,750	$1,705,000	$3,435,000
	Risk adjustment	↓10%			
Atr	Knowledge transfer and improved training (risk-adjusted)		$421,875	$1,534,500	$3,091,500

Improved Field Service Quality And Productivity

Interviewees detailed the factors driving improved field service quality and productivity:

- Organizations used Vuforia Chalk to assist field service technicians installing and servicing equipment at customer locations. The ability to aid service technicians in real time with a shared view and visual cues improved the accuracy of work. Normally, technicians would rely on paper manuals or phone conversations, both of which provided limited context and led to slow work and errors.
- The rate of correct installations and first-time fix rates increased, allowing service technicians to complete more new jobs — and not have to revisit sites — each day. Being able to work through their backlog and not have to redo work limited the amount of overtime needed to fulfill existing jobs.
- A senior manager of IT product service at a medical equipment firm told Forrester: “If you install something incorrectly, you go another trip. You get incremental hours, you’ve got more materials, you get customer dissatisfaction. With our new model, there is a reduction in overtime hours.”

For the composite analysis, Forrester assumes:

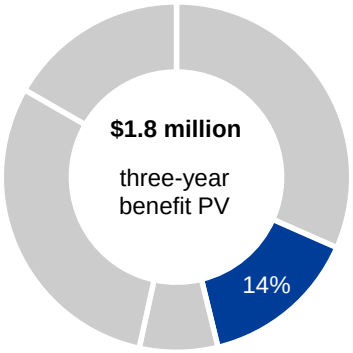
- The organization maintains a team of 250 field service technicians.
- The average technician accrues $30,000 in overtime pay annually.
- Productivity impacts reduce overtime spend by 10% in Year 1, which accelerates to 12% by Year 3 as the deployment matures, devices improve, and the organization gains further efficiencies.

The reduction in overtime spend will vary based on:

- Size of field service team and volume of work.
- Baseline productivity.
- Prevailing labor market and wages.

To account for these risks, Forrester adjusted this benefit downward by 10%, yielding a three-year risk-adjusted total PV of $1,835,838.

10%
Reduced overtime burden



Improved field service quality and productivity: **14%** of total benefits

Improved Field Service Quality And Productivity: Calculation Table

REF.	METRIC	CALC.	YEAR 1	YEAR 2	YEAR 3
B1	Field service technicians		250	250	250
B2	Average annual overtime accrued per worker		$30,000	$30,000	$30,000
B3	Reduction in overtime		10%	11%	12%
Bt	Improved field service quality and productivity	B1*B2*B3	$750,000	$825,000	$900,000
	Risk adjustment	↓10%			
Btr	Improved field service quality and productivity (risk-adjusted)		$675,000	$742,500	$810,000

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Documentation Savings

Interviewees detailed the factors driving documentation savings:

- Organizations required their employees to document manufacturing processes, product specifications, and descriptions of equipment used in factories. While the organizations did have technical writers dedicated to creating product documents, employees in factories were largely required to document their own work and tools during the course of normal shifts. This conflicted with their mandate to maintain certain levels of throughput and was often overlooked.
- As workforces aged, firms dedicated their technical writers to creating new training guides and repositories for knowledge gleaned from experienced workers. However, this still relied heavily on employees sharing information with writers, which was frequently delayed by production demands.
- With Vuforia Expert Capture, employees could quickly and effectively document steps within their daily processes and provide writers with rich details to create AR experiences. Furthermore, technical writers created new technical documents using Vuforia. The new method of collecting and synthesizing information reduced technical writers' efforts in creating documents by 60% while improving the quality of documentation.

For the composite analysis*, Forrester assumes:*

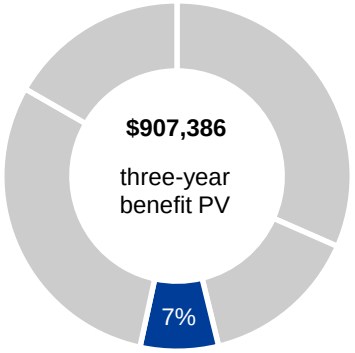
- The organization creates 150 technical documents in Year 1, which grows by 5% annually.
- Prior to deploying Vuforia, the organization required an average of 100 hours to develop a technical document.
- The fully burdened hourly rate of a technical writer is $43.

Documentation savings will vary based on:

- Scale of processes, equipment, products, and their accompanying documentation.
- Baseline requirements to create documents.
- Prevailing labor rates.

To account for these risks, Forrester adjusted this benefit downward by 10%, yielding a three-year risk-adjusted total PV of $909,435.

60%
Reduction in documentation effort



Documentation savings: **7%** of total benefits

Documentation Savings: Calculation Table

REF.	METRIC	CALC.	YEAR 1	YEAR 2	YEAR 3
C1	Technical documents created	5% annual increase	150	158	166
C2	Average time (in hours) to create documentation		100	100	100
C3	Reduction in time to create technical "experiences"		60%	60%	60%
C4	Fully burdened technical writer hourly salary		$43	$43	$43
Ct	Documentation savings	C1*C2*C3*C4	$387,000	$407,640	$428,280
	Risk adjustment	↓10%			
Ctr	Documentation savings (risk-adjusted)		$348,300	$366,876	$385,452

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Reduction In Spoilage, Rework, And Waste

Interviewees detailed the factors driving reductions in spoilage, rework, and waste:

- Better training, via Vuforia augmented reality experiences, created a smarter and more productive workforce. The richness of the Vuforia training and the ability to give simulated hands-on experience earlier in a new employee's tenure improved their familiarity with equipment and accelerated the learning curve.
- Organizations were also able to provide real-time assistance to line factory workers, aiding them in day-to-day processes. Having AR overlays to aid in tasks improved the quality of work and reduced errors.
- Improved training and AR augmentation decreased mistakes, improved efficiency, and ultimately reduced the amount of waste and spoiled materials.

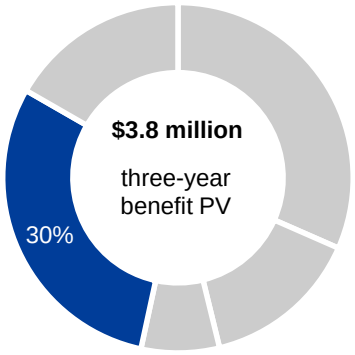
For the composite analysis*, Forrester assumes:*

- The annual revenue is $6 billion, growing at 5% annually. The organization's historical average for inventory as a percent of revenue is 12%.
- Normal spoilage, rework, and waste as a percent of revenue averages 3% annually.
- The reduction in spoilage, waste, and rework accelerates over the three-year period due to continual gains in efficiency from a maturing Vuforia deployment.

The reduction in spoilage, rework, and waste will vary based on:

- Baseline percentages of inventory and normal spoilage.
- Workforce skill sets.

To account for these risks, Forrester adjusted this benefit downward by 10%, yielding a three-year risk-adjusted total PV of $3,759,106.



Reduction in spoilage, rework, and waste: **30%** of total benefits

Reduction In Spoilage, Rework, And Waste: Calculation Table

REF.	METRIC	CALC.	YEAR 1	YEAR 2	YEAR 3
D1	Annual revenue	Growing at 5% annual increase	6,000,000,000	6,300,000,000	6,615,000,000
D2	Inventory as a % of revenue		12%	12%	12%
D3	Normal spoilage, rework, and waste as a % of inventory		3%	3%	3%
D4	Reduction in normal spoilage, rework, and waste with Vuforia		5.0%	7.5%	10.0%
Dt	Reduction in spoilage, rework, and waste	D1*D2*D3*D4	$1,080,000	$1,701,000	$2,381,400
	Risk adjustment	↓10%			
Dtr	Reduction in spoilage, rework, and waste (risk-adjusted)		$972,000	$1,530,900	$2,143,260

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Reduction In Selling Expenses

Interviewees detailed the factors driving reductions in selling expenses:

- Organizations displayed their products at trade shows and on jobsites when bidding for projects. Products consisted of large, complex, and sometimes custom machinery, which was burdensome to transport and assemble once onsite.
- With Vuforia Studio, organizations created AR experiences for their products, eliminating the need to transport equipment. Instead, potential customers could encounter virtual versions of products.
- Sales teams could remotely assess jobsites, overlaying machinery to ensure that it would fit in a location.
- The VP of digital growth at an industrial manufacturing firm told Forrester: “Some of the projects are so big that there are real questions in terms of how or whether we can fit [our product] in a space. With AR, we’re able to see and visualize more readily whether or not it will fit into the tunnel. We can actually OK the implementation of a design without actually having to go onsite. There’s a cost benefit and convenience factor throughout the design and build process.”

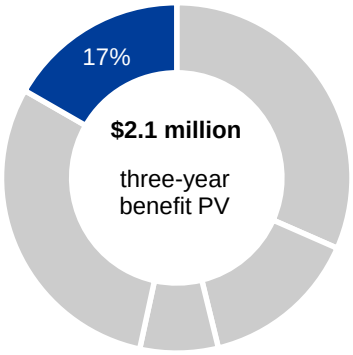
For the composite analysis*, Forrester assumes:*

- The annual revenue is $6 billion, growing at 5% annually. The organization’s historical average for selling, general, and administrative (SG&A) expenses as a percentage of sales is 5%.
- The average percentage of SG&A sales expenses incurred through travel and shipping is 1%.
- The reduction in travel and shipping costs accelerates through Year 3 as the Vuforia deployment matures and the organization recognizes further efficiencies.

The reduction in selling expenses will vary based on:

- Baseline sales, travel, and shipping expenses.

To account for these risks, Forrester adjusted this benefit downward by 10%, yielding a three-year risk-adjusted total PV of $2,099,296.



Reduction in selling expenses: **17%** of total benefits

Reduction In Selling Expenses: Calculation Table

REF.	METRIC	CALC.	YEAR 1	YEAR 2	YEAR 3
E1	Annual revenue	D1	6,000,000,000	6,300,000,000	6,615,000,000
E2	SGA as a % of sales		5%	5%	5%
E3	Travel and shipping as a % of SGA		1%	1%	1%
E4	Reduction in travel and shipping with Vuforia		25%	30%	35%
Et	Reduction in selling expenses	E1*E2*E3*E4	$750,000	$945,000	$1,157,625
	Risk adjustment	↓10%			
Etr	Reduction in selling expenses (risk-adjusted)		$675,000	$850,500	$1,041,863

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Unquantified Benefits

Interviewees also identified a variety of benefits achieved with PTC Vuforia that they could not quantify for this study. Organizations:

- **Improved customer satisfaction.** The VP of digital growth at an industrial manufacturing firm said: “Once the product is received by a customer, there’s the unboxing experience. They’d be looking at these components, reading a manual, or talking to someone and being instructed on how they fit together. Now they have the knowledge in front of them, they can see that there are tricks on how to do things, and we can make sure they have all the information we feel they need to complete the task. We believe that will help them get into production, get to value with the product, more rapidly.”
- **Improved visibility into channel sales and product usage.** The VP of digital growth at an industrial manufacturing firm stated: “Really importantly, the AR app is giving us a parallel path to the customer along with the distribution channel. Right now, we don’t actually know where our product is sold sometimes. We know that we sold it to a distributor, who sold it to the end customer. This allows us to more tightly close the loop, not to get the distributor out of the way but to provide us feedback on how the products are working in the field. Information about the application of products is a huge value from a product-centric standpoint.”
- **Differentiated product and service offerings.** Organizations differentiated their products from similar offerings on the market by pairing them with AR experiences. Organizations also used AR at trade shows and on jobsites to create unique and immersive product experiences for potential customers. Furthermore, organizations offering services augmented their workforce with AR, improving the quality of service and rising above competitors.
- **Reduced contact center costs.** The ability to visually assist customers using Chalk or provide them with self-help experiences reduced the frequency and length of customer contacts and lowered contact center costs.
- **Enriched sales leads and improved sales environments.** Organizations used AR experiences to showcase their offerings at trade shows, increasing traffic to their booths and subsequent leads. Furthermore, the ability to demonstrate industrial products in an office setting instead of in loud factories created a more comfortable environment for customers and sales teams.
- **Improved safety and working conditions.** Providing real-time assistance to workers and highlighting operation hazards with AR overlays reduced the likelihood of accident and improved overall safety. Additionally, instructing employees on virtual versions of tools rather than physical machinery provided a safer training environment.

> “[Vuforia] has increased leads and increased the percent of good leads from trade shows and events. We provide a richer experience, and while one person is being given a talk, another can be looking at their phone and seeing our machines in action. We keep them longer in our booths. Also, our equipment is usually running in extremely loud environments, and just the ability to interact with the process behind closed doors and have a conversation about it is a huge benefit to our sales team. We can do or see everything that an operator would, but in a conference room.”
>
> *VP of digital growth, industrial manufacturing*

Flexibility

The value of flexibility is clearly unique to each customer, and the measure of its value varies from organization to organization. There are multiple scenarios in which a customer might choose to implement Vuforia and later realize additional uses and business opportunities, including:

- **Creating digital twins of products.** According to Forrester, “Digital twins of products in the field aggregate and analyze several sources of relevant data, allowing product makers to manage their products more efficiently, prevent product downtime, and offer value-added services to improve customer experience (CX).”[4] Organizations expressed an interest to create digital twins of their products in the near future, leveraging the Vuforia studio of products they had currently deployed. A senior manager of IT product service at a medical equipment firm stated: “If you’re able to create a digital twin, you’re able to share more with the customer. You can diagnose issues and quickly respond to their requests. A lot of home devices, what we typically do for service is swap them out and send a new one. It’s very costly to us, and we believe, with a digital twin, we can avoid this. If the customer calls and says their device is broken, there’s nothing in the phone call to allay that fear. With digital twin capabilities, we could provide a visual explanation of what the issue is and how we are going to resolve it without a swap.”
- **Incorporate new hardware to further improve operations.** In the future, hands-free, head-mounted devices will boost the benefits of AR even further. The global head of innovation at a semiconductor manufacturing firm explained: “The voice-activated, hands-free nature inherent to these new AR devices is going to change the way we do work. In principle, we can be hands-free and can have what I call ‘data following the user.’ Up until now, users chase after the data by using a laptop or similar devices that they have to go after every time they are in need of information. That concept is changing, where we can have employees harness the capabilities of natural language processing and hands-free devices to command or query.”
- **Redefining the human-machine interface.** Using new devices and adjacent technologies, organizations plan to change the way their employees interact with factory equipment. The global head of innovation for a semiconductor firm explained: “Being able to walk up to a machine and interrogate it, not by using a keypad but by talking to it, will be a lot easier. What we plan to do is use AR to create a task for every machine that workers can interact with.”

Flexibility would also be quantified when evaluated as part of a specific project (described in more detail in Appendix A).

Flexibility, as defined by TEI, represents an investment in additional capacity or capability that could be turned into business benefit for a future additional investment. This provides an organization with the "right" or the ability to engage in future initiatives but not the obligation to do so.

Analysis Of Costs

QUANTIFIED COST DATA AS APPLIED TO THE COMPOSITE

Total Costs

REF.	COST	INITIAL	YEAR 1	YEAR 2	YEAR 3	TOTAL	PRESENT VALUE
Ftr	PTC fees	$0	$159,600	$305,550	$600,600	$1,065,750	$848,851
Gtr	Internal planning and development	$682,500	$682,500	$955,500	$1,228,500	$3,549,000	$3,015,614
Htr	AR devices	$28,875	$169,313	$184,669	$568,969	$951,825	$762,889
	Total costs (risk-adjusted)	$711,375	$1,011,413	$1,445,719	$2,398,069	$5,566,575	$4,627,354

The table above shows the total of all costs across the areas listed below, as well as present values (PVs) discounted at 10%. Over three years, the composite organization expects risk-adjusted total costs to be a PV of more than $4.6 million.

PTC Fees

For the composite analysis*, Forrester assumes:*

- The composite organization has licenses for Chalk, Studio, and Expert Capture.
- License totals for Studio and Expert Capture increase from Years 1 to 3 as Vuforia is deployed in more factories.
- Licenses for Chalk remain static during the three-year period.

PTC fee expenses will vary based on:

- Size and scope of operations, total user base, and the resulting license count.

To account for these risks, Forrester adjusted this cost upward by 5%, yielding a three-year risk-adjusted total PV of $848,430.

PTC Fees: Calculation Table

REF.	METRIC	CALC.	INITIAL	YEAR 1	YEAR 2	YEAR 3
F1	Annual PTC Vuforia license expense			$152,000	$291,000	$572,000
Ft	PTC fees	F1	$0	$152,000	$291,000	$572,000
	Risk adjustment	↑5%				
Ftr	PTC fees (risk-adjusted)		$0	$159,600	$305,550	$600,600

Internal Planning And Development

For the composite organization, Forrester assumes:

- The organization maintains an innovation and development team. This team is tasked with analyzing processes, identifying use cases, and deploying Vuforia. Additionally, this team trains internal stakeholders on the use of Vuforia and creates experiences using Studio.

Nine FTEs
dedicated to planning, development, and deployment by Year 3

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- Initially, the organization staffs five FTEs on the innovation team, which grows to nine by Year 3. As the Vuforia deployment grows and becomes a more integral component of operations, the organization dedicates additional staff.
- The fully burdened annual salary for members of the development team is $130,000.

Internal planning and development costs will vary based on:

- Size, scope, and complexity of operations and Vuforia deployment.
- Internal skill sets.
- Prevailing labor market rates.

To account for these risks, Forrester adjusted this cost upward by 5%, yielding a three-year risk-adjusted total PV of $3,015,614.

Implementation risk is the risk that a proposed investment may deviate from the original or expected requirements, resulting in higher costs than anticipated. The greater the uncertainty, the wider the potential range of outcomes for cost estimates.

Internal Planning And Development: Calculation Table

REF.	METRIC	CALC.	INITIAL	YEAR 1	YEAR 2	YEAR 3
G1	Developer team		5	5	7	9
G2	Fully burdened developer rate		$130,000	$130,000	$130,000	$130,000
Gt	Internal planning and development	F1*F2	$650,000	$650,000	$910,000	$1,170,000
	Risk adjustment	↑5%				
Gtr	Internal planning and development (risk-adjusted)		$682,500	$682,500	$955,500	$1,228,500

AR Devices

For the composite organization, Forrester assumes:

- The organization purchases head-mounted devices for testing before deploying Vuforia. The organization does not need to procure tablets or smartphones for this purpose.
- The organization uses tablets for training in Years 1 and 2, upgrading to head-mounted devices in Year 3.
- Technicians use their BYOD smartphones for field service, which the organization reimburses at a rate of $60 per device.

AR device costs will vary based on:

- Types of devices used.
- Scale of operations and size of workforce.
- BYOD reimbursement policies.

To account for these risks, Forrester adjusted this cost upward by 5%, yielding a three-year risk-adjusted total PV of $762,889.

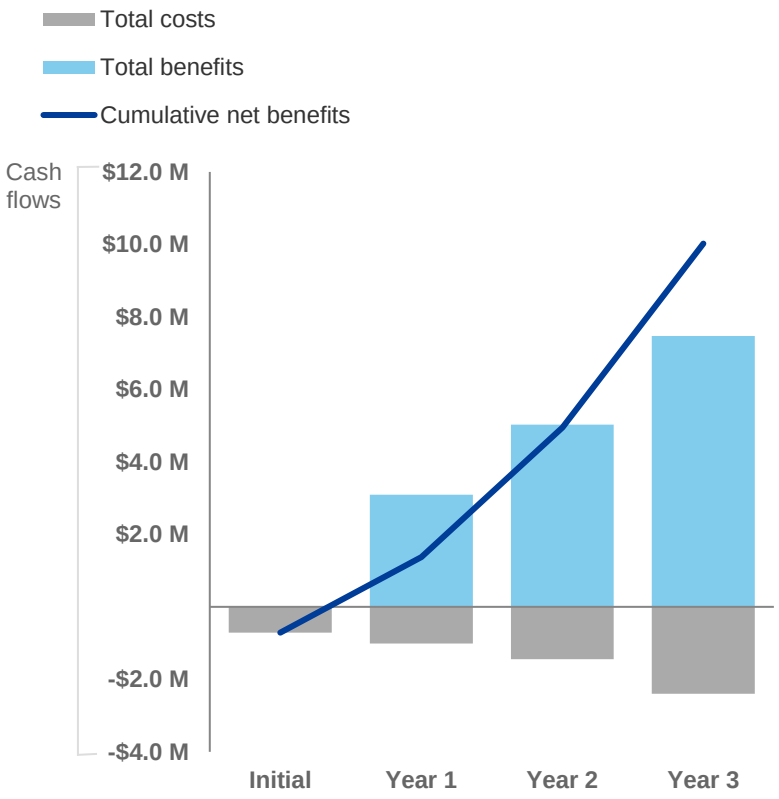
AR Devices: Calculation Table

REF.	METRIC	CALC.	INITIAL	YEAR 1	YEAR 2	YEAR 3
H1	Training devices	A4*50%-H1$_{PY}$		37.50	86.25	142.50
H2	Average training device value	Mix of tablets and head-mounted		$300	$300	$2,750
H3	Training device costs	H1*H2		$11,250	$25,875	$391,875
H4	BYOD technician devices	B1		250	250	250
H5	Annual reimbursement per device	$50*12 months		$600	$600	$600
H6	Total BYOD reimbursement cost	H4*H5		$150,000	$150,000	$150,000
H7	Demo and testing devices		10			
H8	Per-unit demo device price		$2,750			
H9	Total demo and testing device costs	H7*H8	$27,500			
Ht	AR devices	H3+H6+H9	$27,500	$161,250	$175,875	$541,875
	Risk adjustment	↑5%				
Htr	AR devices (risk-adjusted)		$28,875	$169,313	$184,669	$568,969

Financial Summary

CONSOLIDATED THREE-YEAR RISK-ADJUSTED METRICS

Cash Flow Chart (Risk-Adjusted)



The financial results calculated in the Benefits and Costs sections can be used to determine the ROI, NPV, and payback period for the composite organization's investment. Forrester assumes a yearly discount rate of 10% for this analysis.

These risk-adjusted ROI, NPV, and payback period values are determined by applying risk-adjustment factors to the unadjusted results in each Benefit and Cost section.

Cash Flow Table (Risk-Adjusted)

	INITIAL	YEAR 1	YEAR 2	YEAR 3	TOTAL	PRESENT VALUE
Total costs	($711,375)	($1,011,413)	($1,445,798)	($2,398,069)	($5,566,654)	($4,627,419)
Total benefits	$0	$3,092,175	$5,025,276	$7,472,075	$15,589,526	$12,578,069
Net benefits	($711,375)	$2,080,763	$3,579,479	$5,074,006	$10,022,872	$7,950,650
ROI						172%
Payback period						<6 months

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PTC Vuforia: Overview

The following information is provided by PTC. Forrester has not validated any claims and does not endorse PTC or its offerings.

PTC is continually innovating with a robust portfolio of industrial AR applications, each with unique attributes to help you quickly navigate from pilot to production.

Vuforia Expert Capture is an out-of-the-box solution that enables senior experts to rapidly author and publish hands-free, step-by-step instructions for frontline workers. Expert Capture is the *fastest* and *easiest* way to rapidly document expert knowledge and scale that knowledge to new or redeployed workers, so they can get their jobs done quickly and accurately the first time. See Expert Capture in action.

Vuforia Studio accelerates the creation of easily consumable 3D content that can improve service, manufacturing, and training processes with a visual, low-code AR authoring environment. Studio adds contextual knowledge to real-world equipment and environments by bringing CAD and internet-of-things (IoT) data to life, without requiring skilled programmers or custom designers. See how Studio works.

Vuforia Chalk connects frontline workers and field technicians to helpful remote experts with a mobile-based AR experience that facilitates real-time problem-solving and collaboration across the enterprise. Chalk removes geographical barriers by virtually placing experts onsite through a shared-view live video stream that they can annotate and draw over to assist junior colleagues. See how workers collaborate with Chalk.

Vuforia Engine is a cross-platform AR solution for developing high-end, consumer-facing AR experiences that bring people closer to brands and products. Engine's robust computer vision provides unmatched flexibility and target recognition, so users can easily detect and launch fully branded AR experiences across a range of devices. Learn more about Engine.

As the leader in industrial AR, PTC has a proven track record partnering with industrial companies to build AR success. For more information about how you can experience AR-driven digital transformation, contact an AR specialist at PTC today.

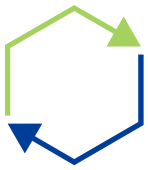
Appendix A: Total Economic Impact

Total Economic Impact is a methodology developed by Forrester Research that enhances a company's technology decision-making processes and assists vendors in communicating the value proposition of their products and services to clients. The TEI methodology helps companies demonstrate, justify, and realize the tangible value of IT initiatives to both senior management and other key business stakeholders.

Total Economic Impact Approach

Benefits represent the value delivered to the business by the product. The TEI methodology places equal weight on the measure of benefits and the measure of costs, allowing for a full examination of the effect of the technology on the entire organization.

Costs consider all expenses necessary to deliver the proposed value, or benefits, of the product. The cost category within TEI captures incremental costs over the existing environment for ongoing costs associated with the solution.



Flexibility represents the strategic value that can be obtained for some future additional investment building on top of the initial investment already made. Having the ability to capture that benefit has a PV that can be estimated.

Risks measure the uncertainty of benefit and cost estimates given: 1) the likelihood that estimates will meet original projections and 2) the likelihood that estimates will be tracked over time. TEI risk factors are based on "triangular distribution."

The initial investment column contains costs incurred at "time 0" or at the beginning of Year 1 that are not discounted. All other cash flows are discounted using the discount rate at the end of the year. PV calculations are calculated for each total cost and benefit estimate. NPV calculations in the summary tables are the sum of the initial investment and the discounted cash flows in each year. Sums and present value calculations of the Total Benefits, Total Costs, and Cash Flow tables may not exactly add up, as some rounding may occur.

Present value (PV)

The present or current value of (discounted) cost and benefit estimates given at an interest rate (the discount rate). The PV of costs and benefits feed into the total NPV of cash flows.

Net present value (NPV)

The present or current value of (discounted) future net cash flows given an interest rate (the discount rate). A positive project NPV normally indicates that the investment should be made, unless other projects have higher NPVs.

Return on investment (ROI)

A project's expected return in percentage terms. ROI is calculated by dividing net benefits (benefits less costs) by costs.

Discount rate

The interest rate used in cash flow analysis to take into account the time value of money. Organizations typically use discount rates between 8% and 16%.

Payback period

The breakeven point for an investment. This is the point in time at which net benefits (benefits minus costs) equal initial investment or cost.

Appendix B: Endnotes

[1] Source: “Marketers: Get Ready For Augmented Reality,” Forrester Research, Inc., November 13, 2017.
[2] Source: “Emerging Technology Spotlight: Augmented, Virtual, And Mixed Reality,” Forrester Research, Inc., October 22, 2018.
[3] Source: “New Tech: Augmented Reality, Virtual Reality, And Mixed Reality, Q1 2019,” Forrester Research, Inc., January 23, 2019.
[4] Source: “Digital Twin Links IoT Data With Customer And Business Outcomes,” Forrester Research, Inc., October 31, 2018.