National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Exemplar for Internal Achievement Standard

Technology Level 2

This exemplar supports assessment against:

Achievement Standard 91365

Demonstrate understanding of advanced concepts used in manufacturing

An annotated exemplar is an extract of student evidence, with a commentary, to explain key aspects of the standard. It assists teachers to make assessment judgements at the grade boundaries.

New Zealand Qualifications Authority

To support internal assessment

	Grade Boundary: Low Excellence
1.	For Excellence, the student needs to demonstrate comprehensive understanding of advanced concepts used in manufacturing. This involves discussing how and why quality management techniques have been important in changing manufacturing practices. This student discusses the origins of the Toyota Production System (1), and how the system has progressively evolved to adapt to domestic and international political and economic considerations. Examples include post-war economic recovery, globalisation and environmental restrictions (2). Quality management procedures at the Toyota Australia plant in Melbourne are discussed in detail, including the reasons for the company decision to discontinue domestic manufacturing (3). For a more secure Excellence, the student could strengthen the discussion by comparing and contrasting management strategies in the development and operation of the Toyota Australia car manufacturing plant and that of another factory (for example, the Mercedes-Benz Astros truck factory in Europe).

Student 1: Low Excellence
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[1] The basic foundations of what has become known as the Toyota Production System (TPS) started in the early 1900s in Japan within the operating procedures established by the Toyoda Spinning and Weaving Company. This was a manufacturing company that had built a solid reputation for producing high quality hand looms. Its founder Sakichi Toyoda had a personal management philosophy that was based on human respect. This respect applied to everyone involved in the production chain - from his material suppliers, all those working in his factory through to the eventual customers and those who used the looms his company produced. The Toyoda Company developed and mass manufactured the first steam powered loom that could detect a broken thread and stop itself automatically. This prevented much of the expensive waste which was a feature of the textiles industry at that time. It was an innovation that not only signalled the company's drive for manufacturing efficiency through minimisation of waste but also for continuous process improvement by developing and using intelligent automation.

….Sakichi's son Kiichiro took an interest in the emerging field of automotive manufacturing and in 1937 founded what later became the Toyota Motor Corporation. Kiichiro took his father's faith in intelligent automation and paired it with his own complimentary philosophy – 'Just in Time' (JIT) manufacturing.

[2] The impact of the high levels of debt and shortage of raw materials in the years following the involvement of both Germany and Japan in the 1939 – 44 Second World War hit hard and was potentially crippling. The USA was the established and largely unchallenged world leader in the post-war global manufacturing market with industrial productivity many times greater than that of Japanese manufacturers. In Toyota's move towards post-war economic recovery the need to be able to manufacture vehicles efficiently became greater than ever.

In Japan one of Toyota's young engineers Taiichi Ohno, was given the challenging responsibility for increasing the company's productivity to try to match that of its American competitors. Taiichi succeeded in merging Kiichiro's JIT concept with the Toyota principles of intelligent automation and human respect. His aim was to create a manufacturing system with a smooth continuous optimised flow of work – cutting out any wasteful storage of yet-to-be used or waiting-to-be-sold materials. He based his work on the thinking of the American pioneer of quality control Dr. W. Edwards Demming. His recommended management strategies focused on improving quality at every stage in a business – from product design, through manufacturing to after sales support. A new Toyota Production System was established. Its aim was to fully satisfy customer demand by linking all production activity to marketplace demand – with inventory costs minimised by having the required parts arriving at their point of use just as they are needed. Processes would be re-designed to be more flexible to allow for easy switching of products allowing the exact quantity of what is needed to be produced when it is needed. In this type of production system all waste is minimised – including not only inefficient use of raw materials, but also things like over-production, the need for re-work and unnecessary transport and long-term storage.

The result of this restructuring meant that the Toyota motor company recovered more quickly than other equivalent companies after the Second World War and by the mid -1950s the company had become the leading car manufacturer in Japan.

When the global oil crisis hit the automotive industry over the early 1970s and into the 1980s Toyota proved to have much more resilience than equivalent American car producers. General Motors recognised Toyota as a growing player in the global car manufacturing industry and approaches were made for the setting up of a joint venture to make small cars in the USA. Joint production started in California in 1984. Despite some initial resistance, the Toyota Production System was successfully integrated, and was largely responsible for the new manufacturing plant becoming the highest ranked in USA for quality. The plant then stood as a clear indicator of the mutual benefits to be gained from well-planned industrial collaboration between Japan and USA.

As car manufacturing moved into the 21st century industrial globalisation became the norm and the successful implementation of the TPS solidified Toyota's position as an industry leader with manufacture and sales expanding into over 150 countries world-wide. A management commitment to continuous improvement in every phase of products and operations has remained as the basis of this success, however the Toyota model has had to adapt and evolve to suit what has become a constantly changing global operating environment. Rapid developments in new technology have opened up possibilities for both new product and process design. However, the competitive nature of the operating environment has increased the pressure on management to invest selectively and wisely in order to maintain competitive levels of productivity.

[3] In Australia, Toyota rationalised its car manufacture with production being centralised at the Altona plant in Melbourne to produce expected productivity benefits. Among the models produced at the factory was the environmental friendly Camry Hybrid – a model developed to address world-wide customer demands for increased fuel efficiency and reduced harmful environmental emissions. Engines for this new model and other Camry models had been initially imported for final car assembly. In 2012 a new 'Powertrain' plant was commissioned by Toyota with financial support from the Australian government. This would allow not only the manufacture of these Camry engines for Australian consumption, but created opportunity for export of the engines to other car manufacturing plants in South East Asia. The plant went into full production in early 2013 producing approximately 450 engines per day.

However in February 2014 Toyota made the surprise announcement that it will stop building cars in Australia by the end of 2017 and revert to a national sales and distribution company. This means that local manufacturing of the Camry, Camry Hybrid and Aurion vehicles, as well as the production of four-cylinder engines, will cease by the end of 2017.The company emphasised that the decision that it is no longer viable to continue building cars in Australia was not based on any single factor. Market and economic factors contributing to the decision include the impact of an unfavourable Australian dollar that restricts the viability of exporting, high costs of manufacturing and low economies of scale for the vehicle production and local supplier base.

	Grade Boundary: High Merit
2.	For Merit, the student needs to demonstrate in-depth understanding of advanced concepts used in manufacturing. This involves explaining how quality management techniques have impacted on a manufacturing process. This student focusses on the car manufacturing industry, and in particular the paint shop area to explain the impacts of new technologies and techniques on processes (1). For example, they explain quality and environmental safety improvements as a result of developments in dip primers and electro-deposition (2). The ‘clean room’ innovation (3) and the use of robots (4), and how these quality management techniques have impacted on the car manufacturing process, is explained. The student also explains how the influences of drivers related to water wastage (5) and recycling paint residue (6) have led to the development of quality management techniques that have positively impacted on the car manufacturing process. The importance of both active and passive safety design innovation, and how this has impacted on the car manufacturing process, is also explained (7). To reach Excellence, the student could show more evidence of discussing why these quality management techniques have been important in changing manufacturing techniques.

Student 2: High Merit

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[1] Improved productivity, control of harmful emissions, waste elimination and better utilisation of available resources have been flow-on effects from the introduction of more flexible equipment and process design. The constant drive to increase productivity and reduce costs has led to speedy adoption of proven new technology, with the move towards lowering the numbers of people required through increased automation particularly evident in critical areas like the paint shop.

The efficient painting of the car bodies has traditionally been a major cost factor in the automotive production process and so the paint shop has been an obvious focus for investment in new technologies and techniques to improve process efficiency and product quality to produce a significant overall increase in productivity.

[2] Recent developments such as the movement from solvent-borne to water-borne dip primers and from anodic to cathodic electro-deposition have improved both the corrosion protection of the metal car body and environmental safety in the plant through reduced emission levels.

[3] Picking up on the 'clean room' concept has become an important part of the paint shop structure. This innovation produces a more stable application environment which means that painting defects arising out of dirt and dust particles carried in by people and residues stuck to the car bodies from previous procedures can be considerably reduced. However, to achieve a real 'clean room' condition the direct entry of outside air has to be prevented. To do this the area next to the spray booths is totally enclosed, with separate ventilation and air filters cleaning very fine dust particles from the metal car or truck body before it moves to the spray booth. An air lock is used to provide monitored access for workers who are required to wear special lint free clothing made of asbestos-resistant fibres. Automatic control systems for heating, cooling and air conditioning are incorporated in the air supply line. A control room monitoring system graphically displays all of the critical operating parameters and makes sure that they stay aligned with the programmed optimum levels.

[4] Robots are used extensively in the paint shop in modern automobile plants. This is because of their ability to maintain the spray gun application at the constant optimum required speed and angle to the body surface to make sure that a uniform coating of paint is applied. Use of robots has allowed high lustre coatings accurate to a very precise +/- 5 microns to be reliably applied – and this application can be accurately maintained over long periods of time.

[5] Achieving the high quality of paint finish required to meet customer requirements means that large volumes of high quality demineralised water are needed. Supplying this water needs expensive ion exchange equipment. However, on the plus side, improved system design has led to previously high levels of water wastage being reduced, with some manufacturers claiming a reduction from the industry average of 900 litres per body to as little as 200 litres per completed painted body.

[6] After the electro-deposition coating, each of the cars gets three coats of paint – a primer, a colour and a clear coat. Through its movement to convert to the use of water-borne electro-deposition paints Toyota has developed new processes for recycling paint residues from the washings from the walls and floors. During the spraying process a high percentage of the paint coming out of the spray gun inevitably ends up as overspray and if it can't be recovered, this paint ends up as expensive wastage. At the Toyota plant the paint now recovered can be mixed with new paint to create an almost waste-free painting process.

[7]….Throughout the rapid global adoption of automotive technology vehicle collisions have consistently been one of the highest causes of human deaths from accident - with two thirds of those killed being pedestrians. Personal safety has therefore been a major consideration of car and truck manufacturers since the early days of motor transport. In terms of ongoing vehicle design both active and passive safety innovations are significant customer considerations.

Well established active safety design features such as mirrors, headlights and electronic signalling were introduced to assist with crash prevention. Passive safety features such as safety belts and air bags are design elements introduced to help to protect the occupants in the event of a crash. As research results have shown new active and passive design features to be effective in saving lives they have been progressively standardised by increasingly internationalised legislation.

Safety innovation has now become a key marketing feature and new crash avoidance systems like infra-red night vision and adaptive cruise control, and crashworthy feature such as body crumple zones and tempered glass side widows have become standard in truck design to minimise driver injury on long trips. In the Mercedes-Benz factory many of the new features are fitted as standard to all vehicles while many others are well established optional extras that can be specified for fitting when the vehicle is ordered.

	Grade Boundary: Low Merit
3.	For Merit, the student needs to demonstrate in-depth understanding of advanced concepts used in manufacturing. This involves explaining how quality management techniques have impacted on a manufacturing process. The student explains the impacts of lean manufacturing and continuous improvement quality management techniques on satisfying individual customer needs at the Mercedes Benz truck manufacturing plant (1) and Toyota's Altona car manufacturing plant (2). The origins and impacts of the Toyota Production System (TPS) are explained. This includes explaining how the goal of creating a smooth, continuous and optimal flow of work to meet customer demand was achieved through an inventory control system (3). The student also explains how the Toyota Production System encourages workers to take an active role in quality control (4). The strategic importance of the andon cord system (as a means to notify of quality, process and safety problems on the production line) is explained (5). For a more secure Merit, the student could explain a broader range of aspects of the development work in similar detail.

Student 3: Low Merit
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[1] In the Mercedes Benz truck factory production is managed in a way that will completely satisfy individual customer needs. Successful customisation is achieved by using well established 'lean manufacturing' techniques. Lean manufacturing creates a system designed to increase the value of the outcome using production techniques that are simple to implement but which result in maximum efficiencies. The whole manufacturing process is planned around the need for full customisation of each individual truck to suit the specific requirements of the driver. The production system is structured to be flexible enough to allow a number of different truck models to be produced at the same time on the same line, with each individual set of specifications being successfully met. To do this reliably requires a very efficient part-handling system.

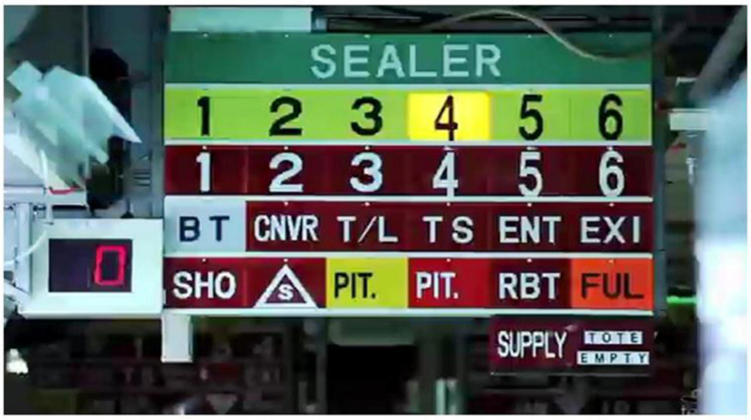
[2]…The foundation of the quality management system used by Toyota at the Altona plant in Melbourne is the empowerment of its workers to strive to continually improve the quality of the work they are doing. Quality control during production requires that the correct materials are available at each stage of the process. All materials need to be fitted with the required precision and accuracy so that the end result is a product that can fully meet the expectations of all their customers.

[3]...The post-World War 2 Toyota Production System (TPS) successfully merged the novel just-in-time concept with the well-established Toyota principles of intelligent automation and human respect. Its goal was to create a manufacturing system with a smooth, continuous and optimised flow of work – cutting out any wasteful storage of yet-to-be-used or waiting-to-be-sold materials. Customer demand was to be satisfied by linking all production activity to marketplace demand – with inventory costs minimised by having the required parts arriving at their point of use just as they are needed. Processes would be re-designed to be more flexible to allow for easy switching of products allowing the exact quantity of what is needed to be produced when it is needed. In the system all waste is minimised – including not only inefficient use of raw materials, but also things like over-production, the need for rework and unnecessary transport and long-term storage.

In the Toyota plant this system hinged on the use of Kanban cards. Fully loaded supply trucks bring in combinations of parts required for the assembly process. These parts are transported to racks alongside the appropriate assembly lines in the factory. When parts are picked up for use the worker removes the attached Kanban card. This is then returned to the delivery point for sorting and pick-up by the transport driver for delivery back to the supply company and speedy replenishment of the parts. This means that the production processes in the supplier plants only uses those parts that have been withdrawn for use. That prevents a wasteful build-up of inventories and ensures that the suppliers are effectively linked into the requirements of the Toyota plant. All processes carried out internally in the car factory itself are linked in the same way…..

[4]…From the moment workers join the company they are encouraged to take an active role in quality control by treating the next person on the production line as their customer and making sure that they never pass on a defective part or piece of work to the next stage in the process. Where opportunities are seen for improvement they are actively encouraged to discuss their ideas with other team members and to submit their idea to senior management. The best ideas can end up being adopted company wide. Workers do receive a small reward for this type of contribution to process improvement, but the main driver is being able to contribute in some way to the process of continuous improvement.

This team effort is combined with thousands of rigorous inspections of the work being done as the cars move down the production line. Individuals working on the production line have to take responsibility for the suitability of the parts they use. They must act as inspectors of their own work and that of their fellow workers. If they spot a problem the expectation is that they will do something about it.



[5] In Toyota plants word-wide a rope called the 'Andon cord' stretches the whole length of the assembly line. When a problem is spotted by a worker, this can be pulled to alert supervisors that assistance is required.

The first Andons introduced in the Toyota factories were not very complex – just simple lights that enabled operators to signal the status of the production line at that point. The lights were coloured – green for normal operation, yellow when help was required, and red when the production line was down. Today the systems used are much more sophisticated and can include using text, graphics, or audio elements. Audio alerts may be carried out using coded tones, music with different tunes corresponding to the various alerts, or pre-recorded verbal messages.

Reasons for workers to look to activate the Andon system include shortage of parts, defects found or unexpectedly created in the process, tools not working properly, or sudden safety problems. Getting some additional assistance will usually solve the problem, but if sufficiently serious, work can be stopped until a solution is found. In their modern factories new data collection technology allows each incident to be automatically logged to a database and machine-analysed as part of the plant's continuous-improvement programme.

Although technical sophistication may have improved over the years the original intent of the introduction of the Andon remains the same - to increases the accountability of production workers by providing a simple and effective method for them to communicate the current status of the production process to their supervisors. In this way the Andon cord increases the supervisors' ability to identify and resolve any potentially serious quality, down time and safety problems that occur in the manufacturing process.

<table>
<tr><td></td><td>Grade Boundary: High Achieved</td></tr>
<tr><td>4.</td><td>For Achieved, the student needs to demonstrate understanding of advanced concepts used in manufacturing.

This involves:
explaining how safety issues were addressed in a manufacturing process
identifying the impacts of new technologies and/or techniques on the suitability of different types of manufacturing systems and increased possibilities for quality control
identifying the influences of customer, social and environmental drivers on priorities within a manufacturing process.
This student demonstrates understanding of advanced concepts used in manufacturing by focussing on the impacts of the Toyota Production System (TPS) used within Toyota vehicle manufacturing facilities (1). This includes explaining the impact of time planning (2) and product flexibility (3) on the manufacturing process (4).

The explanation includes how Toyota is able to address safety issues immediately through quality checking of visible processes (5). The link between safety and quality is made clear when the student explains the international quality assurance recognition that Toyota's Altona plant has received (7).

The student specifically identifies the influences of customer, social and environmental drivers on monitoring harmful CO2 emissions (6).

The influence of new technologies and techniques on the TPS and increased possibilities for quality control through consideration of ergonomic factors and overall health and safety is identified (8).

To reach Merit, the student could explain the impact of the quality management techniques that have been described (for example, process improvement, built in quality checking) on the manufacturing process.</td></tr>
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Student 4: High Achieved

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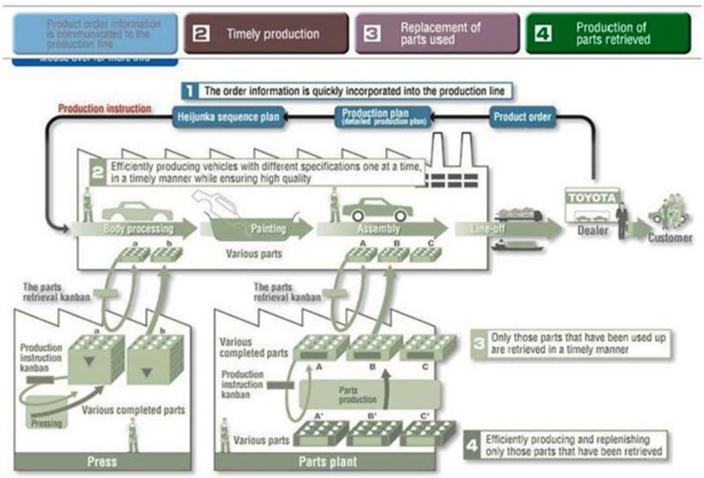

[1] Throughout the Melbourne factory, as in all Toyota facilities, the core values of 'The Toyota Way' are shared and practised by employees - at every level in their daily work and in all relations with others. This is the foundation for the over-riding company aim of continuous improvement to ensure sustainable customer satisfaction. Under this system employees are formed into teams and empowered to optimise quality by making constant improvement in the processes used and cutting out all unnecessary waste. This Toyota Production System (TPS) has established a global reputation as a proven business philosophy that delivers measurable benefits in terms of efficiency and quality in manufacturing.

[2] Time planning is a central consideration of TPS, with the optimum time for each new task initially calculated and regularly monitored. This reduces waste and inefficiency by eliminating the risk of time delays, or excess production, throughout the process.

[3] Product flexibility, with efficient, smooth workflows requires the right tools and materials at the right place at the right time. In TPS it means having just the right components to build the product. Use of kanban cards means that only a minimum stock of components is held in the assembly area. This stock control process is based on a 'pull' principle – with items called only as they are required, as opposed to a 'push' principle that may not take account of actual need.

[4] Application of TPS produces a smooth, continuous and optimised workflow, with carefully planned and measured work-cycle times and on-demand movement of goods. The costs of wasted time, materials and capacity are reduced allowing team members to concentrate on their tasks without interruption. The end result is simple - safer practice, better product quality, more timely delivery, and satisfied customers.

[5] When it comes to quality the TPS ensures that there can be no compromises. Quality checks are built into each step of the production process, and by ensuring that all processes are visible, any abnormalities are made visible and so safety and quality issues can be addressed immediately. Improvements to the production process are regularly made as a result of discovering problems. When a problem is found the emphasis is on getting a thorough understanding of the nature of the problem before attempting a solution. In this way problems do not generally re-occur.

[6] TPS is a strategy which can successfully address new company policy like the current drive to reduce environmental risk factors. Harmful CO2 emissions are carefully monitored at all stages in the life cycle of the car, and care is taken to ensure that necessary resources are used efficiently. The belief is that it is only by taking a responsible approach that real environmental benefits will be achieved – and that this respect for the environment will fit in with increasing customer-awareness of their individual responsibility towards minimising environmental impacts.

[7] Safety is not just a priority but a necessity in all of the practices that make up the TPS. The company-wide effort to consistently do things in the best possible way would never work if worker safety had to be compromised. The belief is that when processes are improved to increase quality, safety is also improved. Manufacturing sites such as Altona have achieved international quality assurance recognition through processes such as OHSAS 18001 certification for occupational health and safety management, anticipating and reducing potential risks factors and working to prevent workplace accidents.

[8] In the Australian factory, as in all other Toyota plants, ergonomic factors and the maintenance or improvement of health and safety are essential when processes are revised or when the introduction of new equipment is considered. TPS is set up to use available automation technology and ongoing process improvement to protect workers. The flexibility which it requires of team members helps them to be alert and better focused as their tasks change. Workstations are specifically designed to be easy-to-use, to make sure that people can work quickly and comfortably as well as efficiently. In making changes all team members, from management to the shop floor, participate in the required safety training and are encouraged to making suggestions for ongoing improvements.

	Grade Boundary: Low Achieved
5.	For Achieved, the student needs to demonstrate understanding of advanced concepts used in manufacturing. This involves: • explaining how safety issues were addressed in a manufacturing process • identifying the impacts of new technologies and/or techniques on the suitability of different types of manufacturing systems and increased possibilities for quality control • identifying the influences of customer, social and environmental drivers on priorities within a manufacturing process. This student explains the safety ethic underpinning vehicle manufacturing at Toyota's Altona plant (2) and their goal of no accidents within the working environment (3). The benefits seen in creating a comfortable and reflective working environment are explained (4). Impacts of new technologies and techniques on the Altona plants and increased possibilities for quality control are identified (5). These include stamping machines (6), robotic assisted processes (7) (8) (9), and technologies/techniques within the painting, engine building and the assembly systems (10-13). The need for a quality job is reinforced through quality gates (14), the andon cord system (15) and an end-point quality control check (16). The student explains the ongoing innovation to enhance driver safety, and the link to the need for a skilled work force and sound product control measures (17). Some local and international influences leading to decisions on manufacturing profitability of Australian-based car manufacturing are identified (18) (19), and the announcement of Toyota's planned closure is detailed (1) (20). For a more secure Achieved, the student could provide more examples of specific technological innovations and/or details of management procedures relating to the Toyota Production System.

Student 5: Low Achieved
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[1] The Japanese auto giant Toyota first began making cars in Australia in 1963 and at the height of production around 3000 workers were employed in the production facilities in Victoria, with many thousands of others involved in component supply and support for the local manufacture of the range of Toyota vehicles. In 1994, all vehicle manufacturing operations were moved from Port Melbourne to Altona in Western Melbourne. In 2010, and after the securing of a $35 million production subsidy from the Australian Government, Toyota started to build the engines for their new Hybrid Camry – a model also produced at the Toyota Motor plant in Thailand.
[2] At Altona there are seven separate plants involved in the car manufacturing process – press, unit, weld, paint, resin, powertrain and assembly. In the factory the efficient movement from manufacture and assembly of parts to produce fully completed vehicles is underpinned by a strong company-wide safety ethic. The health and safety of the company employees is as much a consideration as the safety of the cars produced. The interests of the customers who will be driving the car, their passengers and the impact of the cars on the wider social and physical environment is at the heart of all design and production decisions in the plant.
[3] In all the production processes at the plant, ensuring a safe reliable and skilled work environment is the starting goal. Six types of accidents which are likely to cause death and disability have been identified. These have been designated as “STOP6-type accidents” – the target is to ensure there is a working environment that produces “Zero Accidents” factory wide.
[4] The company has acknowledged that creating a comfortable working environment can reduce employee fatigue and the discomfort caused by over-exertion and constant repetition of tricky working procedures. Sickness and physical injury can also be caused by exposure to harmful substances and electrical and mechanical hazards. With the aim of allowing everyone to work smoothly and comfortably, Toyota introduced its own workload evaluation method. The ongoing creation of smarter and safer processing techniques is encouraged through ergonomic thinking and the introduction of new technology where possible. At Altona the increasing use of robotics (in areas such as welding processes) and computer-assisted working environment monitoring and control has been a feature of this ongoing assessment procedure.
[5] The factory is set up for flexible continuous manufacturing of a range of Toyota models, with the seven separate plants operate separately but in a carefully managed, integrated way.
[6] The first plant is PRESS. Here four massive stamping machines produce the 100 or so different parts required to make up the car body. Ear protection for workers is essential and because of the amount of heavy lifting involved the movement of machinery is a constant hazard.
[7] The smaller UNIT plant sits at the rear of the factory. Here about 40 robots with assistance from a ‘small army of welders’ make a range of assembly parts including struts and the rear and front suspension members. (2)
[8] RESIN is another small but vital part of the factory. It’s here that the front and rear bumper bars are made from melted granulated resin. Computer controlled industrial robots are used to speed up the painting process taking under a minute for the application of successive coats of primer, base and clear glaze. After drying a final inspection takes place to ensure that no defects have occurred.
[9] The WELD plant is sometimes referred to as ‘robot central’. In here there are almost 300 differently sized robots doing the material handling and helping to put the metal body, engine compartment, doors and luggage shelf together . These robots are programmed to safely weld the bulky metal parts with millimetre precision. They are a cost effective production tool, able to produce consistent high quality work. Sparks from the welding process can cause defects such as burrs and scratches on the metal, so not only is this a safety hazard, but it means that close inspection of each body is critical before it leaves this part of the factory to go to the paint shop.
[10] In the PAINTSHOP plant the next stage for these ‘bodies in white’, as they are known, is to get rid of the inevitable covering of oil and welding grime from the prior welding. A 200 metre pathway through a series of cleaning and pre-treatment tanks has to be followed by each car body. A phosphate treatment provides a receptive surface for the paint to bond onto. The paint bath coats all parts of the body but the joints have to be sealed for waterproofing. This sealing is carried out using an innovation suggested by one of the workers as part of the cycle of promotion of continuous improvement. Not only is the body now waterproof, the underbody is also protected from stone chips as well.
[11] The steel has been stamped, welded, cleaned, primed and the body sealed. Now it is ready for adding some colour. This part of the Paint shop has to be entered through an air lock to prevent contamination of the

atmosphere inside. Protective clothing has to be worn - to limit transfer of factory dust and human skin particles, but also to protect the workers from the harmful effects of the paint transfer. The car bodies are given four coats – the paint being applied by elecro- deposition, with a final 'clear' application. The process is highly automated with standard paint cartridges being filled according to the individual car's colour specifications and loaded into robotic sprayers. At each stage there is a close inspection of the surface to check for blemishes.

[12] POWERTRAIN is where the engines for the Camry and Hybrid Camrys are built. The plant is dominated by two huge aluminium casting units. In the first, aluminium ingots are melted and transferred to the second larger furnace which holds the 10 tonnes of molten metal at a constant 700 degrees Celcius to maintain the quality of the metal. 600kg batches of the molten metal are poured out every 30 minutes into the moulds to form the cylinder blocks and cylinder heads for the engines for the new AR Hybrid Camry engines. When completed, the newly built engines move to a 'Hot test' area where they are put through their paces. Before any of the engines leave Powertrain they have to pass an 84 point inspection.

[13] ASSEMBLY is the final plant in the Toyota factory and the biggest. Car bodies come through from Paint shop and are put on a table lifter and dropped onto the production line. The first stage of assembly is the removal of the doors to give easier access to the interior – and to prevent unnecessary damage. The process involves seven separate assembly lines where close to 13 000 separate parts have to be fitted in 237 key processes to bring the whole car together. To aid quality control critical processes are tagged for computer control to check that pre-set specifications have been met.

[14] At each stage of the process the need for a quality job is reinforced with workers taking pride and care in their work. Eight quality gates have to be passed through during the process. No quality defect is accepted and every last nut and bolt has to be right.

[15] Cars are continually moving along the seven assembly lines each with its own teams of workers. Unlike previous parts of the production process, assembly has only one lone robot - in the windscreen fitting area. Every task is sequenced to take less than 120 seconds and every problem has to be fixed quickly. If there is a problem the operator can pull on the andon chord and a light flashes on a ceiling-mounted control board showing where the problem is in the assembly line. Support can be given while the vehicle is moving through the assembly process - if it can't be fixed by the time it reaches the end position stop, only then will the line be stopped.

[16] At the end of the process the doors are then re-attached with the computer- controlled material transfer systems ensuring that it is the exact same doors removed at the start of the assembly process. The cars then move to the quality control area where each completed car is subjected to a meticulous series of tests to make absolutely sure it is fitted to its exact specifications before it can be driven out the door. Inspectors have just 120 seconds per car to check off close to 100 items. Then a check of the wheel alignment is the first in a series of all important dynamic and diagnostic tests. Every electric and driving function is closely scrutinised including the functioning of the on-board computers, with a TVEC system plugged in to carry out an 81 additional checks. When the all clear is given, a final shower of recycled water is jet-blasted onto the car to test the 2.5kg of sealant put on in the paint shop.

[17] Driver safety has always been an important customer consideration in the purchase of a new car, and continuous improvements in both passive and active safety measures have been a feature of ongoing innovation in the industry. Integrated collision avoidance systems (such as ABS braking) are becoming standard and more sophisticated systems like infrared night vision are being explored. This all increases the complexity of the manufacturing process and reinforces the need for skilled work and scrupulous product control procedures.

[18] The environmental impact of the car has also become increasingly important to potential customers and this was the focus of many of the design innovations in the new Hybrid Camry and the incorporation of the dedicated engine production facility at the Melbourne plant.

[19] Powertrain was officially opened In December 2012 making Toyota the first Australian car manufacturer to produce both petrol and hybrid engines for its locally built cars. The new 2.5 litre engine was designed to meet customer expectations by providing significant improvements in fuel efficiency and greater power than the previous 2.4 litre engine. The building of a new engine plant in Australia was seen by Toyota as being at the heart of its global manufacturing strategy and a necessary next step to ensure that local car manufacturing could maintain its presence in the always highly competitive marketplace.

[20] However, despite this massive recent financial investment, the impact of domestic factors such as high wages, low import tariffs and a strong currency together with the close proximity of other better positioned Asia-Pacific competitors has limited the ability of Australian manufacturers to profitably export cars . In February 2014 Toyota announced its decision to stop building cars in Australia and revert to sales and distribution only.

	Grade Boundary: High Not Achieved
6.	For Achieved, the student needs to demonstrate understanding of advanced concepts used in manufacturing. This involves: • explaining how safety issues were addressed in a manufacturing process • identifying the impacts of new technologies and/or techniques on the suitability of different types of manufacturing systems and increased possibilities for quality control • identifying the influences of customer, social and environmental drivers on priorities within a manufacturing process. This student reports on the production process for the Mercedes-Benz Astros semi-trailer truck at the Wörth am Rhein factory (1). New technologies and techniques for assembly processes are identified (1) (2) (3) (4) (5) (6) (7) (8) (11) (12) (13) (14) (15) (16) (17) (18) (19) (20), including those for different models being produced simultaneously on the same lines (9) (10). Influences on priorities within the manufacturing process include speedy and cost-efficient transportation (21), design changes to meet regulatory requirements to minimise the environmental impact of the trucks (15), and a focus on individualised customising of the interior of the cab (2) (18) (22) (23). Some explanation of how safety issues are addressed has been given (6) (7) (18). To reach Achieved, the student could explain in more detail how safety issues had been addressed in the design of the new model of truck and its manufacturing processes and in the driver training programme hosted by the factory's customer centre.

Student 6: High Not Achieved

NZQA Intended for teacher use only

Examining the manufacturing processes of two recent automotive models - the new Mercedes-Benz Actros semi-tractor trailer truck and the Toyota Hybrid Camry - provides many illustrations of effective implementation of management techniques designed to improve manufacturing practices.

The Actros truck is manufactured at the Daimler factory in Worth an Rein in Germany and the Hybrid Camry car at the Toyota factory in Melbourne, Australia.

[1] Both factories are set up to produce over 400 units per day so manufacturing efficiency is essential to ensure that productivity can be maintained without any drop in the quality of vehicle produced.

[2] At the Worth factory the process of delivering the finished truck to the customer begins by establishing and confirming the final needs and specific requests. Care is taken to establish how the driver will use it - will it be a truck that will be driven for long periods of time? What size of cabin will be required? Dozens of features can be altered to suit the individual needs – meaning that each truck produced is unique.

[3] From the time the order of an Actros truck is confirmed by the customer the manufacturing plant has only six weeks to order and bring together all of the required parts for that specific truck.

[4] The truck manufacture involves two main body parts – the chassis, which is the backbone of the truck, and the cab unit in which the driver sits. In the Worth factory both follow separate assembly routes. The chassis comes together following a straight path down one assembly line and the cab takes a roundabout path to the spot when the two come together for the final stages of the process. By the end of the assembly journey approximately 4000 different parts produced by around 1000 different suppliers will have come together to form the final product. In line with current 'lean manufacturing' practice about half of these parts arrive 'just in sequence' – a term which equates to the Toyota 'just-in-time' concept of parts management.

[5] The assembly process for the chassis begins with the arrival of the side members in pairs. They have been predrilled with pilot holes positioned to each truck's specific requirements. These holes act as guides for the dozens of bolts and fittings that will hold the frame together. Access to new technology allows assembly information to be written directly onto the frames with automatic laser chassis labelling - for example the length and the positioning of a particularly critical screw. In this way the worker gets easy access to all information necessary for the chassis assembly.

[6] The chassis assembly lines total 600m in length and it takes six and a half hours to move from set up to the finish. Each piece is secured in place with industrial sized bolts before being moved on to the next stage with the brakes and core wiring requiring particular safety consideration and attention to detail because of the need to install lots of tubes and wires in a very small space .

[7] With the backbone of the chassis assembled, the limbs are added with the installation of the axles, springs and drive shaft. The completed chassis moves on to the chassis turning area where it can be finally flipped 'right-side-up'. All heavy lifting is carefully controlled and carried out using specialised lifting gear to ensure worker safety.

[8] While the chassis is being hand assembled, 350 robot workers are putting the body panels for the cab together. All cabs are custom assembled with each robotic production cell able to be pre-programmed to build any style of cab in any sequence.

[9] In the factory the assembly of an entire truck is scheduled to take just six days. Keeping track of the 4000 parts that have to be ordered and delivered to the correct position on the lines and keeping track of all parts requires complex planning and computerised monitoring systems. Unlike the Toyota plant, this planning is further complicated by the fact that a number of different models are being assembled on the same lines at the same time.

[10] Mercedes-Benz used to assemble its trucks at two different plants nearby. The site of the present Worth plant was originally purchased as an engine manufacturing facility. However in its drive to improve productivity the company decided to concentrate all truck production under one roof. The ability to assemble different models on the same lines produced economies of scale from volume production proved financially beneficial but the management systems have had to respond to successfully meet the logistical challenges.

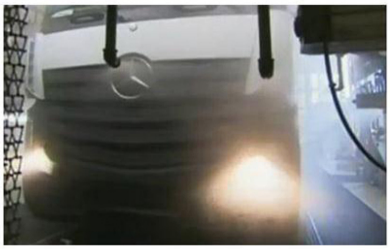
[11] In both plants the increasing use of robots has been a key component in improving productivity. Robots can work quickly and reliably - assembling an entire cab in just nine hours. At the end of the assembly process cabs are directed through a cab-testing area. At this quality control point eight cabs are pulled from the assembly line for a concentrated series of tests to check the accuracy of the robot programming. Panels, rivets and glue must all be applied with perfect precision. To verify accuracy, 400 measurements are taken around the entire cab using automated spatial measuring devices.

[12] In the factory transport of components is managed by a driverless electronic transportation system being one of the first automation construction factories in the world to use this process to streamlines production for maximum efficiency.

[13] The Actros cab shell then moves on to the paint shop for full immersion in a large electro-deposition tank followed by robot spraying with the final colour - selected from a palette of nearly 300 custom colours. Use of available automation technology means that the whole painting process can be completed in about 19 hours - including drying time.

[14] The quality of the final paint finish is critical so detailed checking then takes place. The colour shade is machine - analysed to match it to the standard specifications. Then the efficiency of the paint robots' work goes through a series of systematic checks for evenness and texture and to make sure there are no blemishes on the painted surface due to paint runs, gaps or dirt spots. All flaws are marked for immediate remedial attention.

[15] With the cab assembled and painted its ready for more components to be fitted. Doors, windscreens and interiors are attached to the cab. Then the bumpers and the dashboard follow their own path through the factory to meet up with their specified cab and the new fuel -efficient engine is finally fitted.



[16] Next the interior fitting of the cab takes place. The dashboard is installed within the two minutes allocated to the task and the cab is outfitted with glass. An array of windscreen styles can be provided and when fully assembled the robots take over to do the lifting and placing in position.

[17] After the cab seats are fitted the doors can finally be attached.

[18] The new truck design incorporates many additional safety features including LED lights which are stronger than conventional lights but more energy efficient. Electronic stability control and emergency brake assistance are standard fixtures and the radical new lane alert system caters for situations when driver attention may start to drift.

[19] With the outfitting completed the cab moves to the welding station to join up with its chassis.

[20] From there it's on to the start-up station where all the fluids are added and the lights, steering, engine and brakes are tested. Last on the quality control checklist is a roller-bed test to verify the truck's maximum speed. To check for efficient wet weather sealing of the cabin a sample of cabs are taken off the production line and soaked with water for 15 minutes. Finally all cabs move off the factory floor for storage ready for delivery.

[21] About two thirds of the trucks are shipped direct to their new owners and, with access to both the nearby river and national rail network, the manufacturing plant is ideally positioned for speedy and cost-efficient transportation.

[22] Many customers are able to pick up their new customised truck from the factory's customer centre where they can be introduced to the special features of their individual truck and take advantage of a full day driver training programme.

[23] This attention to detail and individual customisation has ensured the position of Mercedes-Benz in the forefront of the truck marketplace.