For more information regarding baseline references, please visit;

National 4IR Policy

https://www.ekonomi.gov.my/sites/default/files/2021-07/National-4IR-Policy.pdf

National Policy on Industry 4.0

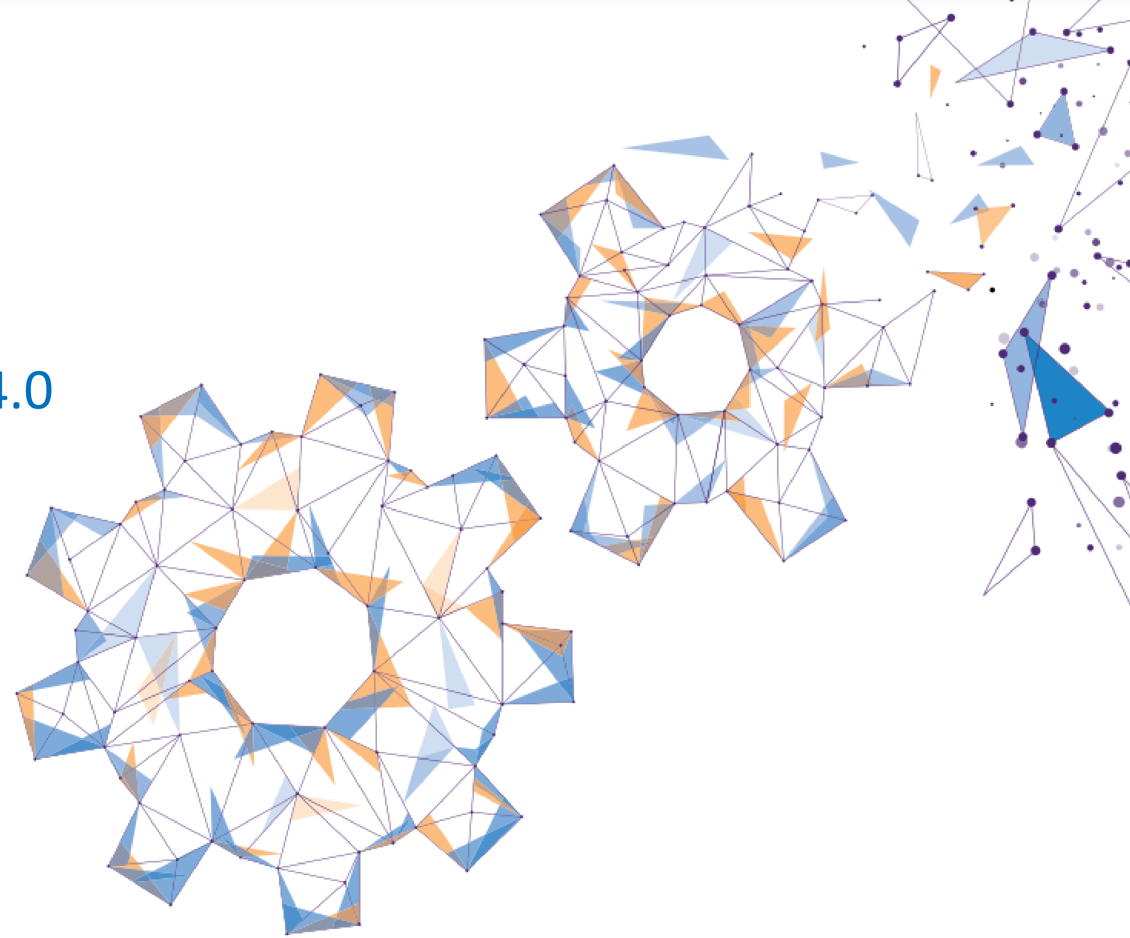
https://www.miti.gov.my/index.php/pages/view/4832

National Robotic Roadmap

https://www.mosti.gov.my/en/dasar/

Smart Manufacturing - ISO

https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100459.pdf



Robotic & Smart Manufacturing in Automotive Welding Shop

For more presentation / articles regarding automotive welding shop, please visit;

https://www.researchgate.net/profile/Rashidi-Asari

https://www.linkedin.com/in/rashidi-asari-b7235140/

SMARTFACTORY

Content Overview

AUTOMOTIVE WELDING SHOP

1 Smart Manufacturing in Automotive Welding Plant

- National Industry 4.0 Policy
- National Robotic Roadmap
- Smart Manufacturing – ISO Perspectives
- Industry 4.0 – Welding Plant Assessment Overview
- Energy Consumption in Welding Plant
- Modern Automation Protocol and System Architecture
- IR 4.0 Adoption in Welding Plant

2 Robotic in Automotive Welding Plant

- Introduction to Robotic
- Total Cost of Ownership for Industrial Robot
- Industrial Robot Selection Criteria for Welding Plant
- Industrial Robot Process Simulation

SMART
manufacturing

NATIONAL INDUSTRY 4.0 POLICY
AN OVERVIEW

Industry 4.0 changes the global landscape of manufacturing competition, reducing the relative competitive advantage of low-cost regions that rely on cheap labor. Nations and manufacturing firms that lead in embracing Industry 4.0 technologies and processes will gain over global competitors. This competitiveness hinges on the ability to transform by responding to market shifts and technology trends. The transformation of the manufacturing industry, through Industry 4.0, is also in line with the United Nation's Sustainable Development Goals (SDGs), especially in support of Goal #9 and Goal #12.

SUSTAINABLE DEVELOPMENT GOALS

GOAL #9
INDUSTRY, INNOVATION AND INFRASTRUCTURE

Build resilient infrastructure, promote sustainable industrialisation and foster innovation. Inclusive and sustainable industrial development is the primary source of income generation, allows for rapid and sustained increases in living standards for all people, and provides the technological solutions to environmentally sound industrialisation. Without technology and innovation, industrialisation will not happen, and without industrialisation, development will not happen.

GOAL #12
RESPONSIBLE CONSUMPTION AND PRODUCTION

Ensure sustainable consumption and production patterns. Sustainable consumption and production is about promoting resource and energy efficiency, sustainable infrastructure, and providing access to basic services, green and decent jobs and a better quality of life for all. Its implementation helps to achieve overall development plans, reduce future economic, environmental and social costs, strengthen economic competitiveness and reduce poverty.

At the heart of Industry 4.0 is a set of rapidly evolving and converging technologies. These are pushing the boundaries of what can be manufactured through additive manufacturing and advanced materials. These technologies are enabling richer insights through big data analytics. They are blurring the lines between physical and digital realms through rich simulations and augmented reality. They are enhancing human capacity through artificial intelligence and autonomous robots. The shift of the way information technology is being used can be seen through cloud computing, system integration and the Internet of Things (IoT). Last but not least, cybersecurity plays an important role in ensuring information systems and manufacturing lines are protected from cybercrime threats.

https://www.miti.gov.my/index.php/pages/view/4832

Many of these technologies have been around or under development for several years. However, the interaction and resulting convergence of these technologies is creating an unprecedented pace and breadth of impact. Completely new industries may be created at these intersections. Thus, these are loosely termed as Industry 4.0 technologies. Given below is an overview of these technologies adopted from BCG, Lux Research, McKinsey & A.T. Kearny.

Additive Manufacturing
Additive manufacturing is advancing with the use of new materials, opening completely new possibilities. For example, 3D printing of organic tissues has created opportunities for growing live organs. It is revolutionising traditional production, aided by a recent surge in metal additive printing.

Artificial Intelligence (AI)
AI is a concept that is made up of numerous subfields such as machine learning, which focuses on the development of programs that can teach themselves to learn, understand, reason, plan and act when exposed to new data in the right quantities. AI technology will supplement the smart factory towards networked factory, in which data from supply chains, design teams, production lines and quality control are linked to form a highly integrated and intelligent engines.

Big Data Analytics
Increasingly big data techniques are being applied in manufacturing industry to improve customer experience and product quality, realise energy efficiency and conduct predictive maintenance. It is now possible to collect masses of data from several different sources to direct decisions that anticipate product or equipment failure.

Advanced Materials
New materials and nano-structures are being developed, allowing for beneficial material properties, e.g. shape retention and thermoelectric efficiency. Together with additive manufacturing technologies, it will allow for massive customisation and development of products that were not possible until now.

Cybersecurity
The industrial communication is expanding and strongly connected, as such, digital security becomes a critical aspect that must not be overlooked in the industrial environment. It has now become more complex as it consists of connected devices and environments that cannot be protected by traditional cybersecurity approaches. Current cybersecurity has largely been developed for IT-centric devices and environments.

Simulation
While many engineers are already familiar with simulations in the field of product design, the advent of augmented reality, AI and big data is expected to take simulations to the next level. It will be possible to simulate manufacturing processes using different production settings to find the optimal way to manufacture a product. Simulations can also be used to test product usage under different operating environment using different types of materials.

Cloud Computing
Past industrial revolutions required significant capital as a ticket for entry. With cloud computing, many of the Industry 4.0 technologies can be made available to even smaller companies as a utility with minimal upfront capital investment. Companies can leverage cloud-based product design, simulation, AI and big data solutions to improve their production processes and build products better suited for their customers.

Augmented Reality
While the initial augmented reality technologies are still in nascent stages, they are advancing at a rapid pace. Some of the first applications can be found in the delivery of information and training, e.g. augmented reality can be used to deliver part replacement instructions to maintenance staff in the field.

Internet of Things (IoT)
Industry 3.0 brought in an era of computing and interconnectedness but it often relied on humans to make even the most trivial decisions. Industry 4.0 technologies embody an unprecedented proliferation of sensors and connectedness among these sensors. Combined with other technologies such as AI and big data, it is now possible to envisage entirely autonomous systems that revolutionise manufacturing.

Autonomous Robots
Machinery and robots are transformed towards their next generation. Robots can do more on their own, including learning on the job and teaming up with other robots and humans. This technology allows systems to think, act and react autonomously as well as conduct remote decision making. This can help contribute to a company's competitiveness, productivity and profitability.

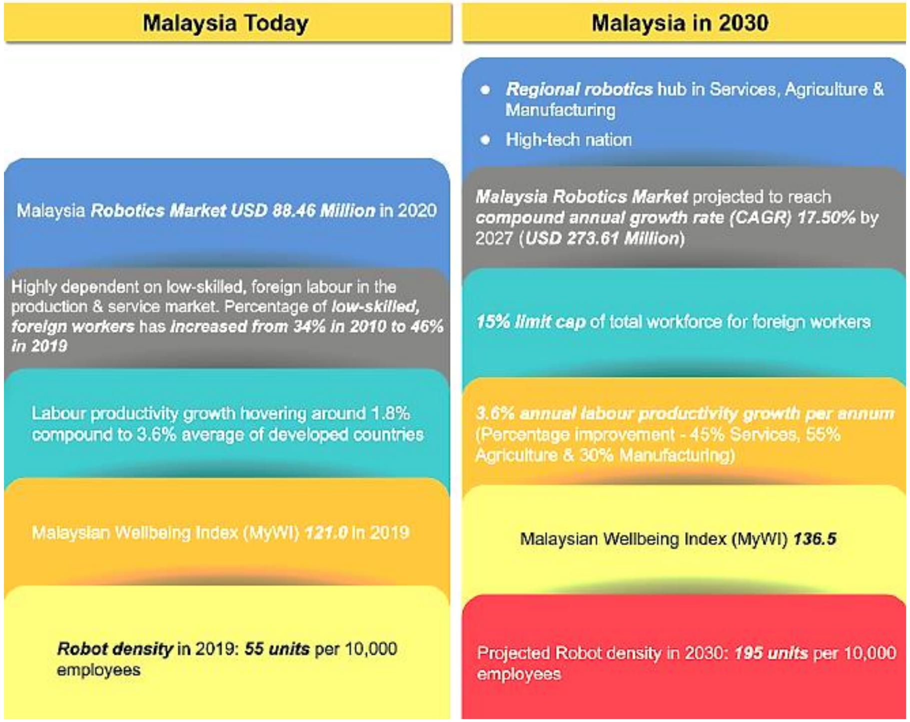
System Integration
System integration occurs in vertical (within the industry value chain) and in horizontal systems (across multiple value chains), eventually achieving end-to-end digital integration across the entire value chain.

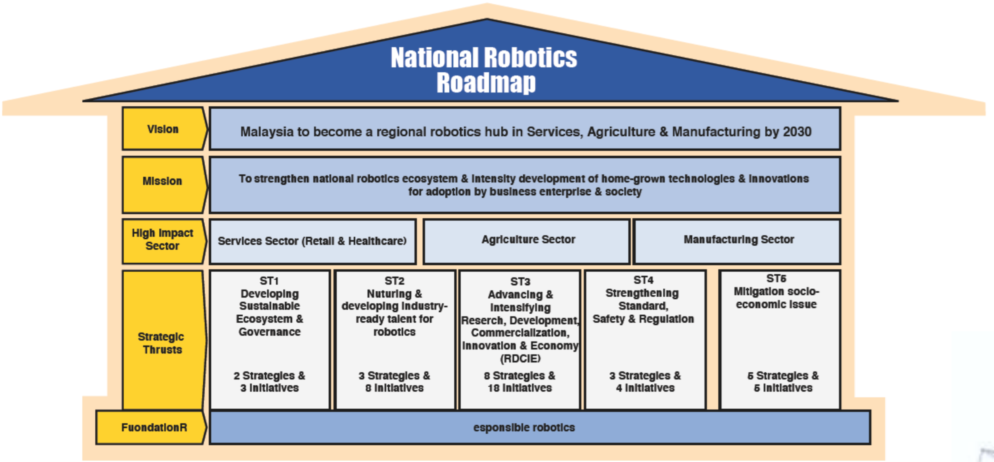
Enabling Technologies

NATIONAL ROBOTIC ROADMAP
AN OVERVIEW

Technology advancement in Fourth Industrial Revolution (4IR) has altered the way people live, work, and relate to one another. Emerging technologies breakthroughs such as robotics, artificial intelligence (AI), and the Internet of Things (IoT) are catalyzing disruptive innovations across socio-economic sectors in the world. Robotics combined with AI and IoT are redefining the advancement and competitiveness of nations.

Robotics is a key catalyst for Malaysia to achieve its aspiration of becoming a progressive, prosperous, and high-tech nation. Through robotics, several main challenges for Malaysia such as productivity, dependency on low-skilled foreign labor, outflow of local currency, quality of life, as well as pandemics and disasters could be addressed. Successful robotics adoption and development will help to accelerate the nation’s gross domestic product (GDP) growth. Thus, aligned with 4IR, robotics is a key technology that is vital to address these challenges and finally contribute to the socio-economic development and advancement of the nation.





In conclusion, high valued, high skilled driven products will define the future global market with the advance of hardware and software technology. Clear vision over the 10 years technological development pathway need to be defined today. Modernization of national strategic areas requires urgent attention from the Government. Specifically, actions need to be carried out in the form of R&D research funds, tax relief, incentive, upskill and reskill initiative, reshuffle of current legislation on robotics and formation of a national robotic governance body. Figure above shows that this roadmap is poised to prepare Malaysia toward becoming a progressive, prosperous and high-tech nation.

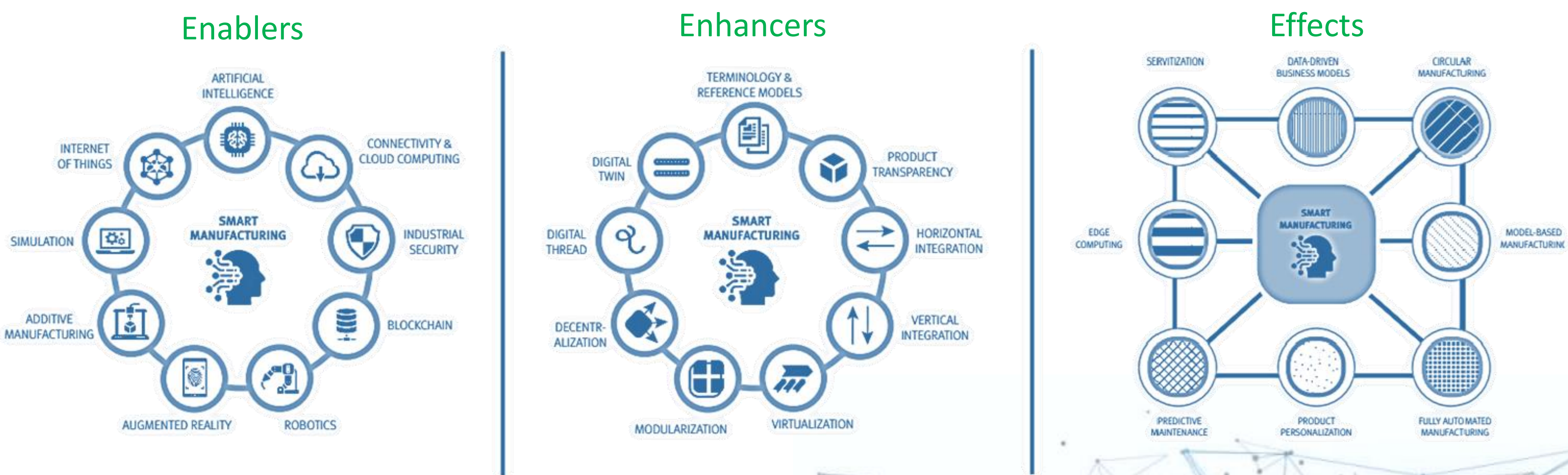
https://www.mosti.gov.my/en/dasar/

SMART MANUFACTURING
ISO PERSPECTIVES

Manufacturing has evolved though paradigm changes, commonly known as “industrial revolutions”. These four revolutions (the first three are considered to be steam / water power, electricity, and automation) have had a great impact on economic growth and living standards. Economic historians agree that the start of the first industrial revolution was the most important event in the history of humanity since the domestication of animals and plants.

The fourth industrial revolution, otherwise referred to as smart manufacturing, can be explained in many ways. New disruptive technologies are regularly becoming available, paving the way for a new wave of innovations. When the effect of these new innovations is large enough, they will revolutionize the current norm of how things are seen and done.

In the following figure presents new disruptive technologies that are mature enough to be leveraged by industry; and it is called the “ enablers ” of smart manufacturing. The figure also present a set of design principles, referred to as the “enhancers” for smart manufacturing, that are currently under development and of high relevance for achieving a successful implementation of smart manufacturing. The last element - the “effects” that are foreseen with smart manufacturing.



https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100459.pdf

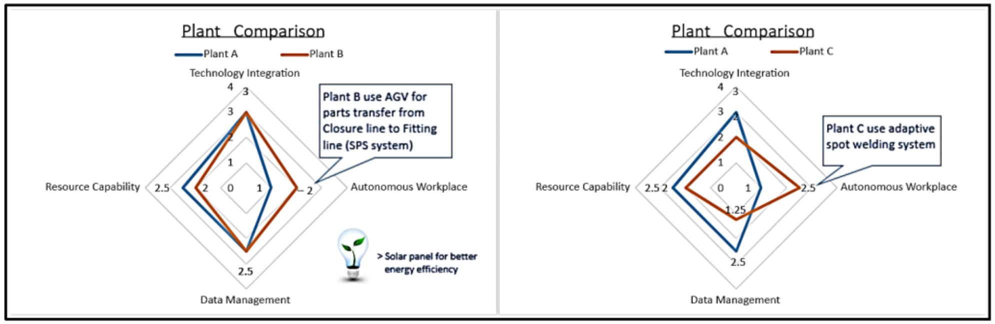
INDUSTRY 4.0
AUTOMOTIVE WELDING PLANT ASSESSEMENT

Industry 4.0 refers to the fourth industrial revolution, which affects every manufacturing domain and comprises advanced manufacturing technologies that capture, optimize, and deploy data. In other words, Industry 4.0 makes factories “smart” by implementing such technologies as the industrial Internet of Things, artificial intelligence, and cyber-physical systems interact seamlessly, communicating and adjusting continuously. Businesses that fully understand and capture the value of these advantages will be best positioned to take on the challenges that lie ahead.

In order to evaluate IR 4.0 readiness for manufacturing and operation, self-assessment tool established by University of Warwick is used. The assessment comprises 4 main elements – technology integration, autonomous workplace, data management and resource capability. As shown in the following table, 3 welding plants in Malaysia are included in this assessment for study purpose in 2019. The score for each element ranging from 1 (beginner level) to 4 (expert level).

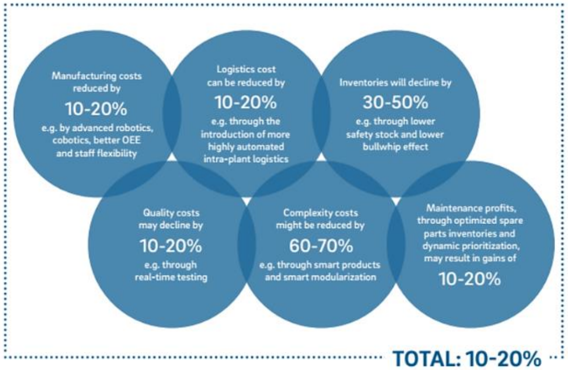
Key Area	Items	Plant (Welding Shop)		
		Plant A	Plant B	Plant C
Technology Integration	Automation	3	3	1
	M2M - Machine & operation integration	3	3	3
Autonomous Workplace	Self - optimise process	1	1	4
	Autonomous guided vehicle / workpiece	1	3	1
Data management	Operation data collection	3	3	1
	Operation data usage	2	2	2
	Cloud solution usage	2	2	1
	IT & data security	3	3	1
Resource Capability	Digital modelling	2	2	1
	Equipment readiness for Industry 4.0	3	2	3
Total Score		23	24	18

Using radar chart, the assessment’s summary is plotted for comparison. Since energy efficiency or renewable energy is not considered as one of assessment criteria, the usage of solar panel to generate electricity for Plant A is put on the note. In addition, Plant A is used as base line for comparison with other plant.



Based on figure above, under ‘Autonomous Workplace’ element, Plant B and C are much better than Plant A. Plant B implements automated guided vehicle (AGV) to transfer parts from closures to fitting line since part supply using ‘Set – Part – Supply’ (SPS) method. Plant C implements adaptive spot welding system in which the controller will automatically adjust welding current or weld time base on recorded dynamic resistance curve to compensate disturbance during welding operation such as bad fitting of the sheets, shunting, variation of coating and welding force. Moreover, all the actual welding parameters are been recorded automatically in the system.

Based on study conducted by Fraunhofer Institute of Manufacturing Engineering and Automation (Roland Berger), the estimated cost saving resulted from IR 4.0 adoption is between 10% to 20% as shown in the figure. One major factor driving improvement in manufacturing will be increasingly advanced robotics or machinery, as technologies such as self-reconfiguring machines and the human-robot collaboration of "cobotics" become increasingly mainstream .

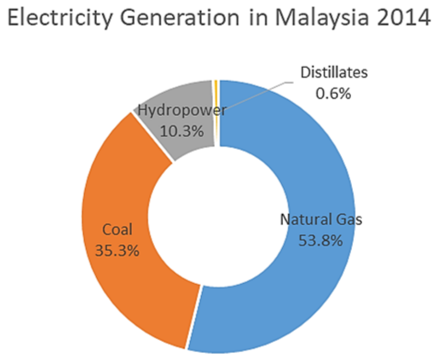


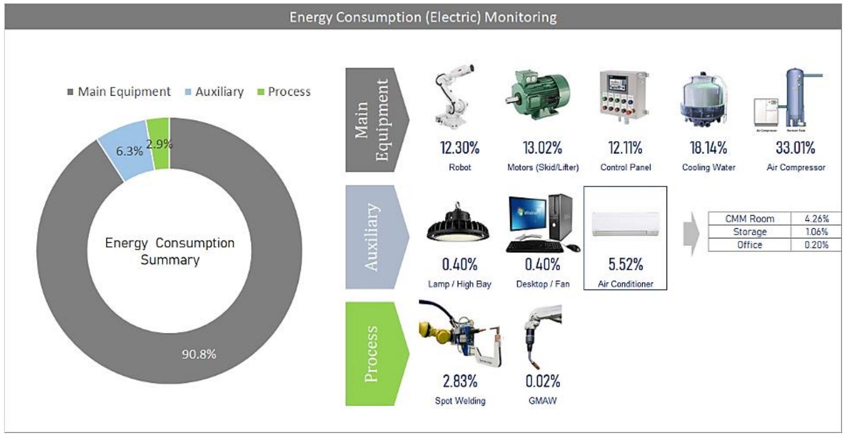
Source: Fraunhofer Institute for Manufacturing Engineering and Automation (IPA), Roland Berger

https://www.researchgate.net/publication/353803517_Analysis_of_IR_40_Adoption_in_Automotive_Welding_Shop

SMART MANUFACTURING
ENERGY CONSUMPTION IN WELDING PLANT

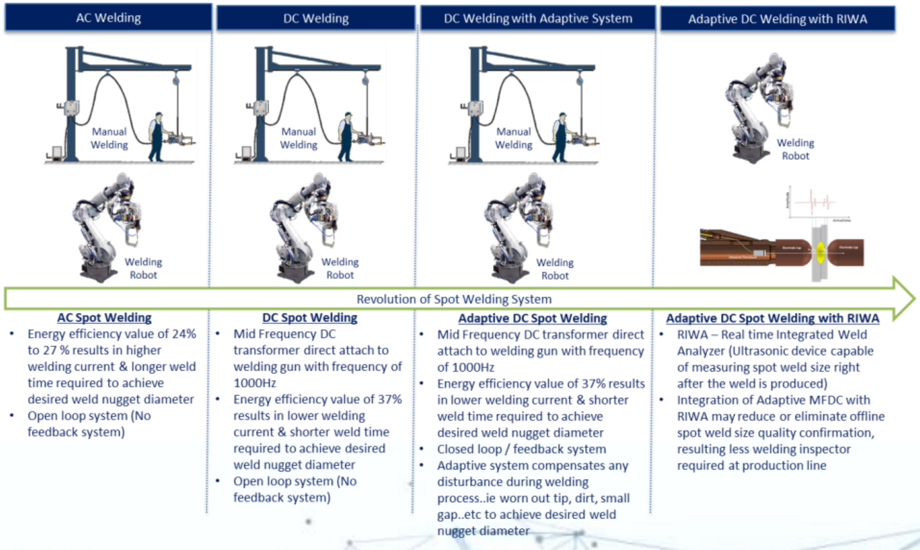
In modern manufacturing practice, energy consumption is getting more and more concern by automotive car manufacturers due to the constantly increasing energy cost and to the ecological burden related to the energy production and use. The great use of electrical energy for industrial operations is responsible for significant CO2 emissions and thus, climatic changes. According to the data from Tenaga National annual report 2014, 53.8% of the electricity generation is met by natural gas, 35.3% is met by coal, 10.3% by hydropower and 0.6% by distillates. Therefore, higher the energy requirement for manufacturing processes, higher the electrical energy generation required. Hence, higher CO2 emission rate since most of electricity generation are met by natural gas & coal.





Based on study conducted in 2019 at welding shop, the equipment & electrical appliances can be divided divided into 3 main categories which are main equipment, auxiliary and welding processes. The highest energy consumption is from air compressor unit. The compressed air are used in several applications or equipment such as welding jigs (pneumatic cylinder), pneumatic welding guns, hoist, tightening tools and sealant pump. The second highest energy consumption equipment is cooling water unit. This unit is used to circulate water through piping as cooling system in spot welding gun. Surprisingly, energy consumption by welding process is relatively small compared to other equipment. Meaning to say that the process itself is energy efficient enough and even its consumables price (electrode tip, holder) higher than energy it consumed.

In order to design energy efficient factory especially in welding shop, energy efficient equipment need to be considered. For example, using DC with servo controlled welding equipment instead of AC welding equipment may save energy up to 10%. Same goes to tightening tools, using electrical tools instead of air tools may save energy up to 38%. Another example is using integrated clamp – cylinder such as Tunkers may saves up to 12% energy compared to conventional clamp method. In general, using electric tool / equipment is more energy efficient compared to air tool / equipment. This strategy is effective in order to reduce compressed air usage in factory.

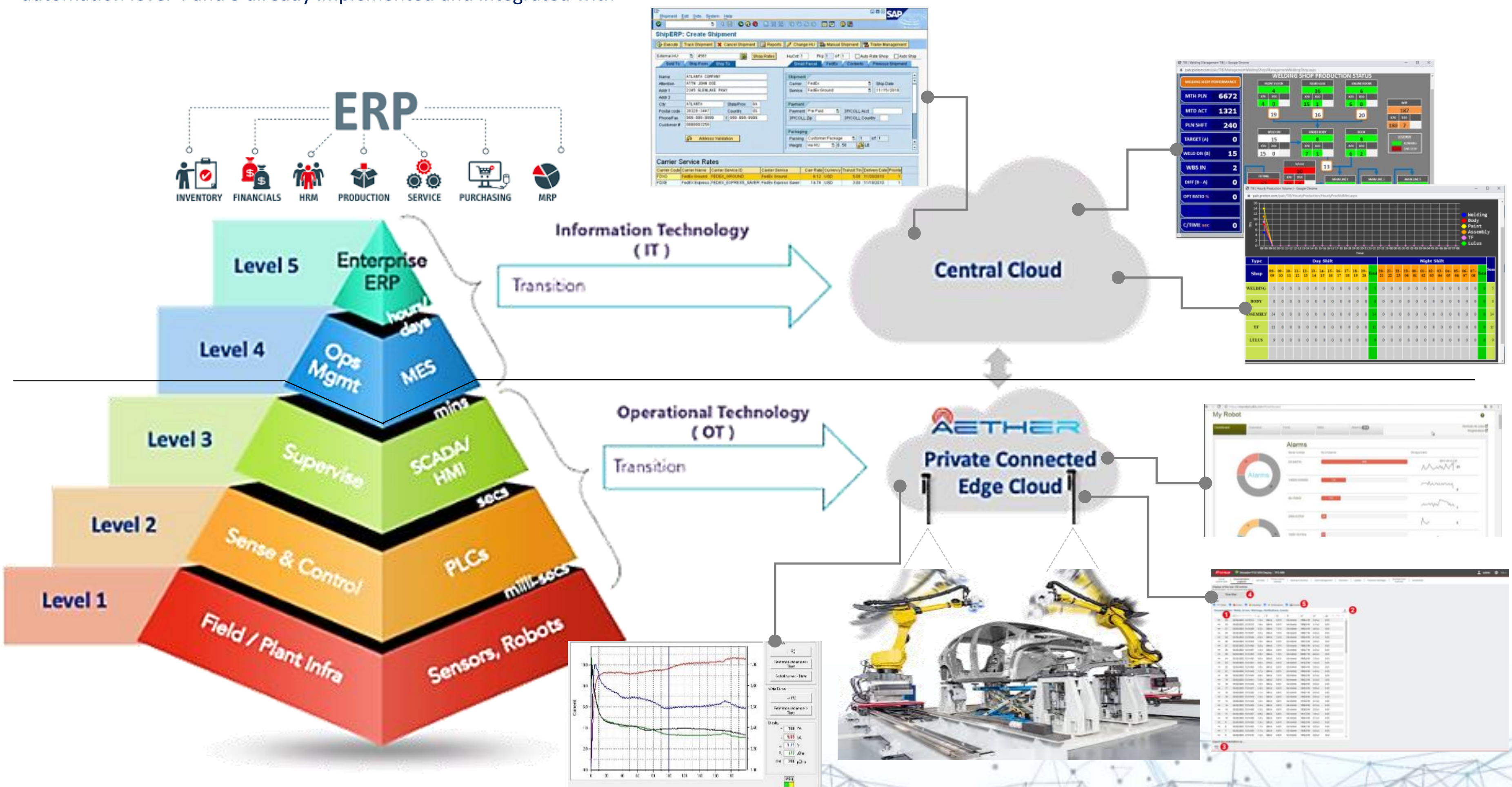


https://www.researchgate.net/publication/353305588_Energy_Consumption_in_Automotive_Welding_Shop

SMART MANUFACTURING

MODERN MANUFACTURING AUTOMATION PROTOCOL

The Automation Pyramid is a pictorial representation of the layers of automation within a typical factory, comprising five layers of integrated devices and technology. In modern automotive factories, automation level 4 and 5 already implemented and integrated with central cloud base on case study done in 2019. Therefore, the improvement or system upgrading towards Cyber Physical system is focused on level 1 and 2 equipment.



https://www.iiot-world.com/industrial-iot/connected-industry/enabling-a-new-era-of-industrial-iot-with-free-use-wireless-spectrum/

SMART MANUFACTURING
AUTOMATION PROCESS CYCLE

The manufacturing automation protocol is a cyclic process from ERP system to shopfloor equipment as shown in the following figure. This is to ensure the whole system can run smoothly across the company and also its supply chain.

HMI

Data flow (Plan)

Data flow (Actual)

RFID

ERP

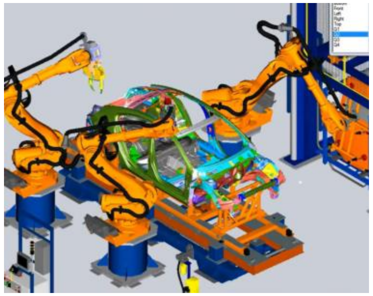
Enterprise Resource Planning (ERP)
is a platform companies use to manage and integrate the essential parts of their businesses with a single system. An ERP software system can also integrate planning, purchasing inventory, sales, marketing, finance, human resources, and more.

MES

Manufacturing Execution Systems (MES)
are computerized systems used in manufacturing to track and document the transformation of raw materials to finished goods. MES provides information that helps manufacturing decision-makers understand how current conditions on the plant floor can be optimized to improve production output. MES works as real-time monitoring system to enable the monitor & track multiple elements of the production performances such as output, efficiency, downtime and vehicle track record.

PLC

The HMI (Human Machine Interface) Panel
is used by operators and engineers to operate, visualize and monitor the process, provide control targets and set-points, execute programs and initiate sequences, and troubleshoot problems via trends, alarms, and events.



Sensors

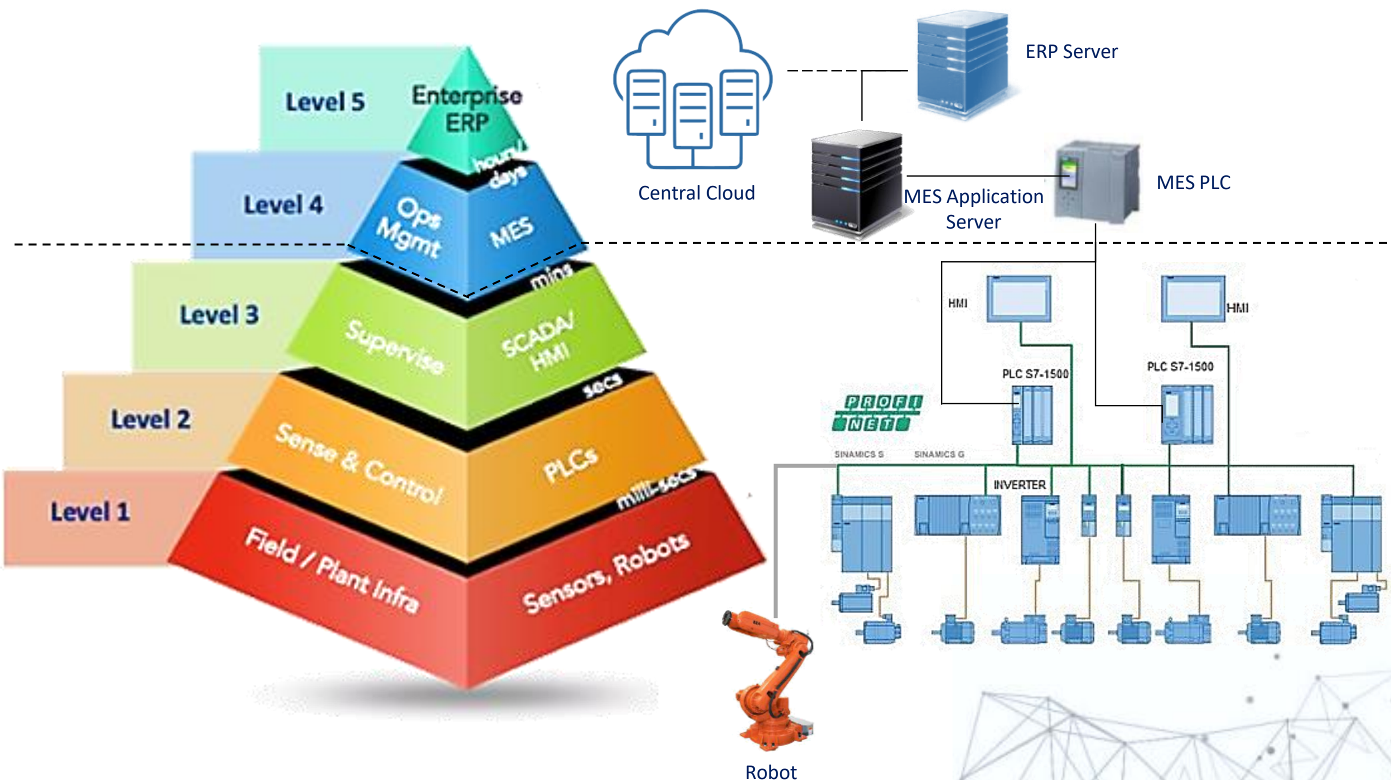
PLC – Equipment – Sensors Integration
In modern manufacturing control, RFID reader will read RFID tag from vehicle to identify it model name, variant, VIN and color code. Then PLC will send signal to equipment to do job base on detected variant or model code. Other sensors such as limit switch and proximity are used to confirm correct parts installed to the vehicle.

https://en.wikipedia.org/wiki/Manufacturing_execution_system

SMART MANUFACTURING
AUTOMATION SYSTEM ARCHITECTURE

The Automation System Architecture represents the main hardware interface or connection across each automation level pyramid. Both ERP and MES are software system that can be accessed using computers, smartphones and other devices that connected to Cloud. MES is often integrated with ERP and other IT systems to meet company's needs and requirements. In order to execute MES system instructions to factory's equipment, MES PLC is required as interface and connected to equipment's PLC devices at shopfloor.

In term of programming and connection between automation protocol level 1, 2 and 3, the basic is same. The only different is the PLC brands & connection / network types drives, sensors and robots to PLC. The following figure shows comparison between 2 welding plants for type of PLC and network used. Automation protocol level 4 and 5 remain the same for both plants.

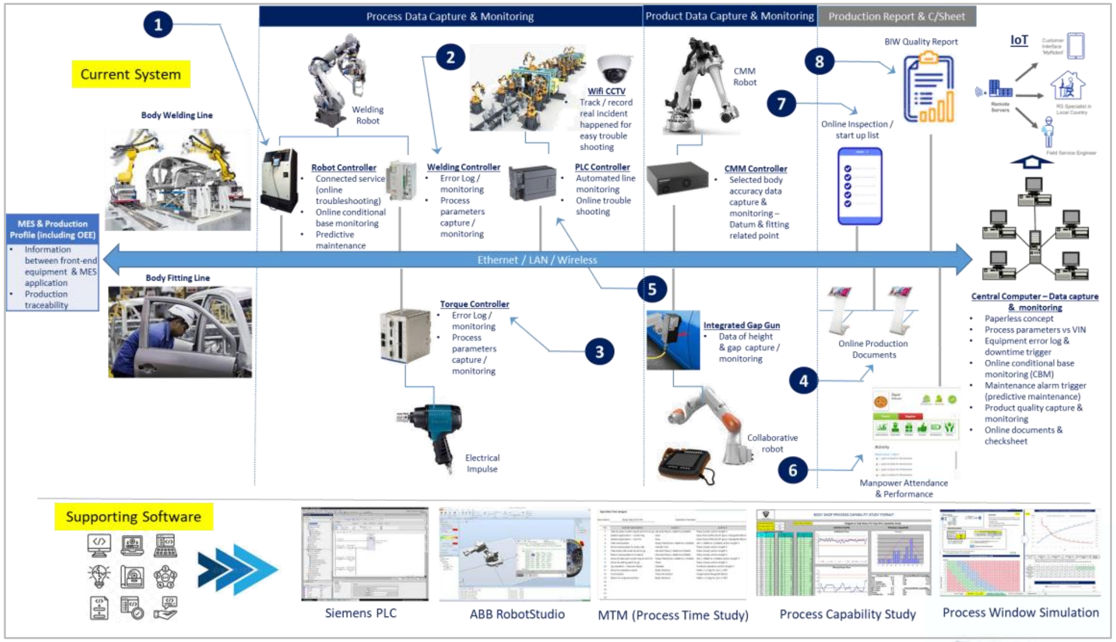


Item	Plant A	Plant B
PLC CPU	Mitsubishi MELSEC-Q	Siemens S7-1500
Software (Troubleshoot & Modified)	GX Developer	TIA Portal V15
Display Panel	GOT	HMI
Programming Language	Ladder Diagram	Ladder diagram Function Block Sequential Chart Structure Text Statement List
Network	CC Link	PROFINET Fiber Optic

SMART MANUFACTURING
IR 4.0 ADOPTION IN WELDING PLANT

The Industry 4.0 adoption in welding plant's shopfloor should have detail analysis especially on equipment readiness and implementation cost since based on study by Roland Berger, the estimated manufacturing operation cost saving is from 10% to 20% only. Therefore, the top priority must go for improving energy management system such as installing solar panel to generate electricity and using energy efficient equipment since this initiatives will greatly reduce manufacturing operation cost between 40% to 60%. Another option is to adopt Karakuri concept in equipment design. It is simple but intelligent automation of processes based on physical principles – with no drives, sensors, electricity or compressed air.

In the following graph shows some of the systems that can be upgraded in level 1 and 2 automation level pyramid based on study done in 2019. The system samples cover online process and product quality confirmation, equipment remote monitoring, adaptive welding system and paperless production document concept at shopfloor.



No	Item	Description	Merit
1	Robot remote monitoring & service	Online capabilities to monitor robot performance, predictive maintenance, robot back up & trouble shooting (connected service)	•Reduce service cost (labour & travelling by ABB personnel) •Faster breakdown maintenance to reduce robot downtime
2	Spot welding system	Online capabilities to do welding parameters setting & monitoring	•Dedicated person for parameters adjustment (avoid illegal & unrecorded adjustment) •Online welding current data monitoring – eliminate manual checking & paperless concept
3	Torque / tightening system	Online data (torque) monitoring & data capturing	•Eliminate manual torque confirmation process •Paperless concept
4	IT based production doc ument system	Production kiosk displaying production document such as AOS, SOP, maintenance manual and quality standard online.	•Avoid outdated document display at production side •Paperless concept
5	Online production line monitoring & troubleshooting	PLC based production line control – Online condition base monitoring & breakdown troubleshooting	•Faster breakdown maintenance to reduce equipment downtime
6	Staff performance / status record	Online manpower attendance, COVID 19 & performance status update	•Faster daily report circulation & easy access
7	Maintenance / TPM / start up status	Online equipment checksheet	•Faster daily report circulation & easy access
8	BIW quality status	Online BIW quality update	•Faster daily report circulation & easy access

In modern manufacturing system, the factory personals also are equipped with relevant software products to support processes starting from project development stage to normal running production state. The software range from equipment offline / online programming and simulation, production process time simulation, process capability study and process window simulation. The following slide shows the detail of system samples that can be adopted to align with IR 4.0.

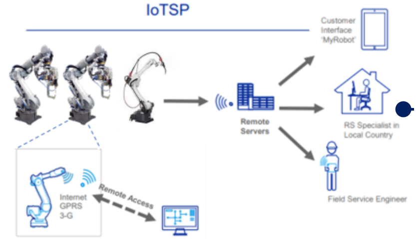
SMART MANUFACTURING
IR 4.0 ADOPTION IN WELDING PLANT

1 Internet of Things, Service & People (IoTSP) – Robot Remote Service

ABB's Remote Services portfolio

- Remote Support 24/7 – immediate support and reduced downtime
- Remote Monitoring and Failure Prediction - avoid unplanned stops and increase time between failures
- Remote Services Robot Back-up - increase uptime and disaster recovery
- MyRobot - information and reporting any place, any time

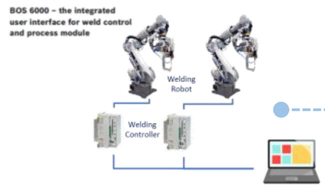
IoTSP



2 Cyber Physical System – Spot Welding System

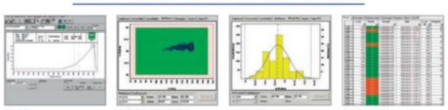
BOS 6000

The windows-based BOS 6000 user interface with built-in SQL database function makes it very easy to operate the system and monitor performance. You can operate both the welding controller and the process module on a standardized BOS 6000 user interface. The BOS 6000 also provides connectivity to higher-level data processing systems.



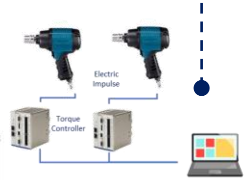
3 Cyber Physical System - Tightening / Torque System

CS351 Compact System



ADVANTAGES OF THE SOFTWARE

- All in one software package includes an extensive and user-friendly statistics package.
- System installation and programming of individual tightening tasks is done via convenient, icon-supported tools.
- 180 curves are available for an analysis of the tightening joints.
- Step by step programming structure allows for a logical breakdown of the tightening rundown and easy identification where an issue occurs in the rundown process.



4 Production Line Kiosk

IT Base Production Document System

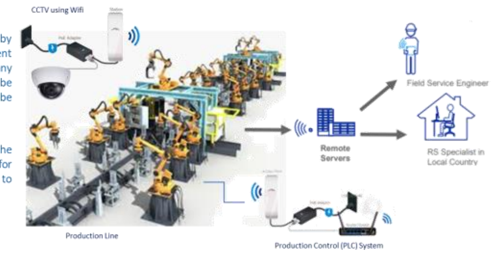
The production kiosk is PC based online documents system for production related groups as reference such as work AOS, Flow Chart, SOP, Quality Standard , MSDS...etc

Smart Factory

5 Remote service – Online Production line Troubleshooting

Online Automated Line Monitoring & Troubleshooting

- PLC system can be accessed by maintenance personnel / equipment maker thru internet access, so that any issue during breakdown can be identified faster and downtime can be minimized
- CCTV is required to track & record the real incident - before, during & after for easy troubleshooting process (easier to identify issue using record playback)



6 Online Staff Daily Status & Performance Monitoring

Staff Performance Status / Record

- Each group's supervisor to update their staff status (annual leave, MC, etc) including quality record thru application on tablet / hand phone.
- Staff health especially on COVID 19 status can be updated
- The summary report will be automatically generated base on application updated by each group & can be retrieved by any requested date.

7 Online Start Up & Maintenance Record

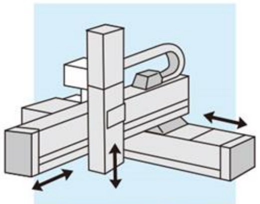
Online Maintenance / TPM / Start Up Checksheet

- Robotman / PM members to scan QR code on robot controller.
- Then, online checksheet for that particular robot will appear on tablet / handphone. The related staff will fill in the checksheet base on their physical inspection on robots.
- The summary report will be automatically generated base on application updated by each group & can be retrieved by any requested date.

Industrial Robot in Automotive Welding

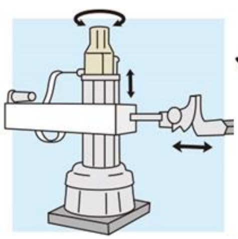
ROBOTIC IN AUTOMOTIVE WELDING
AN INTRODUCTION

According to Japanese Industrial Standards (JIS), Industrial Robots are defined as "machines which have manipulation features or mobility functions that are controlled automatically, able to perform various tasks through a program, and are used for industrial purposes". In other words, industrial robots are defined not by shape but according to their broad functions. There are several types of industrial robot such as cartesian robot, cylindrical & polar robot and articulated robot.

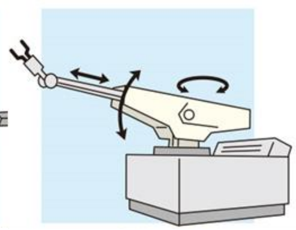


Cartesian Robot

Cartesian Robots have a simple structure of two or three sliding axes where the sliding axes are joined together. While they are unable to perform complicated movements, their precision level is high, and they are easy to control, making them appropriate for use in the areas of semiconductors, healthcare, or chemicals for tasks such as the assembly of small parts or outfitting electronic circuits.

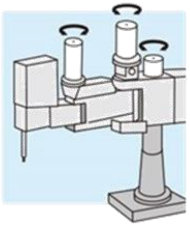


Cylindrical Robot



Polar Robot

Cylindrical and polar robots consist of structures that were first used for industrial robots in the early years. While their field of operation is broad, they aren't very suitable for complicated tasks that require them to make roundabout movements. The arm of cylindrical Robots rotates vertically and expands and contracts from the pivotal axis. Meanwhile, the arm of Polar Robots moves vertically, expands, and contracts from the pivotal axis.

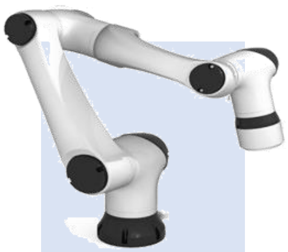


Horizontal Articulated Robot

Vertical Articulated Robot

Multiple joints of Horizontal Articulated Robots and Vertical Articulated Robots are connected through links, each of which makes rotary movements around the joints. The greater the number of joints, the greater the level of freedom, which enables these robots to make complicated movements including roundabout moves. Because of this, many robots today are multi-jointed. The makeup of Vertical Articulated Robots are similar to that of human arms, which makes it possible to say that they are probably the most rational form of robots to use for work to be done "in the place of humans".

Traditional industrial robots must not be confused with a newer robotic technology called collaborative robots. Collaborative robots, or cobots, work closely and simultaneously with a human operator. They are safe to use around human operators as they have a maximum speed limit for cobot operation and are limited as to how much force they can generate. This, along with more precise motor current sensing, allows them to stop if encountering an object or an operator.

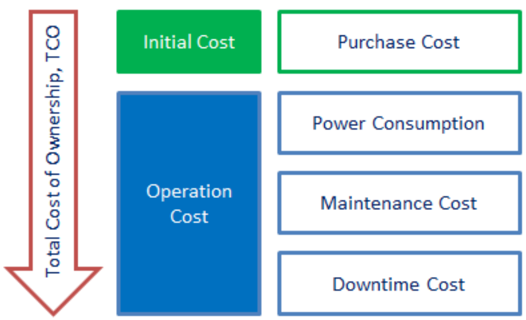


Collaborative Robot

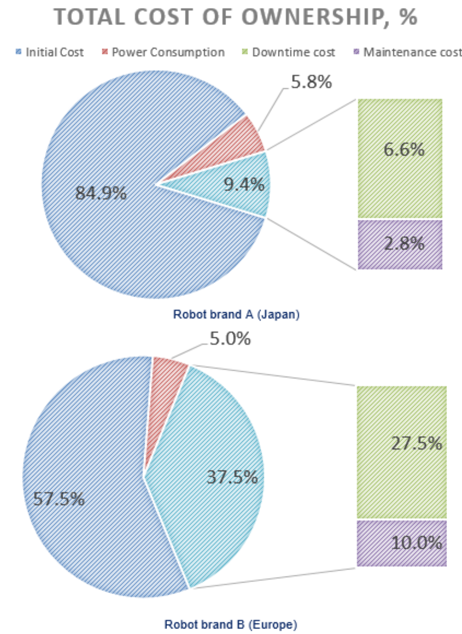
ROBOTIC IN AUTOMOTIVE WELDING
TOTAL COST OF OWNERSHIP (TCO)

In automotive manufacturing processes, industrial robots are widely used to increase productivity while maintaining desired quality standard and design specification in production line. The typical method of selecting robot's type and brand is matching robot's specification with product and manufacturing process requirements, then, choosing the robot's brand base on the lowest purchase price offered by robot's makers. This method is actually not really effective since it is not considering the operational cost, which may start right away after robot installation till end of production (EOP) of a car's model. The average of effective and productive period of robot's operation is only 7 years. After this period, major refurbishment required such as servo motors, gears and servo pack replacement in order to prolong robot's lifespan.

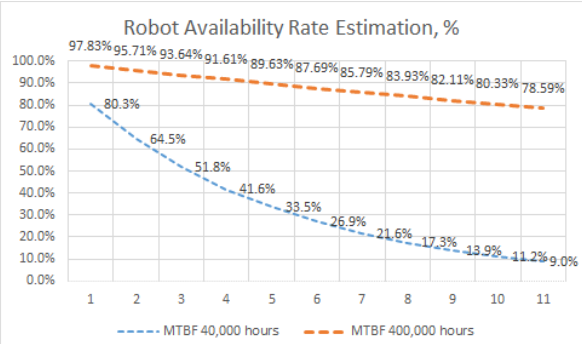
The recommended method to evaluate robots from various robot's makers is using Total Cost of Ownership (TCO) method. TCO is a financial estimate intended to help buyers and owners determine the direct and indirect costs of a product, for this case - robot brand's selection. The elements of TCO are described as follows;



There are 2 elements of TCO, which are initial cost and operational cost. Initial or purchase cost includes robot and it system cost, initial spare parts, training and extended warranty cost. For operational cost, 3 main elements need to be considered - robot power consumption, maintenance and downtime cost. The following chart shows 1 case study of 2 different robot's brands, operating 1 shift a day, for 7 years. From the chart, initial or purchase cost contributes 57.5 % to 84.9%, while operational cost contributes 15.1% to 42.5% from total cost. For operational cost, 5.0% to 5.8% of cost is contributed from electrical power consumption, 2.8% to 10.0% contribution comes from maintenance cost, and 6.6% to 27.5 % comes from cost of downtime. Therefore, it is recommended to consider robot's reliability since low robot's reliability will cause high downtime and spare part cost (includes in maintenance cost) in total operational cost.



For robot downtime cost, it is a bit difficult to estimate without robot downtime history record. However, from mean time between failure (MTBF) values extracted from robot technical specification, it is possible to estimate robot availability rate. Downtime rate is just inverse of robot availability rate. The average MTBF of industrial robot is around 40,000 hours. It does not mean that robot will only fail after 40,000 hours (4.6 years), but the value is used to estimate availability rate as shown in the above graph.



For example, when looking at MTBF 40,000 hours curve, for 1st year, the estimated availability rate is 80.3%, equal to 19.7% of downtime rate. Then, will decrease over the years of operation. When comparing with MTBF 400,000 hours curve, the availability rate goes higher than MTBF 40,000 hours curve. It means, higher the MTBF value, higher the robot availability rate, resulting higher robot reliability index.

ROBOTIC IN AUTOMOTIVE WELDING

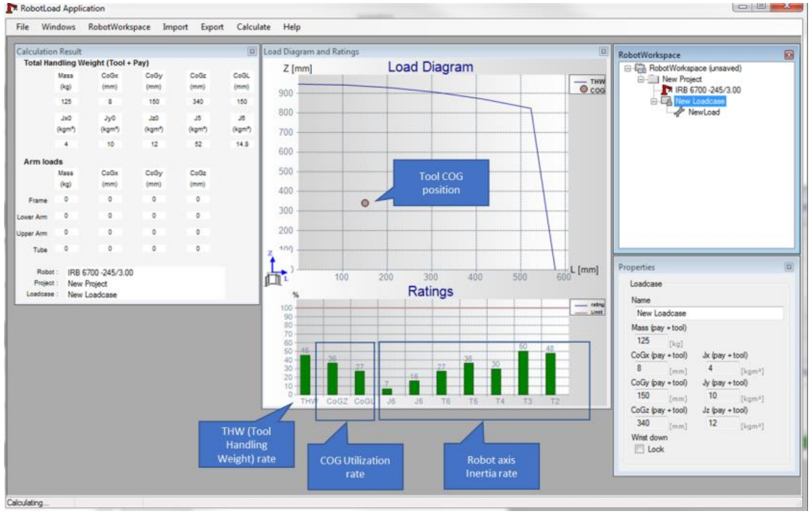
SELECTION CRITERIA

In automotive manufacturing processes especially at Welding Shop, industrial robots are widely used to increase productivity while maintaining desired quality standard and design specification in production line. The application are mainly on welding (spot / arc welding), sealant / adhesive application and material handling. Before selecting any brand of type of robot to be used, process requirement must be confirmed to meet robot specification. The sample of process requirement is as shown in the following table;

	Spot Welding Position	Gripper Location	Sealant / Adhesive Length
Position Tolerance Standard	10% from drawing position / ± 5mm (min)	± 0.2mm	± 5mm

Depending on area of application to the automotive body structure, generally, there are 2 types of industrial robots - shelf and floor mounted types. The practical way in robot selection method is by determining the robot specification that meeting process specification and requirement, then, cost evaluation is done by using Total Cost of Ownership (TCO) method. The following table shows the comparison of robot specifications for different robot's makers which gives general ideas on what to be taken into account during robot selection processes.

	Brand	ABB	KUKA	Yaskawa
	Picture			
Basic Specification	Model	IRB 6700 Series	KR 210 R2700	MS 210
	Payload (Max)	150 kg~ 300 kg	210 kg	210 kg
	Type	Floor mounted	Floor mounted	Floor mounted
	Controller	IRC 5	KR C2 Edition 2005	DX 200
	Software (Instruction Language)	RAPID	KRL (Kuka Robot Language)	INFORM
	Software (Simulation) - Offline	RobotStudio	KUKA.Sim	MotoSim
	Power Rating	7.7 kVA	7.3 kVA	5.0 kVA
	Repeatability (Position Consistency)	± 0.06 mm	± 0.06 mm	± 0.2 mm
	Payload diagram, max COG range (Z-dir)	500mm	600mm	600mm
	Axis max speed, °/sec	126.7 (Avg)	108.0 (Avg)	140.3 (Avg)
	MTBF (Manufacturer claim)	40,000 hours	40,000 hours / -	36,000 hours

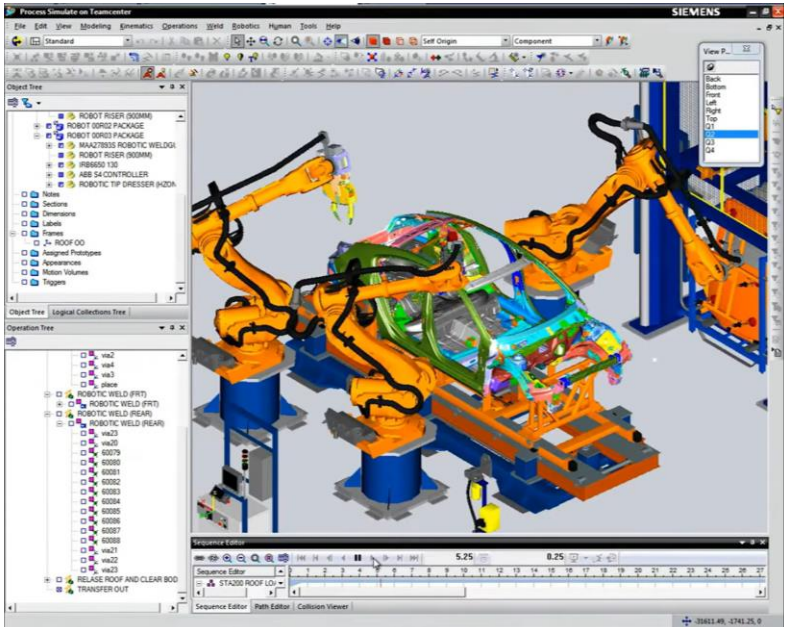


In order to match tool such as welding gun, gripper or sealant applicator with robot, usually 3D drawing of tool is required to identify it COG. Then, the identified tool's COG need to be matched with robot load diagram. This step is very crucial to avoid robot overload and shorten robot lifespan. As shown on the diagram above, the sample of robot payload simulation using RobotLoad application by ABB. The maximum utilization rate requirement may vary between car manufacturers.

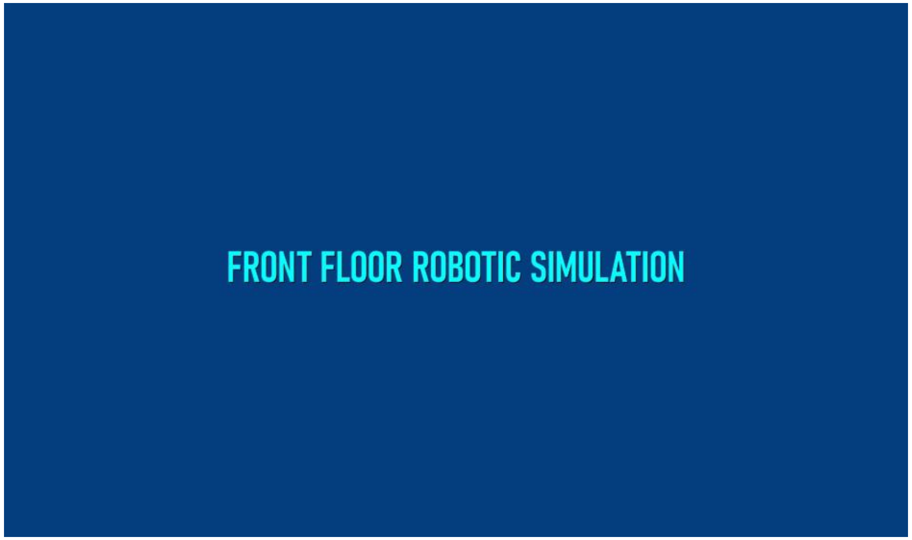
ROBOTIC IN AUTOMOTIVE WELDING

ROBOT PROCESS SIMULATION

In recent years, technological advancements in electrification, sensors, artificial intelligence (AI), and the industrial internet of things (IIoT) have resulted in a new wave of industrial robotics in automotive manufacturing. While these advancements improve productivity, they also increase the risk of delays due to programming and installation errors during launch or while incorporating engineering changes. Nowadays, a lot of Smart Manufacturing solution for the automotive industry includes robotics simulation and virtual commissioning capabilities that enable automotive OEMs and suppliers to plan, optimize, and test manufacturing lines virtually before commissioning them physically. This virtual environment delivers multiple advantages during manufacturing development to ensure a flawless launch and streamline engineering changes throughout production.



Full Station Process Simulation using Siemens PLM Software



Single Process Simulation using RoboDK Software

There are several simulation software available in the market depending on the complexity of the process to be simulated. For complex simulation such as new factory setup, digital manufacturing software like Delmia and Siemens PLM software are used since these software can integrate wide range of equipment including robot and conveyor. Other robot simulation software are mostly provided by robot manufacturers and can be bought separately. The examples are ABB Robot Studio by ABB, KUKA Sim by KUKA and MotoSim by Yaskawa.

Some of robot simulation software such as RoboDK offers powerful and cost-effective simulator for industrial robots and robot programming. This software is capable to simulate almost all brand of industrial robot, which makes it suitable to use for small or medium robotic project.

For more references, please visit;

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Process Window Simulation in Automotive Welding Shop

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RSW – Weldability Lobe Simulation Development

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Automotive Industrial Robot – Total Cost of Ownership (TCO)

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Automotive Industrial Robot – Selection Criteria for Body Assembly Application

https://www.globalscientificjournal.com/researchpaper/Automotive_Industrial_Robot_Selection_Criteria_for_Body_Assembly_Application.pdf

The End