THE ULTIMATE GUIDE TO WELDING AUTOMATION

For Welding and Fabrication Operations

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Contents

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Introduction

> *Amid this state of change, one thing remains clear: the potential benefits offered by robotics in welding are enormous; yet the issue for Australian industry has been poor adoption rates.*
>
> **Emeritus Professor John Norrish**

The welding and fabrication sectors are facing a plethora of pressures in the global economic marketplace. Never before has there been such a need to increase the quality and productivity of welding and fabrication operations, while simultaneously reducing costs. To achieve this, welding companies have had to find ways to improve process repeatability and lower labour costs through automation. Technologies such as robotics have been key in satisfying these demands.

Local manufacturers are finding it increasingly difficult to compete on price with imports from foreign companies that operate with lower wage and overhead costs and have greater economies of scale. Imports captured an estimated 61.2% of domestic demand in 2016-17, up from 51.2% in 2011-12[1]. Intensifying competitive pressures have narrowed industry profit margins and forced many companies in Australia to exit the industry, with both enterprise and employment numbers falling over 2016-17.

Research shows that these market and operational pressures are now forcing manufacturers to focus on acquiring capabilities delivered by automation technologies that will enable them to remain competitive by optimising overall operational performance.

Robots are transforming productive processes as we've known them. In 2015, robot sales increased by 15% to 253,748 units — by far the highest level ever recorded for one year. By 2019, it's forecast some 2.6 million robot units will be working around the world.

That's another 1.4 million new industrial robots on today's figures, according to the latest forecast from the International Federation of Robotics[2].

With industry experts predicting that robotics automation technologies are set to transform operations as we've known them, perhaps you've thought about how they could transform your organisation's operations too.

What seems certain is that leaders of companies in virtually every industry now need to start planning how they will step forward into growth equipped with latest technologies or step back into what they may consider to be safety.

DiverseCo is committed to helping the welding and fabricating industry remain viable in highly competitive global market, so we have created this guide for industry stakeholders. This guide offers insights into:

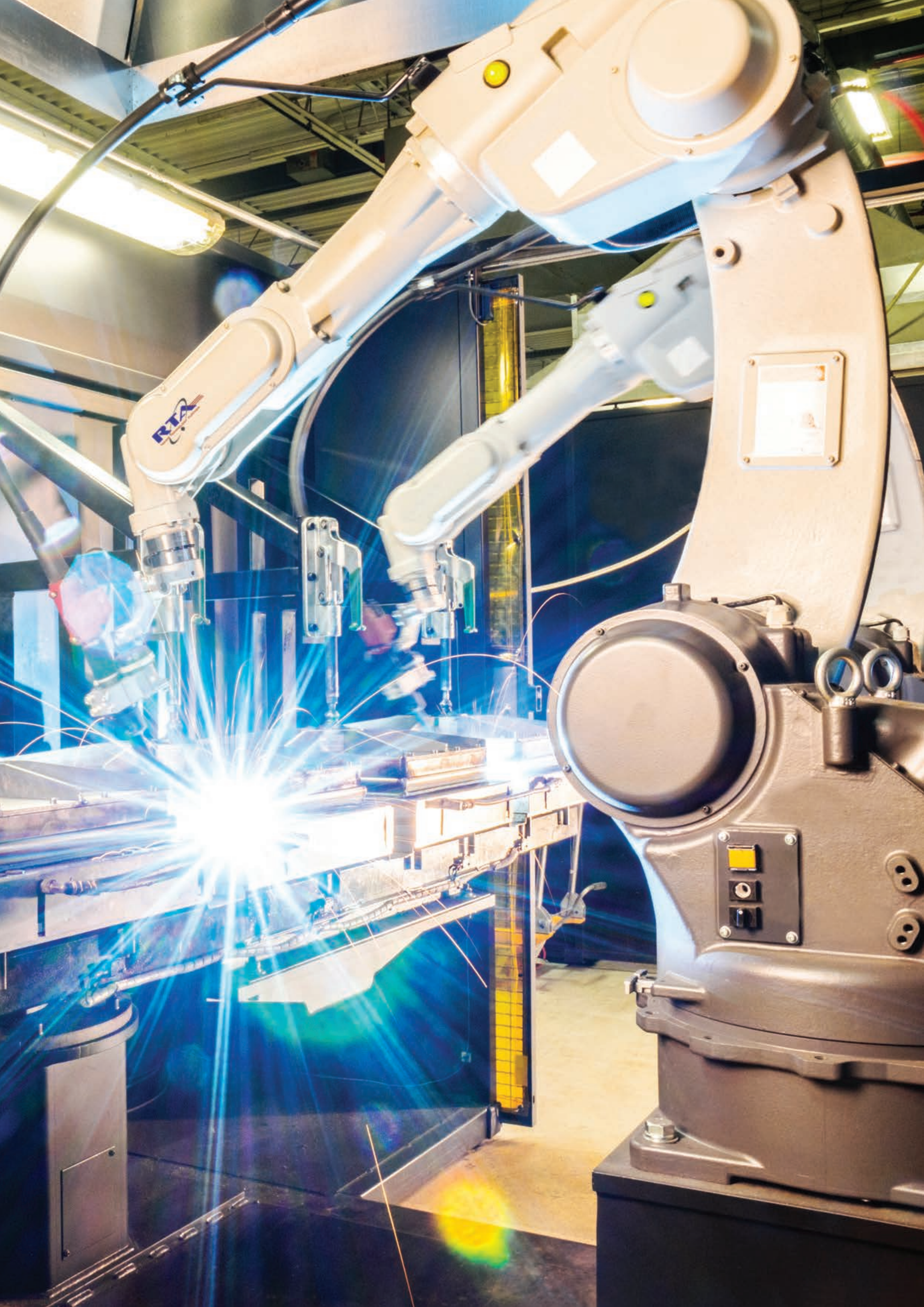
- The issues facing the sector
- The current welding and fabrication automation technologies being employed
- How robotics can be integrated into welding operations, and
- How to identify and quantify all sources of increased profits, cost savings and operational improvements.

All welding and fabrication workshops need a thorough understanding of technological advancements in order to stay ahead of the curve and remain competitive and profitable.

This guide is designed to help industry leaders make informed decisions and employ advanced technologies for the betterment of both their own workshop and the welding and fabricating industry as a whole.

1. IBISWorld Industry Report C2299 Fabricated Metal Product Manufacturing in Australia.

2. World Robotics 2016 Industrial Robots Report. International Federation of Robotics.



The Past in Perspective

Industry experts know the impact that robotics should be having on welding in Australia. However, the impact that robotics is actually having is very different in reality, particularly in terms of uptake.

Historically, the limitations of robotics have meant that the introduction of this technology was limited to routine applications characterised by large production volumes and simple geometry. Despite the simplicity of these applications, robotics delivered significant advantages through improved quality thanks to consistency, reduced operating costs and improved production.

Where robotics fell short was the ability to make the real-time adjustments on which high-quality welding is dependent. During the course of a weld, changes need to be made relating to variables such as wire feed, voltage, torch angle, oscillation, travel speed and heat input. While humans are adept at this, robotics were traditionally unable to deliver such output.

Until recently, there were inherent difficulties translating split-second decision making into a robotics program that could respond to and change variables throughout a welding process. This difficulty meant that only a select number of variables could be programmed and parameters adjusted, which limited the scope of application.

Most welding applications require a variety of fit-up tolerances from joint to joint, and robotics problems were unable to account for these variances. This meant that semi-automated welding could only be used for highly-standardised joints, while fully-automated welding was limited to the repetitive applications as mentioned above.

These difficulties have been overcome thanks to the advent of 'dynamic process control' technologies. These technologies, such as automated offline programming and sophisticated sensor systems, such as laser vision, have wholly transformed the ways in which robotics can be integrated into welding and fabricating processes and procedures.

Dynamic process control allows for increased manufacturing applications due to the fact that it enables parameter adjustments to be made on the go. New technology can:

- Make adjustments to the robot welding path, including travel speed, voltage, wire feed speed and weaving through the use of sensors and laser vision systems. This means the robotics can respond from it-up to fit-up and joint to joint. This process can be carried out via a pre-scan and during the weld.
- Robots can now be programmed for a variety of functions, rather than being suitable only for single tasks. Thanks to the ability to store a number of programs in each robot's memory, some tasks can be moved between quickly, particularly if the tooling nests have been designed for quick changes.
- The time it takes to program robots has also been drastically reduced, thanks to the ability to use offline programming software. The software itself has also been enhanced, which means speed, accuracy and quality have been enhanced, while costs have been lowered.
- Robots can now weld much larger components, and can be mounted on gantries and tracks.
- The price of robots has also steadily declined over the years.

Due to these developments, robotics is now a foundational technology that is being employed in virtually all industries, markets and geographies.

The question is then: why are robotics adoption rates across Australian industry still so low when welding automation systems have changed so much over the last decade?

It seems that the rates of robotic technology adoption and integration have remained low across the Australian welding and fabricating due to persistent beliefs:

- Lack of knowledge about technological improvements and increased scope of robotic applications
- A hesitance to invest in the technology due to a lack of understanding
- Robotics is only suited to high-quantity production of small parts
- Robots cannot be used to weld very large parts or assemblies
- Robotic operators needed to be highly -trained and paid a corresponding salary
- Programming time is too excessive for small production runs
- The risk and complexity of integrating robotic processes is too great

Despite the deep-seated nature of these beliefs and fears, it is inevitable that the undeniable benefits of robotic welding technology will take hold, and investment and uptake in the welding and fabricating sectors will boom to address market challenges.

> *"The new era of welding robotics will be concentrated in both the manufacturing sector and, to an ever-greater extent, jobbing shops that perform metal fabrication."*
>
> **Peter Kuebler, BOC's Technical Manager**

> *Innovation and technology are central to securing the future of the steel industry. All welding workshops need to take advantage of technological advancements such as welding robots, and help promote the idea that welding is no longer a dirty job on the factory floor, rather it is one that requires both engineering and IT skills.*

Ron Barrington, Cullen Steel

Game-changing Technologies Transforming Welding Automation

Sensor Systems

3D robot-vision and sensing systems allow for the transfer of multi-dimensional feedback on targets. This input is provided in a language that is instantly recognisable by the robotics system. It is essential in allowing for the intricate visual inspections that are integral in increasing the scope of robotic applications, enabling robots to take complex actions based on visual interaction with the target piece.

The difference between this new form of sensor and older models is that it allows the robot to analyse and interpret data from an entire image, rather than a singular point. New sensors consist of a camera that takes a photo of sections of the part. These photos are then sent to the memory where it is processed and analysed via a series of comparisons against pre-set parameters.

For welding and fabrication, these parameters include aspects such as wire feed speed, weaving, travel speed and voltage. As the vision sensor tracks the part, it compares what it sees against the set parameters of these aspects, determining whether the component matches the inputs. This feedback then allows the robot to dynamically adjust the welding parameters to complete the weld.

The applications of these parameters range from a focus on V-prepped joints for volumetric 'fill,' to more advanced adaptive welding systems which can find and track seams, find parts, coordinate motion, monitor in-process weld quality and offer adaptive process control and multi-pass welding through root pass memorisation (RPM).

When a laser vision system is used in conjunction with offline programming, it makes it possible to integrate robotics into small production runs.

To learn more about one of DiverseCo's numerous applications of this technology (within a harsh work environment characterised by excessive heat and fumes), please read Appendix A. SMC Case Study.

You can learn more about Sensor and Vision Systems Technology in Appendix B.

Offline Programming Software Technology

Physical attributes of robots have advanced at a far higher rate than programming software. Today, there is a range of robots for all tasks, from very small robots that you can pick up with one hand to massive robots with heavy payloads that are perfect for force control for grinding and cutting.

However, the need for excessive programming, combined with the need to devote significant time and resources to learning how to use robotics, has hindered widespread uptake and investment.

Programming robotic software requires skill and knowledge, which is why teaching operation programs for industrial robots is such an integral part of the integration process. The teaching has to cover everything, from programming the robot for movement, to using the controller for sequential memorisation of the position of the robot. To complete the program, repeat verification is performed by playing back the program on the robot and making the necessary adjustments.

Offline programming offers a way around the previously laborious task. CAD models of both the robotic system and the environment allow for the programs to be planned, developed and tested through simulation before they are uploaded into the robot for real-world application.

This reduces the need for programming within the workshop and slashes the time and resources business owners and operators need to dedicate to robot teaching, both of which have a significant bearing on production costs.

Kawasaki has even developed automatic robot teaching software—KCONG—which creates robotic operation programs in a short amount of time while eliminating the need for conventional teaching methods. Using 3D CAD data of work-pieces, verification and adjustments are made simple through the software's simulation capabilities. This means that the use of fully automated systems is possible for small production runs, immediately improving efficiency and productivity. The beauty of KCONG is that it allows engineers with no expertise in robotics to easily program and use robot systems, and promote the use of robotics from a non-specialist standpoint.

To learn more about one of DiverseCo's numerous applications of this technology, please see Appendix C. Thales Bushmaster Case Study.

To read more Kawasaki's offline programming software, please see Appendix D. Kawasaki-KCONG-brochure

Steps to a Successful Implementation

Here at DiverseCo, we are focused on meeting the production needs of welders and fabricators. This ensures that all our clients are delivered a successful robotic system implementation. Rather than focusing on the hardware of the robotic system that is being installed, we take the time to understand how our client's operational and production objectives can be met — both with and without robotics. This enables us to devise much more detailed studies into the feasibility, scope and design of any robotics implementation project and, ultimately, delivers efficiency, productivity and affordability for our clients.

STEP 1: Work Methodically

The most important point to recognise is that automating a welding system requires investment in both technology and employees. A balance must be maintained between increasing productivity and reducing waste, neither of which can be met at the expense of quality. If this balance is maintained, human and physical capital will grow together, as robotic cell operators are trained to use the technology in the quest for increased productivity and quality.

Welding automation projects must be broken down into steps, with each level completed one at a time. For example, the production of simple, repeatable parts can be automated before complex parts.

DiverseCo designs pre-engineered robotic weld cells, which are ideally suited to automated welding novices. These systems are inclusive of all necessary equipment to conduct robotic welding, meaning they are pre-assembled and wired, and little programming is required.

STEP 2: Gain Buy-In and Input

Your investment in a robotic welding system will only be as successful as your ability to sell its advantages to both management and staff. You need support from management to accrue the capital necessary to invest, and you need buy-in from the operators to ensure that this investment is translated to results on the workshop floor.

You need to be aware that many welders fear that the introduction of a robotic system will eventually mean their position will become redundant. You need to assuage this fear and reassure operators that the system is there to complement their skills and make their job both more comfortable and more productive. There is a skills shortage in the welding field, so skilled welders will always be of high-demand.

Automated systems represent an opportunity for your operation staff to further their skills, and become a more valuable member of the company and the broader industry. This could lead to career progression, as welders become robotic programmers and their skills are freed up to engage in more complex welds, as the robot takes care of more repetitive tasks.

The Consultation Process

Robotic system integrators analyse the business and system needs of end-users and provide a plan for automation, along with support for programming, commissioning, maintenance, and repair. Systems integrators aid in merging robots, peripherals, and manufacturing machinery into a single unit for helping in performing manufacturing tasks.

Ultimately, robotics systems integrators help customers to transform their operations equipped with the latest industrial automation technologies.

For these reasons, DiverseCo will undertake a through business analysis and strategic review of your company's requirements. This, of course, will inform the development of recommendations on how to apply robotic automation to realise your company's business and operational objectives.

Our consultation process consists of four key phases, each of which is outlined opposite.

PHASE 1: Review of Part Mix and Fit-Up

Firstly, we review your parts and determine if they are a good fit for automation. This is crucial in determining if robotics is the right step for your company. To make this determination, we focus on:

- Weld joint accessibility
- Parts that require welding
- Repeatability of parts
- Tooling nest requirements
- Means to compensate for distortion
- Determination of the welding process to be used.

By conducting these evaluations, we can provide you with an upfront review that eliminates any unnecessary investment. This process is quick and easy, as we can often evaluate parts through an electronic CAD drawing.

PHASE 2: Workflow Analysis

A robotic welding system can significantly increase throughput, so it's important to consider how this will affect your entire system. For example, will your upstream manufacturing processes be able to deliver the necessary quantity to the robot? And, can downstream processes - paint, packaging, assembly – cope with higher production? Welding operations are often a complex ecology, and without looking at the entire picture, increased production in one area could create adverse effects in others.

Workflow needs to continue to run smoothly, or your investment in robotics could unintentionally slow down production by

altering your workflow. The first goal is always to improve production; total production, not just single-stage production.

The introduction of robotic welding systems also requires that considerable attention is given to the quality of the piece part manufacturing process.

The clamping and fixturing also need to be precise, which is why tooling nest design issues need to be considered during the purchase decision process.

A robotic welding system with vision capabilities can adjust electrode position and welding parameters to permit quality automated welding on parts with variations. This allows robots to perform routine and repetitive tasks, as well as certain complex tasks, so workshops can reduce labour costs by hiring a smaller, more skilled workforce.

However, for automated welding to be successful in routine or repetitive applications, it is essential that parts are made to a quality specification that is repeatable. Tooling and parts locators or fixtures must provide a reproducible means for the robot to positively locate and present parts for processing.

DiverseCo will work with you to determine the appropriate system accessories, including safety devices, the optimal layout for the robotic cell, human resources and training requirements, and service and maintenance requirements that are necessary for optimal performance when integrating robotic systems into your workflow.

PHASE 3: Peripheral Equipment

While the robot itself is important, it is not actually the most vital aspect in an automated system. The most essential element of an automated system is the end-of-arm tooling.

End-of-arm tooling is the mechanism that is mounted to your robot—it is the item that performs the work. For example, a tooling mechanism may spray paint, grip a workpiece, or undertake grinding or welding. In welding applications, the welding torch is attached to the robot wrist with an intervening collision sensor or break-away coupling. Wire cutters, neck inspection figures and nozzle cleaning stations are other peripherals associated with robotic welding applications.

PHASE 4: Cell Design

Cell encompasses the entire automated welding system, consisting of the robot, controller and peripherals. A turnkey cell provides a fully-integrated, pre-configured solution. In designing the layout of your cell, consideration must be given to creating space for the work motion device, power source robot controller and wire feed package. The way the piece part is delivered and leaves the area must also be considered. The key is always to create a cell layout that allows for workflow simplicity.

Our Services

Design

After the consultation process is complete, DiverseCo will begin designing your robotic automation project. Our planning process includes the production of a 3D parametric model and 2D drawings, which will be linked to the modelling.

We use Autodesk Inventor for our CAD modelling, as this affords us with the highest degree of accuracy, data integrity and flexibility in design.

Our design team possess in-depth knowledge and experience in Australian Standards pertaining to robotic technology, automated cells and welding. All designs produced by the DiverseCo team are fully compliant with all relevant Australian Standards, including AS/NZS ISO 3834.

Simulation

Many welding applications won't require a fly-through of the robotic cell process. However, when needed, we can offer a tangible, birds-eye view of the complete automation process. This gives both our design team and you the opportunity to review and revise plans, ensuring that the finished product will optimise your production line, while removing the costs associated with trialling on a 3D model.

Programming

Robots come alive with programming!

The programming stage is where you see your investment come to life. We commission a system that performs all programming for you, and then provide extensive training and support. This ensures that you receive the maximum benefit possible from automation. The DiverseCo team are experts in robotic programming languages, as well as the methodology behind robotic automation.

There are two methods of programming an industrial robot:

1. The use of a Teach Pendant, where the robot is manually positioned and posture and auxiliary parameters (such as speed and motion type) are recorded.

2. The use of a Programming Language with the controller. This offers the most flexibility and scope, but it is also the most difficult as it requires an understanding of structured programming. Luckily, the DiverseCo team is fluent in this method of programming.

Installation

Before we install and commission your robotic automation system, we assemble it and test it at our own facility. After testing, it is partially dismantled, with a focus on keeping as much constructed as possible. Before we ship it to you, we check to see that all preparatory services (including the availability of air, water, gas and electricity requirements, mechanical construction and site preparation) have been organised and completed.

We only hand-over the cell after a full risk assessment has been conducted on-site. This ensures that all hazards are eliminated or minimised. This process also ensures that you are entirely comfortable with the operating procedures as documented and explained.

Rest assured, you're not on your own after hand-over. You will be allocated a specialist technician, who will provide you and your staff with support until production is stable and reliable, and all your staff are competent and comfortable with the features and operation of the automated system. This ensures a smooth transition and a minimal disruption to the flow of your current production procedures.

Training

At DiverseCo, we view formal training as an essential component of installing an automated robotic system. All your staff will receive comprehensive training, which covers all aspects of the system, including operation, maintenance and programming.

If we are providing you with a cell that we have programmed, we encourage maintenance and engineering staff to participate in training, so they are familiar with aspects of operation and programming. If we provide an automated cell that is pre-programmed, we encourage staff to be comfortable with the method that has been used to program your cell.

In addition to formal training, we also furnish your staff with a range of education resources, including User Training Manuals, Training Notes and Presentations.

Support

The team at DiverseCo continues to support customers long after we have handed over the automated robotic equipment. We are always on hand for ongoing service and support, and are committed to ensuring that your investment delivers the results you need.

We have a team of industrial robotics engineers and technicians that have the mechanical, electrical and programming expertise to provide you with expert advice and support. We can offer fast fault finding, run diagnostics and identify root cause problems to ensure your system remains online and operates at its optimum.

For minor support issues, we offer telephone support. We also guarantee a 20-minute response to any significant or urgent problems from anywhere in Australia. We know that your investment in automation is only worthwhile if your equipment is online.

Our preventative maintenance and servicing keep your machinery running correctly and prevent costly breakdowns. We pick up minor issues before they cause failures and losses in productivity. This support is provided through the DiverseCo Service Agreement, which guarantees:

- A reminder service for servicing
- Discounted rates for repairing
- Discounts on spare parts
- Access to a priority breakdown service
- Access to 24-hour breakdown service.

Spare Parts

As a leading supplier of robotic equipment, DiverseCo has access to an extensive spare parts inventory. We have several complete robots in stock, which we can provide for emergency stations, 100% spare parts back-up or temporary exchange.


RTA

Calculating Return on Investment

It's no secret that robotics technologies can automate repetitive, time consuming manual tasks. In fact, robotics enable any enterprise to boost productivity, quality and efficiency. All this leads to lower costs, increased profitability, improved customer satisfaction, and reduced WH&S risks.

What is often less understood are the processes involved in visioning, designing and commissioning a robotics system that realises your operational objectives and how to calculate the rapid return on investment.

DiverseCo has devised the following framework to help businesses identify and quantify all the sources of increased profits, cost savings and operational improvements that are delivered by a welding robotics automation system.

Justifying the cost of a robotic welding system comes down to the ability to gain (and prove) a payback on your investment. This is achieved by comparing the financial benefits of your current system against automating welding with robotics.

While the economic justification is based on the capital costs and operating expenses of the robotics installation compared with current costs and projected cash flow benefits, other benefits should also be taken into consideration. Some of these benefits cannot be easily quantified, such as the competitive advantage your organisation is likely to gain that will support long-term growth rather than just provide short-term savings.

Assigning quantitative values to intangible factors such as 'competitive advantage' is necessary if these factors are to be included in your financial analysis. Otherwise, they can only be used as weighting factors when determining the best alternative for your organisation.

Factors to consider for an in-depth cost analysis of initial capital investment include:

- Robot(s) price
- Peripheral equipment (such as safety barriers, sensors, PLCs and HMIs)
- Engineering costs (such as programming, installation and commissioning)
- Project management costs
- Training costs
- Production line modifications

Continued on following page...

Capital investment costs then need to be compared against your current operating costs and the long-term measurable economic benefits provided by robotic systems. These include:

Reduced direct and indirect full burdened labour costs

- It is important that fully burdened labour costs, which include general liability, workers' compensation insurance, paid holidays, sick days, vacations and share of utilities are accounted for in your calculations (rather than only your employees' hourly rates).
- Another contributing is the fact that extensive training is required to produce skilled welders, and there is a skills shortage. While worker turnover is rarely considered during costings, it does play a significant role in justifying the cost of a robotics system.

Increased productivity

- Comparing your company's current productivity with what can be achieved through welding automation is calculated by forecasting product volumes and production times. For example, the manual or semi-automated deposition rate might be 300mm per minute before a skilled welder needs to rest. In comparison, a robot can consistently provide quality welds for 600mm per minute—and beyond—without any issues. Depending on the application, welding robots can complete tasks up to five times faster, significantly increasing part cycle times.
- From a productivity perspective, it's also important to consider the reliability of robots; a robot does not impact productivity by taking sick leave or seeking employment elsewhere.

Increased product quality

- Robotics will improve the quality of your welding operation by eliminating common problems and discontinuities such as undercutting, excessive melt-through, incomplete fusion, incomplete joint penetration, porosity, weld metal cracks and heat affected zone cracks. These issues are primarily eliminated due to the removal of human error.
- A robot is adept at producing the consistent high-quality welds for longer periods of time than semi-automated or manual welding. This leads to increased product quality, increased customer satisfaction and demand, reduced waste and fewer instances of costly, time-consuming rework.

Increased production flexibility

- Modern robotics welding automation systems can manage quick tool and fixture changes, accommodating increased mix, volume and multifunction flexibility. For example, flexible layouts in the robotic welding cell can include several different tooling nests. The robot can then be programmed to attend to one welding process using one nest for an extended period, or it can perform tasks on small batches of each part. Plus, with a robot able to store multiple programs in its memory, the operator need only select a different program and the robot will weld a completely different part.

Reduced manufacturing input and energy costs

- Overwelding is a common and costly occurrence in semi-automated welding. For example, a weld bead that is 3mm larger than necessary can double filler metal costs. However, a robot reduces those costs by only depositing as much filler metal as necessary. Furthermore, automated welding systems conserve energy by running consistently with fewer start-ups.

Increased WH&S

- Flash, toxic fumes, sparks and heat, and performing repetitive tasks make manual welding taxing, hazardous and, at times, downright dangerous. With the introduction of robotic welding, you eliminate many of the dangers associated with welding, thereby protecting your workers, increasing production and reducing your costs.

Simple Return on Investment Calculator

While the following simple return on investment calculator describes an example of results over a 7 year period, the average lifetime of a robot is 12 years. This means that, in many cases, you can expect an even shorter payback period. It should also be noted that more complex ROI analysis will consider all previously mentioned factors, as well as the 'time value' of money.

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7
LABOUR COSTS	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,00
CUMULATIVE LABOUR COSTS	$100,000	$200,000	$300,000	$400,000	$500,000	$600,000	$700,000
ROBOT COST	$250,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000
CUMULATIVE ROBOT COST	$250,000	$251,000	$252,000	$253,000	$254,000	$255,000	$256,000
ANNUAL SAVINGS	-$150,000	$99,000	$99,000	$99,000	$99,000	$99,000	$99,000
TOTAL SAVING OVER 7 YEARS							$444,000

Payback Period

The payback period is calculated by dividing the initial capital cost of the robotics system by annual savings.

In this example, the initial capital cost of the robotics system is $250,000 and annual savings amount to $99,000. Therefore, the payback period is 2.5 years.

Want to learn more about how DiverseCo can help your company to realise all the benefits provided by welding automation? Contact the expert DiverseCo team for a no obligation feasibility study.

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SA (Adelaide) T: (08) 8447 5011
New Zealand (Auckland) T: +64 9 951 9685
Singapore T: +65 800 852 3315

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