Unpacking Automotive Components Manufacturing SIC codes and activities of companies in the manufacturing, engineering and related industries sector for sectoral profiling to assess and understand industry readiness for the 4th industrial revolution

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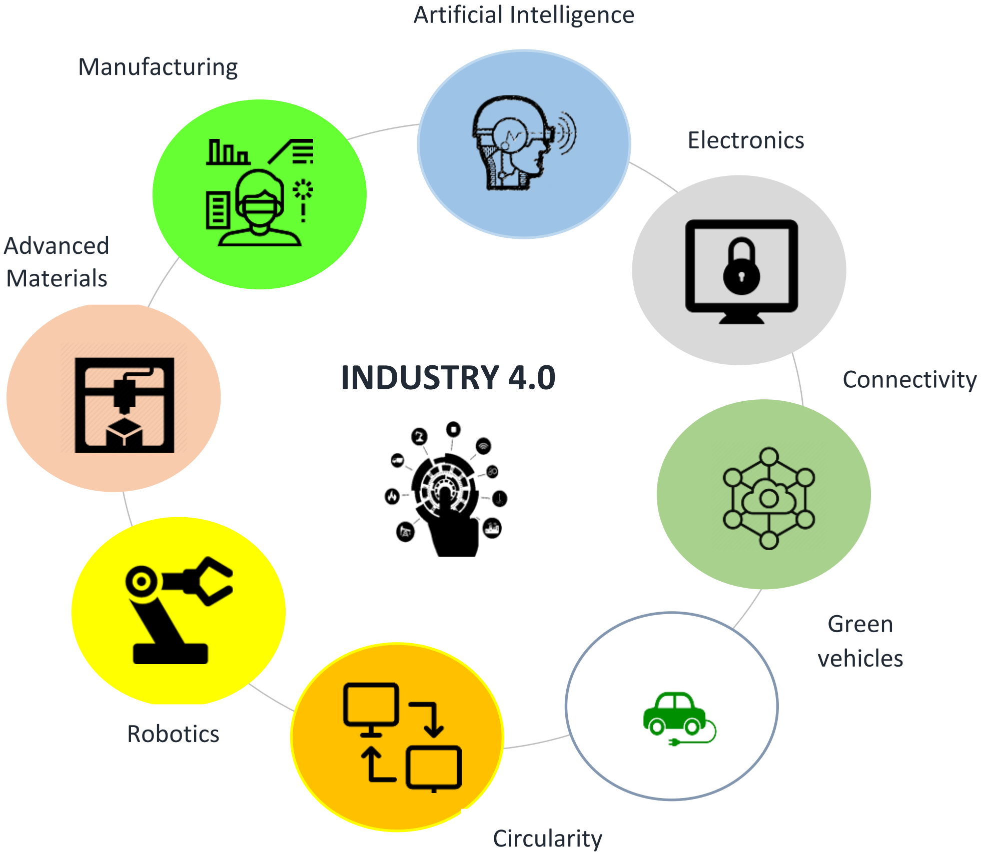
EXECUTIVE SUMMARY

Problem Statement

- Need for ACM labour market profile
- Need for correct chamber designations for firms
- Need to assess firm-level readiness for Industry 4.0
- Need to deal with Industry 3.0 skills shortages
- Need to translate Masterplan into skills development interventions

Industry 4.0 Elements



RECOMMENDATIONS

TRANSFORM MASTERPLAN INTO ACTION PLAN

Transform Masterplan skills development statements into actionable programmes adopting a value chain approach

IMPROVE THE WORKFORCE TRAINING RATE

Improve the employee training rate in the sector (number of employees trained as a proportion of the total workforce)

FOCUS ON SKILLS DEVELOPMENT

Improve graduate, making training accessible and responsive to employer demand

ADOPT FLEXIBLE TRAINING MODALITIES

Recognise and incentivise non-formal and informal learning to reskill, upskill and increase the training rate

MAKE AUTOMOTIVE ATTRACTIVE FOR TALENTED

Develop career pathways for youth and employees at all occupational levels

DIGITAL MATURITY

Assess individual firms' digital maturity level and develop a plan and capacitate the workforce

TABLE OF CONTENTS

LIST OF EXHIBITS

ABBREVIATIONS

ADAS	Advanced Driver Assistance System
AI	Artificial Intelligence
ASTM	American Society for Testing and Materials
AV	Autonomous Vehicle
BD	Big Data
CC	Cognitive Computing
CF	Carbon Fibre
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
DSRC	Dedicated Short-Range Communication
EC	Electric Car
EV	Electric Vehicle
FRP	Fibre Reinforced Plastic
GFRP	Glass Fibre Reinforced Polymer
H_2	Hydrogen
H_2O	Water
HDPE	High-Density Polyethylene
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
IIoT	Industrial Internet of Things
IoT	Internet of Things
IT	Information Technology
MV	Machine Vision
OWC	Optical Wireless Connectivity
PET	Polyethylene Terephthalate
PHEV	Plug-in Hybrid Electric Vehicle
PM	Precision Machining

R&D	Research & Development
RF	Radio Frequency
SF	Smart Factory
SAAM	South African Automotive Masterplan
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
V2X	Vehicle-to-everything

SECTION ONE: ORIENTATION

1.1 INTRODUCTION

This research study is commissioned by the recently established Automotive Components Manufacturing (ACM) Chamber of the Metal, Engineering and Related Services Sector Education and Training Authority (MERSETA). The Chamber commissioned FR Research Services to examine the Standard Industrial Classification codes (SIC) and activities of ACM companies and, secondly, to assess and understand the sector's readiness for the 4th industrial revolution from a skills development perspective. Thirdly, offer recommendations to the Chamber of priority skills development interventions.

The ACM chamber is responsible for conducting skills development research in its sector to ensure that training investments resonate with labour market demand. It is achieved by promoting skills development, identifying current and future skills needs, proposing new qualifications development, and determining priority skills development interventions. The Chamber's work ensures that skills mismatches are reduced so that employees have the requisite skills that employers need. The research findings contribute to the MERSETA Sector Skills Plan, Strategic Plan, and Annual Performance Plan.

The South African Automotive Master Plan (2021-2035) are local market optimisation, regional market development, localisation, infrastructure development, industry transformation, and industry-required technologies and skills development. Well trained and skilled employees are critical for the long-term success of a business. Human resources development remains vital to picking up any economy's manufacturing capability and competitiveness. The domestic automotive industry should enhance the development of the critical technical skills required in the manufacturing sector.

The global automotive industry's skills requirements are advancing with technology advances. It requires a fundamental shift in the number and the level of skilled personnel recruited into the local automotive sector. Global automotive competitors are developing skills in advance of industry requirements to ensure that skills bottlenecks do not stunt growth and development. The local automotive sector must follow a similar model to the government and the social partners.

Very few industries globally match the high-value skills development opportunities in the automotive sector at OEM and component manufacturing levels. The Masterplan aims to increase the domestic industry's technological content by favouring technology transfer, foreign direct investment, and cooperation with foreign universities and research centres to develop workforce skills. Appropriate workforce skills and technologies can make South Africa an early mover in the African continental automotive hub. The sector can significantly develop Black technical, professional, and management skills at an OEM and Tier 1 level through to 2035, with this benefit amplified by the projected growth in employment.[1]

1.2 PROBLEM STATEMENT

Labour Market Profile: **There is a need to develop the ACM sector's labour market profile for effective skills planning.** It is speculated that there are between 140 to 300 employers in the sector, depending on which database is sourced. These figures should be examined. An accurate labour market profile is necessary for the Chamber to engage in skills prioritisation and training spending.

Definition: **There is a need to define the ACM sector and assess whether MERSETA levy-paying employers are assigned to the correct MERSETA chamber.** ACM firms may be allocated to other MERSETA chambers, while "non-ACM" firms may be in the ACM chamber. Therefore, the SIC codes of motor retail, auto manufacturing, ACM and Tyre manufacturing firms of the MERSETA database should be examined.

Fourth Industrial Revolution**: 4IR is gaining traction in the global automotive value chain and driving firm-level competitiveness.** Motor vehicle technology advancements are immense, and its speed is expected to accelerate. 4IR dimensions such as mobile connectivity, artificial intelligence, Big Data, the Internet of Things (IoT), next-generation robotics, additive manufacturing (three-dimensional printing), blockchain and machine learning are driving innovations. These developments are impacting ACM firms, workers and customers.

There is a concern about whether the South African ACM industry is ready to embrace emerging technological innovations. 4IR can fix low productivity, job losses, rising costs, pollution and skills shortages. Firms must embrace new technology to be part of the global automotive value chain. The local ACM sector's success depends on its readiness to adopt new applications, processes and products. The sector is experiencing challenges with rising fuel prices, operating costs, diminishing localisation, energy shortages, and weak domestic market demand.

Skills Development Challenges: **The challenges discussed in the South African Automotive Master Plan (SAAMP) have implications for skills development and 4IR readiness.** These include increasing the local content of assembled vehicles from <40% to >60%; doubling employment in the automotive value chain; improving manufacturing competitiveness; deepening value addition; and identifying value chain opportunities. One of the plan's focus areas is to increase (the NEV roadmap) and associated skills development (focusing on future industry needs and priority skills). Developments in

[1] Department of Trade & Industry (2018) *South Africa's automotive industry masterplan to 2035*, 18 December. DTI: Pretoria.

safety technologies, material composites, environmental sustainability, infotainment technologies, nanotechnology, additive manufacturing, and product recycling are likely to feature prominently.[2]

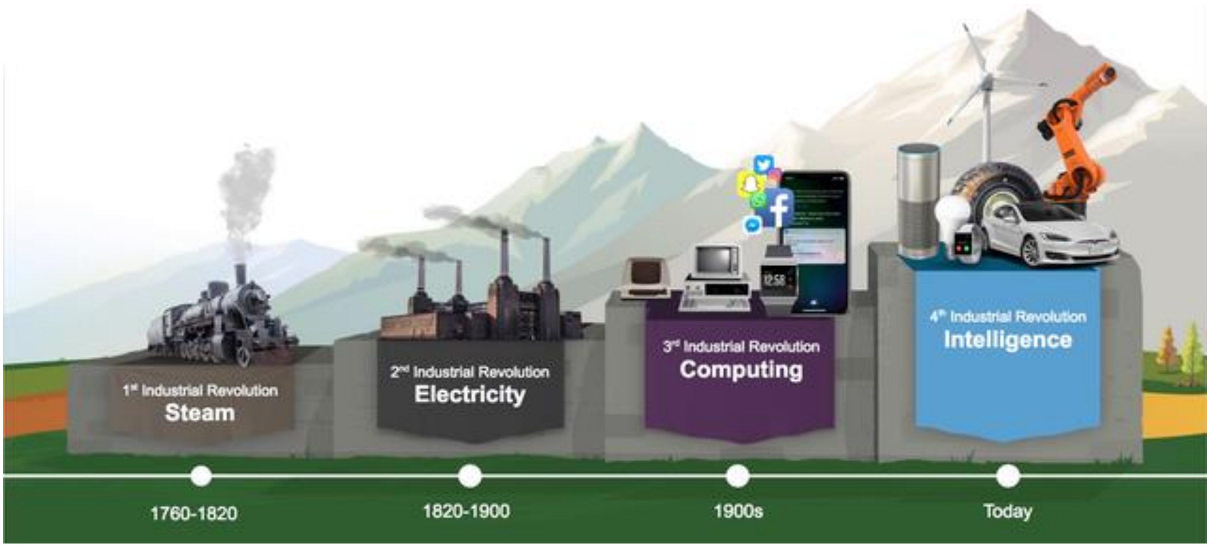
Industry 3.0 Challenges: The automotive sector has Industry 3.0 skills development challenges. Interviewees expressed concern about lacking basic literacy, numeracy, production and artisan skills. The research shows that the training rate (the number of workers trained in the total workforce) is very low. Graduation rates from NQF qualifications are also very low. Previous studies show that skills gaps exist at all occupational levels. Therefore, the challenge is not only about preparing workers for Industry 4.0 but also for Industry 3.0.

1.3 FOURTH INDUSTRIAL REVOLUTION CONUNDRUM

The subject of 4IR is controversial. The study aims *"to understand industry readiness for the fourth industrial revolution (4IR)"*. The term "revolution" means fundamental. However, 4IR builds on technologies that have evolved from previous "revolutions" over decades. Only when these technologies merge, they are labelled as new "technologies". Therefore, the Fourth Industrial Revolution is an evolving process of making innovations. For example, autonomous guided vehicles have been used in open-pit mining for decades.

A study of the First, Second and Third Industrial Revolutions demonstrates that it encompasses a complex, mutually generative range of economic, social and political transformations.

Exhibit 1: Industrial revolution



[2] Department of Trade & Industry (2018) *South Africa's automotive industry masterplan to 2035*, 18 December. DTI: Pretoria.

Source: ICT Works

For example, academics initially used the internet with the first e-mail systems developed in the 1970s and the World Wide Web in the 1980s. It was only when the commercial potential of these technologies was fully realised in the 1990s that the use of the Web began to expand rapidly**. Nissan launched it battery-powered Leaf vehicle in 2010 in Japan, USA and Europe. It was a revolutionary all-electric car. There are 577 000 Leafs on the road that have travelled 9.8 billion km. It won European Car of the Year, World Car of the Year and Japanese Car of the Year in 2011/2012.** Hence, most things associated with the Fourth Industrial Revolution are improved ideas and products. [3]

It makes little sense to think of automotive manufacturing and production occurring in discrete stages.

Therefore, for this study, it is appropriate to adopt terms such as "emerging technologies", "cutting edge technologies", "advancing technologies", and "state of the art technologies". These terms take cognisance of transient changes and the fusion of earlier technologies to create new products and processes.

1.4 OBJECTIVES

The objectives of this study are to:

- Define automotive components manufacturing.
- Review the employer SIC code allocation in the motor retail, tyre, metal, plastics and ACM chambers.
- Identify technological changes occurring in the automotive sector.
- Assess the skills readiness of ACM firms and employees to adapt to 4IR.
- Identify the skills needs of ACM firms and employees.
- Recommend priority skills development interventions to the ACM Chamber.

1.5 DEFINITION

Automotive Component Manufacturing: ACM is the **production of parts used to assemble a vehicle (before market) and the vehicle's service (aftermarket)**. ACM firms manufacture and fabricate according to specific motor vehicle industry specifications for OEMs, first or second-tier manufacturers in the value chain.

[3] Unwin, T (2019) 5 Problems with 4th Industrial Revolution. https://www.ictworks.org/problems-fourth-industrial-revolution/#.YfzbOupBy5c

Standard Industrial Classification: The MERSETA ACM Chamber has **three** SIC codes:

SIC	DESCRIPTION
38200	Manufacture and repairs of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
38300	Manufacture and repair of parts and accessories for motor vehicles and their engines
38710	Manufacture and repair of motorcycles

Technically, only **SIC 38300** refers to automotive components manufacturing in the purest sense. **38710** refers to motorcycle manufacturing and repairing. **38200** refers to vehicle body work, including panel beating and spraying paint. **However**, 38710 and 38200 are allocated to the ACM Chamber.

Twenty-seven SIC Codes: Strictly speaking, the ACM's scope of industrial coverage as per the above definition will include the following **27 SIC Codes (including the three ACM SIC codes) belonging to the Tyre, Plastics and Metals and Auto Manufacturing Chambers (24 SIC codes)** since it involves manufacturing motor vehicle parts. However, the 24 SIC codes belong to the latter mentioned chambers.

The 27 SIC codes below belong to the Tyre (2); Auto (1); ACM (3); Plastics (6); Metals (15). However, by definition, they fit into automotive components manufacturing.

The 27 SIC codes are the following (ACM is shaded)

SIC	DESCRIPTION	CHAMBER
33711	Manufacture of tyres and tubes	Tyre
33790	Manufacture of other rubber products	Tyre
33801	Injection moulding	Plastics
33802	Blow moulding	Plastics
39001	Rotational moulding	Plastics
39002	Dip coating	Plastics
39003	Compression moulding	Plastics
39004	Cast moulding	Plastics
35419	Manufacture and repair of structural metal products and components	Metals
35520	Treatment and coating of metals; general mechanical engineering on a fee or contract	Metals
35521	Treating and coating of metals	Metals
35592	Manufacture of cables and wire products	Metals
35593	Manufacture of springs (all types)	Metals
35594	Manufacture of metal fasteners	Metals
35620	Manufacture of pumps, compressors, taps and valves	Metals
35630	Manufacture of bearings, gears, gearing and driving elements	Metals
35780	Manufacture and repairs (and) installation of pneumatic and hydraulic systems	Metals
37500	Manufacture and repair of optical instruments and photographic equipment	Metals
38100	Manufacture of motor vehicles	Auto

SIC	DESCRIPTION	CHAMBER
38200	Manufacture and repairs of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	ACM
38300	Manufacture and repairs parts and accessories for motor vehicles and their engines	ACM
38301	Manufacture and/or repairs of radiators	Metals
38302	Activities of specialised automotive engineering workshops working primarily for the motor trade	Metals
38309	Manufacture and repair of other motor vehicle parts and accessories	Metals
38710	Manufacture and repair of motorcycles	ACM
86015	Manufacture and repair of alarm systems	Metals
88201	Precision engineering	Metals

Database Analysis: We analysed the MERSETA database of all levy-paying firms across the six chambers.

The MERSETA database is relatively "clean". However, 7 777 unallocated firms on the database should be addressed. We identified ACM firms that are incorrectly allocated to the other five chambers. We also identified firms in the ACM Chambers that should be allocated to other chambers or SETAs.

Findings: The MERSETA data consists of the following:

Chamber	Number of Firms
Tyre	97
Plastics	110
Metals	1 322
Auto Manufacturing	59
Automotive Components Manufacturing	**298**
Motor Retail and Aftermarket	2 552
No Chamber Allocation	7 777

We analysed all firms and found the following:

ACM Chamber	Number of Firms	Examples
The total number of firms that should be in the ACM Chamber	**424**	These firms are not OEMs, Tiers 1, 2 and 3
383300 (parts manufacturing)	205	Motor cars repairs / metal parts
383200 (body repairs)	231	Spray painters / Panel beaters
383710 (motorcycles)	3	Motorcycle repair shops

The 424 firms are not in the ACM value chain. We advise that they should not incorporated into the ACM Chamber.

The following **actions are needed**:

- 83 body repair firms are currently in the Motor Retail Chamber and Not Allocated List. They should be transferred to the ACM Chamber.
- 12 of firms should be transferred out of the ACM Chamber because they belong in motor retail chamber and ETDP SETA (training providers).

Researcher's Opinion: It is **not plausible** to transfer 24 SIC codes from existing chambers to the ACM chamber because:

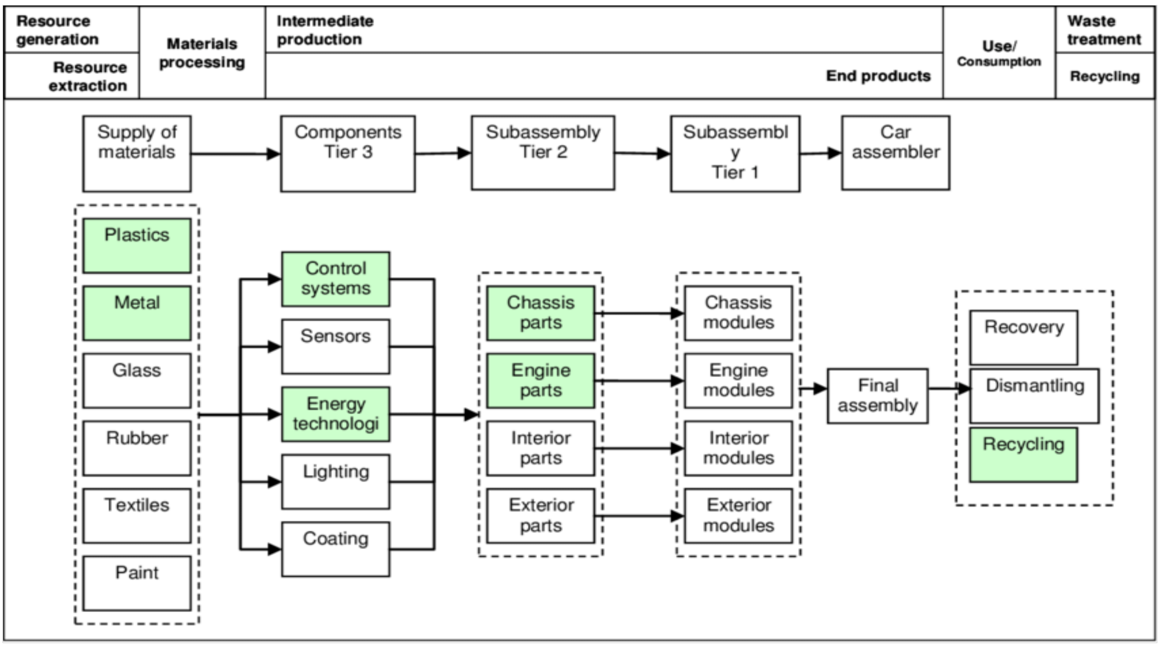
- The other chambers would not allow it (**dead-end debate**), nor is it advisable to pursue this idea.
- It will **disrupt** the MERSETA chamber, governance and staffing structures.
- The other chambers specialise in tyre assembling, plastics, metals and auto manufacturing. Therefore, they are **best placed** to drive skills development.
- The ACM firms comprise 2.4% of all MERSETA registered firms. The ACM Chamber should **not reduce** its SIC codes as it will **lessen** its revenue.

Researcher's Recommendation: We recommend that the ACM Chamber SIC code status quo remain (SIC codes 38200, 38300 and 38710). The ACM Chamber's primary goals are to upskill the workforce and improve firm-level competitiveness. The Chamber should not be distracted by technical definitions of the scope of industrial coverage or SIC codes.

1.6 VALUE CHAIN

The South African automotive value chain is the following:

Exhibit 2: Automotive value chain



OEMs: The automotive sector consists of automotive manufacturing and automotive retail functions. These sub-sectors are responsible for the manufacturing, marketing, and selling motor vehicles. In contrast, the vehicle design function is principally conducted by Original Equipment Manufacturers (OEMs), working with third-party design partners. The OEMs are headquartered off-shore but maintain a local presence to enforce strict quality standards for South African-based vehicle manufacturers. They are also involved in branding, sales and aftermarket services.

Tier 3: Component Manufacturers produce automotive components from raw materials. It includes electronics, foundry/forge, glass, harnesses, heat transfer, JIT Assembly, metal fabrication, metal form/press, plastic moulding, precision machining and trim.

Tier 2: Component Manufacturers supply parts to Tier 1 OEMs and are parts brand-specific.

Tier 1: Component Manufacturers supply parts or systems to OEMs.

Other activities in the value chain are automotive bodybuilding and trailer manufacturing, homologation and testing, maintenance and repairs, engineering and refurbishing, and ancillary services.[4]

1.7 RESEARCH METHODS

Literature Review: Industry publications sector strategies and plans, periodicals and journal articles were examined

Key Informant Interviews: Interviews were conducted with key role-players in the sector. It includes CEOs, managers, trade union officials, employer body representatives, industry experts and some ACM Chamber representatives.

Key informants are people with experience, knowledge and insights into the sector; level of involvement, influence and interest in the sector; and knowledge of ACM skills needs.

In-depth interviews using a semi-structured interview schedule were used. It allowed interviewees to express themselves freely, confidentially and without interruption. *The Interviewee List is given as Annexure A.*

Focus group discussion: A focus group discussion was convened with industry experts from Tier 1 and 2 companies to get their perspectives of technology and skills development in the sector.

[4] Ansara, D (2018) Motor Industry Skills of the Future - Research project to investigate the relevance of occupations and skills for the South African motor industry. Benchmarking and Manufacturing Analysts SA: Durban.

1.8 LAYOUT

The Report is set out as follows:

Section One	About the Sector: An Introduction to the Sector
Section Two	Sector Profile: Profile of the Sector
Section Three	Literature Review: Advancing Technologies
Section Four	Skills Development: Skills Challenges in the Sector
Section Five	Findings and Recommendations

SECTION TWO: SECTOR PROFILE

We profile the sector based on key market indicators. The data is drawn from the SAAM (2018), NACAAM (2020) and Mashilo (2019).

2.1 ECONOMIC PROFILE

Contribution (2015)

Automotive GDP contribution	7.5%
Direct Automotive Employment	112 000
Employment with Multiplier Effect	320 000

Production (2017/2020)

Global Production Share	6.8%
Global Rankings	22nd
Vehicle production (passenger/light commercial)	238 216/185 691

Automotive Components Manufacturing (2020)

Manufacturing sales	R78 million
Capital Investment	R2.43 billion
Passenger/light commercial production	238 216/185 691

Local Content Targets (2035)

Average local content	38.7%
Target employment growth	224 000
Tier 2/3 Black-owned supplier contribution	25%

Green (2020)

EEVs will be 35% of global market by 2040

Most countries will ban ICE vehicle sales by 2030

UK will outlaw petrol and diesel-powered engines by 2030

2.2 LABOUR MARKET PROFILE

EMPLOYEES	**113 000**
SMALL (1 - 49)	**1 232**
MEDIUM (50 - 149)	**2 375**
LARGE (150 +)	**20 490**

Firm Distribution

Percentages (5)	
Gauteng	**31.5**
KwaZulu-Natal	**24.5**
Eastern Cape	**24.5**
Western Cape	**11.5**
Rest	**8.0**

2.3 SWOT

A SWOT analysis of the automotive sector is given.

Strength

- The automotive industry in South Africa is the country's largest manufacturing sector.
- The mainstay of the national industrial base.
- Leading contributor to SA manufacturing output and accounts for 33.5% total manufacturing output.
- State is a strong support of the automotive sector and recognises it importance for the economy.
- The SA Automotive Masterplan 2035 provides the sector with a roadmap for the future.

Weaknesses

- SA economic growth is weak.
- Domestic market has stagnated since its vehicle consumption peak in 2006.
- Vehicle imports have surged as global vehicle assemblers have aggressively sought markets to fill their production capacity.
- Sector came to a standstill with COVID-19 pandemic.
- New car sales declined significantly in 2020 while exports of automotive products, which reached a record in 2019 and which account for over 70% of production volumes, also declined in

Opportunity

- Middle class population of SSA will grow from 137 million in 2009 to 341 million in 2030 – growth of 149%.
- At 6.3 people per vehicle in operation, South Africa is far from having a mature market (typically reached between 2.0 and 1.3 people per vehicle in operation).
- Growing South African vehicle production from 0.68% to 1% of global output would take domestic vehicle production to between 1.3 million and 1.5 million units by 2035.
- Growth potential in the African market with the African Trade Agreement
- 60% true local content in South African assembled vehicles by 2035.

Threat

- Continuing weakness in the SA economy
- Electricity shortages and rising prices
- Lack of charging stations to encourage EEV sales.
- Lack of disposal income by consumers
- Lack of investment in workforce skills development and skills gaps across all occupational levels.
- Unresolved sector demarcation disputes
- It is estimated that about 300 000 of the 12.7 million cars on the country's roads are illegally imported vehicles.
- Sector built on the back of assembling ICE powered vehicles and now finds itself in a precarious position.

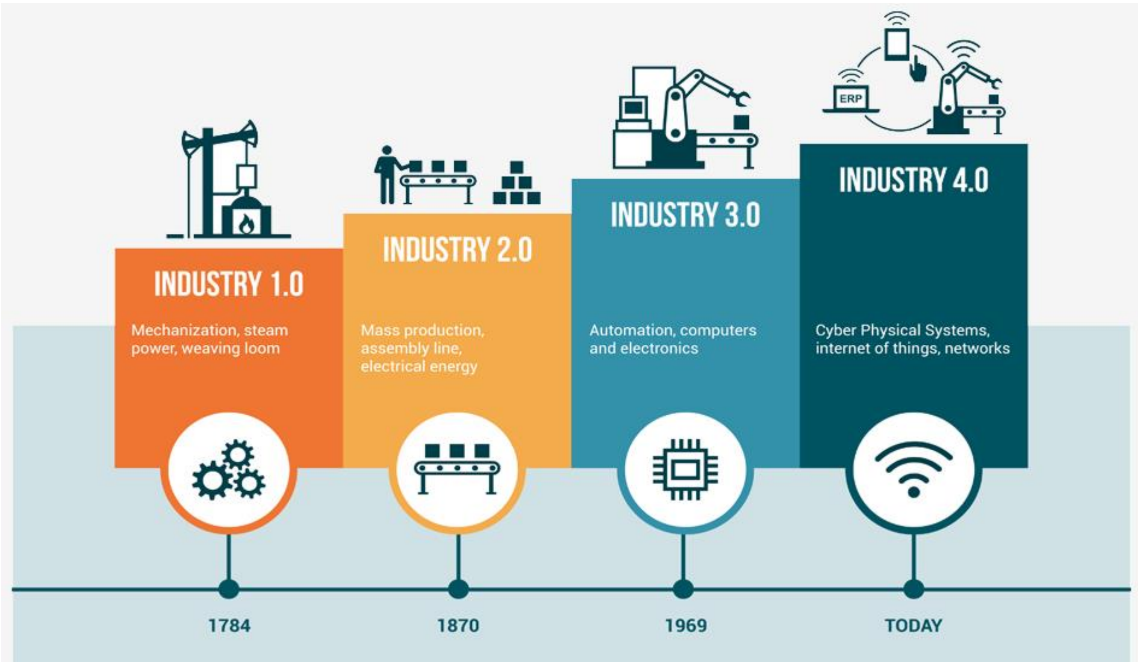
SECTION THREE: LITERATURE FINDINGS

This section discusses the major advancing technologies impacting automotive components manufacturing (ACM) and its implications for skills development. Technologies are ubiquitous. It is not possible to discuss all advancing technologies. The pace of change is so rapid that no organisation can reasonably aspire to adopt a state-of-the-art digital enterprise architecture. The "state-of-the-art" will advance when a new enterprise architecture is deployed.

3.1 INDUSTRY 4.0 MISCONCEPTIONS

There is a tendency to think of the history of manufacturing as a series of four discrete industrial revolutions, culminating in "Industry 4.0." The first industrial revolution saw the introduction of the steam engine; the second introduced wide-scale electrification; the third was computerisation and automation; the fourth was the digitalisation and integration of manufacturing technologies in enterprises and the value chain.

Exhibit 3: Industrial revolutions



Source: Unwin (2019)

However, it is a misconception to conceptualise technological advancements in discrete stages. Robots and automation have been used in manufacturing since Industry 1.0. Mechanisation is the order of the day in automotive manufacturing and assembly plants. The internet of things, simulation, Automation, machine learning, and digitalisation continue Industry 3.0. The digital technologies that gave rise to "Industry 4.0" are advancements from Industry 1.0, 2.0 and 3.0.

Therefore, we prefer to use "advancing technologies" to represent what is happening more aptly. An industry expert remarked, *"I have looked at my work plant. There is nothing significantly new from 20 years ago."*

3.2 ELEMENTS OF TECHNOLOGICAL ADVANCEMENTS

We interviewed twenty experts in the ACM sector. The following major technology advancements were identified:

No	Technology Advancements
1	Artificial Intelligence
2	Electronics
3	Connectivity
4	Automation & Robotics
5	Manufacturing Processes
6	Advanced Materials
7	Green Vehicles
8	Alternative Fuels
9	Circularity

3.3 ARTIFICIAL INTELLIGENCE

Automotive manufacturers started reinventing themselves as "digital companies" some years ago.[5] Following the trauma suffered during the COVID-19 pandemic, the need to complete the digitalisation journey is more difficult. The digitalisation of processes and operations is vital to remain competitive in a competitive market. Artificial intelligence (AI) is key to digitalisation, especially since new vehicles are manufactured with connectivity and autonomy.

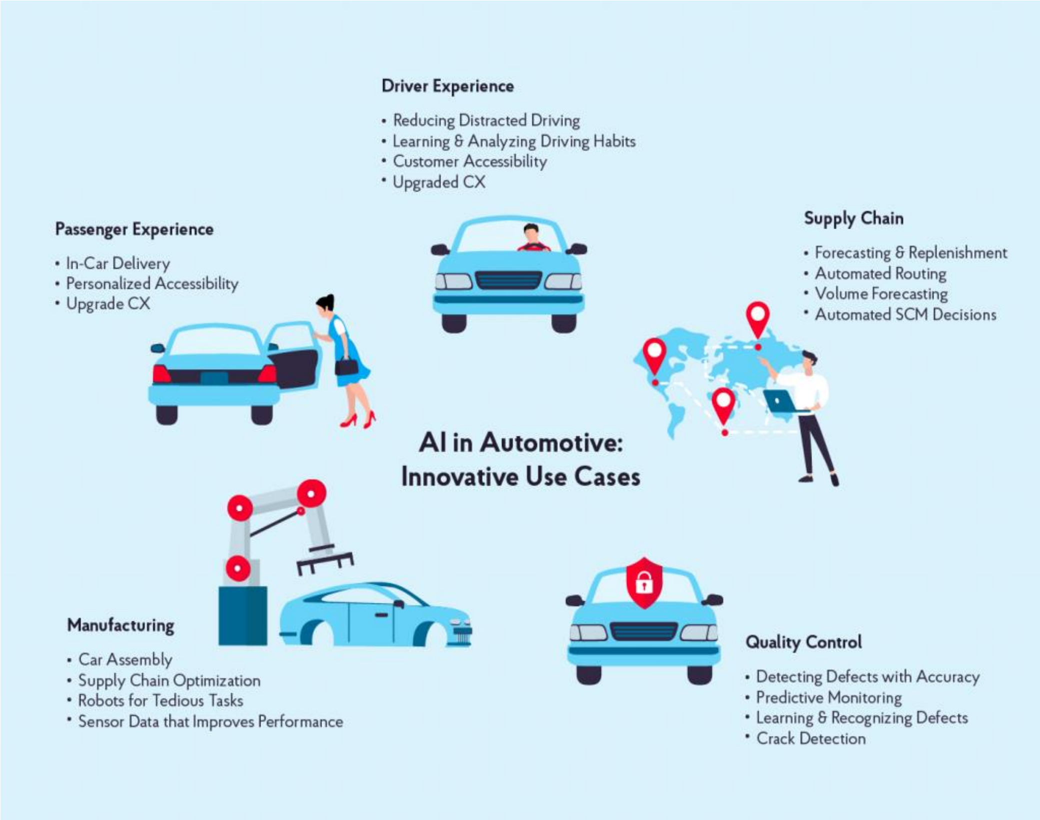
[5] Slansky, D (2021) *Manufacturing trends and technologies in the automotive manufacturing industry.* Chicago, IL: PMMI Media Group. https://www.automationworld.com/business-intelligence/article/21579012/manufacturing-trends-and-technologies-in-the-automotive-industry

3.3.1 Autonomous Cars and Artificial Intelligence

An AI system perceives its environment and takes action to "maximise its chance of success in meeting a goal." Autonomous vehicles employ various AI levels. AI systems in vehicles work in the following sequence:

i. Create and store a map of surroundings such as streets and locations using radar and laser sensors.
ii. The system processes these inputs, plots the most viable route, and relays instructions to vehicle actuators. These actuators are responsible for controlling, steering, acceleration and braking.
iii. The vehicle follows traffic rules and avoids obstacles through coded driving protocols, predictive modelling, obstacle avoidance algorithms, and smart object discrimination (i.e., the ability to differentiate between other vehicle types). [6]

Exhibit 4: Innovative AI used in automotive applications



Source: www.nix-united.com

[6] Plant Automation Technology (2022) *Top 4 automation technologies used in automotive industry.* India: Ochre Media Pvt Ltd. https://www.plantautomation-technology.com/articles/top-automation-technologies-used-in-automotive-industry

3.3.2 AI in Vehicle Manufacture

Leveraging AI-powered or "intelligent" systems, manufacturers can streamline workflows, detect car components defects, and improve quality control. AI assists original equipment manufacturers (OEMs) in decreasing manufacturing costs and predicting vehicle malfunctions while producing safer components. For example, Audi is testing AI "computer vision" to identify tiny cracks in sheet metal. [7]

With computer vision, systems obtain useful information from digital images, videos and other visual inputs. They can take action or make recommendations depending on this information.[8]

3.3.3 AI Transforms Production Operations

AI is used in ACM in several ways. Some applications are human-machine interactions, smart robots and quality assurance. Although robots on assembly lines are not new, the sophistication of new era robotics is revolutionary. Previously, robots operated in strictly defined areas with hardly any human interactions. AI enables smart, collaborative robots (or 'cobots') to operate alongside humans in a shared space. Cobots use AI to sense and detect what is happening in their environments, including irregularities, and adapt operations. AI can be used collaboratively with human workers to identify manufacturing irregularities and issue quality assurance alerts. [9]

3.3.4 Engaging and Personalised User Experiences

AI plays a pivotal role in (advanced) driver assistance technology adopted in new vehicles. AI learns the driver's preferences (temperature and music playlists) and driving style. Vehicles AI systems navigate a journey to make it efficient and less taxing for the driver. ACM companies are partnering with software developers to optimise the internal vehicle environment.[10]

Advanced driver assistance system (ADAS) reduces vehicle accidents frequency to avert deaths and injuries. Basic safety-critical ADAS applications include:

- Pedestrian detection and avoidance

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[7] NIX United (2021) *AI in automotive: a new edge of the automotive industry*. NIX United: Florida, US. https://nix-united.com/blog/ai-in-automotive-a-new-edge-of-the-automotive-industry/

[8] IBM (ca. 2019) *What is computer vision?* United States: IBM. https://www.ibm.com/za-en/topics/computer-vision

[9] Slansky, D (2021) *Manufacturing trends and technologies in the automotive manufacturing industry.* Chicago, IL: PMMI Media Group. https://www.automationworld.com/business-intelligence/article/21579012/manufacturing-trends-and-technologies-in-the-automotive-industry

[10] Gupta, G (2022) *Use of AI in the automotive industry.* India: Times of India. https://timesofindia.indiatimes.com/blogs/voices/use-of-ai-in-the-automotive-industry/?source=app&frmapp=yes

- Lane departure warning and correction
- traffic sign recognition
- automatic emergency braking
- blind-spot detection.[11]

Exhibit 5: Mercedes-Benz EQE digital cockpit

Source: www.dailymaverick.co.za

3.3.5 Making Sense of Data using AI Interfaces

The consensus is to associate AI with autonomous vehicles. AI plays a significant role in the way cars operate. Technology is no longer confined to smartphones. OEMs will soon be able to provide access to AI software embedded in a vehicle's infotainment system (providing informative and entertaining content). These systems respond to voice commands and act as virtual personal assistants. For example, a driver or passenger with specific dietary requirements could request the nearest suitable eatery, and the system will respond. [12]

[11] Synopsys (2022) *What is ADAS?* California, US: Synopsis, Inc. https://www.synopsys.com/automotive/what-is-adas.html
[12] Neumann, T (2022) *Seven automotive connectivity trends fuelling the future*. Florida, US: Jabil Inc. https://www.jabil.com/blog/automotive-connectivity-trends-fueling-the-future.html

3.3.6 Skills Development Implications

- AI and machine learning applications require workers who are literate, numerate and possess digital and communication skills.
- Today's plant operators should be able to record and analyse data to optimise machine setting.
- A tradesman requires a "toolbox" and a "computer".
- Most components in a vehicle are sensorised for the purpose of providing data.
- AI and machine learning will change the nature of work. There are shifts towards on-demand work, outsourcing and partnering to take advantage of new technologies to allow people to work when and where they want.
- AI is used for vehicle design and maintenance. Qualifications with exposure to AI and AI-enabled devices are required to keep abreast of technology.
- There is a demand for improved quality control. The workforce requires to be skilled/upskilled in leveraging AI-powered tools and systems to apply quality control procedures.
- The automotive industry is moving to process automation and autonomous vehicles. These can only be accomplished with AI. AI is a skill requirement for the workforce.
- ACM manufacturers require new recruits to possess Mathematics and Science as a minimum requirement for employment.
- Workers in manufacturing that are not computer literate are regarded as "illiterate".

3.4 ELECTRONICS

Vehicles rely on electronics for functionality. Although vehicle electronics are not new, their applications are constantly evolving. Electronics enhance engine control (e.g. anti-lock braking systems), vehicle comfort, and safety and security (e.g. central locking systems)[13].

3.4.1 Electronics - Enhancing Safety and Comfort

Vehicle evolution is a step closer to the fully autonomous vehicle (AV) from the internal-combustion-engine (ICE) vehicle to electric vehicles (EVs). There are nearly 1.35 million road accident fatalities annually. Automakers are developing better safety systems in vehicles. The electromechanical components enhance handling and safety. These include ADAS and engine start/stop functionalities.[14]

3.4.2 Reliable Electronic Components Enhance the Driving Experience

Most new vehicles are smart. The average sedan possesses over 125 microprocessors. Microprocessors control everything from the vehicle radio to sensors that monitor tyre pressure and fuel efficiency. [15]

Sensors measure physical inputs into interpretable data for human and machine use. While most sensors are electronic, some are simpler, e.g., a glass thermometer. [16]

Examples of electronic vehicle applications: [17]

Entertainment – drivers pair smartphones to the entertainment control panel to access playlists.

Connectivity – vehicles are a component of the IoT (IoT). Drivers can now plan their routes via global positioning system (GPS) navigation systems and lock/unlock vehicles remotely.

[13] *Ibid.*

[14] Walimbe, S (2020) *Advanced electronics spark vehicle-manufacturing tech evolution*. Tennessee, US: Endeavour Business Media, LLC. https://www.electronicdesign.com/markets/automotive/article/21144314/advanced-electronics-spark-vehiclemanufacturing-tech-evolution

[15] ECS Inc. International (n.d.) *Reliable electronic components for automotive applications: smart cars, electric cars and autonomous cars.* Lenexa, KS: ECS Inc. International. https://ecsxtal.com/reliable-electronic-components-for-automotive-applications

[16] Jost, D (2019) *What is a sensor?* United States: Fierce Electronics. https://www.fierceelectronics.com/sensors/what-a-sensor

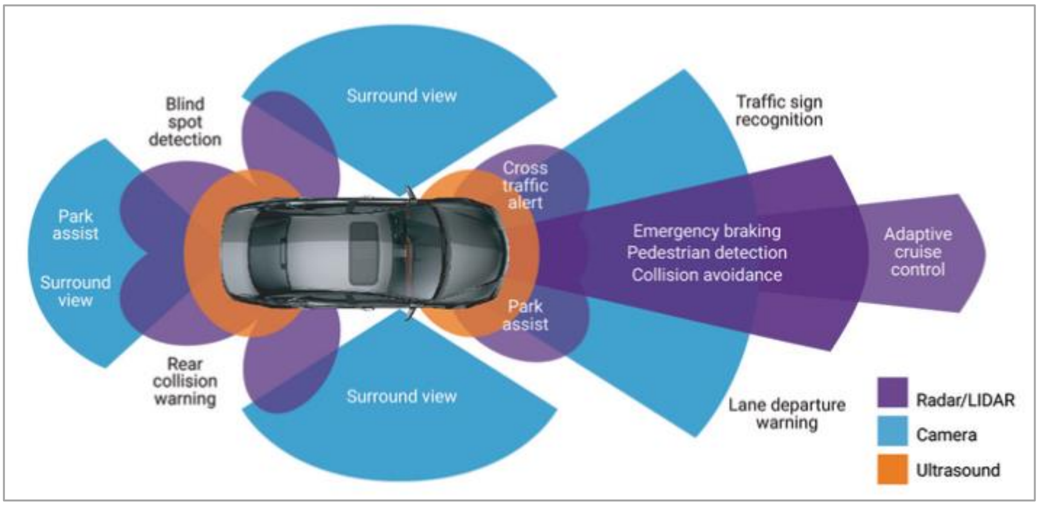
[17] ECS Inc. International (n.d.) *Reliable electronic components for automotive applications: smart cars, electric cars and autonomous cars.* Lenexa, KS: ECS Inc. International. https://ecsxtal.com/reliable-electronic-components-for-automotive-applications

Autonomous Hands-Free Driving Technology – this emerging technology is one of the most innovative automotive industries. Currently, self-driving vehicles are operating in the mining industry. High-end vehicles can park autonomously.

3.4.3 Lidar, Radar, Ultrasonic Sensors and Cameras

Vehicle automation and sensing methods (lidar, radar and cameras) are used in vehicle design. A description of each type follows:

Exhibit 6: Applications of electronics in autonomous vehicles

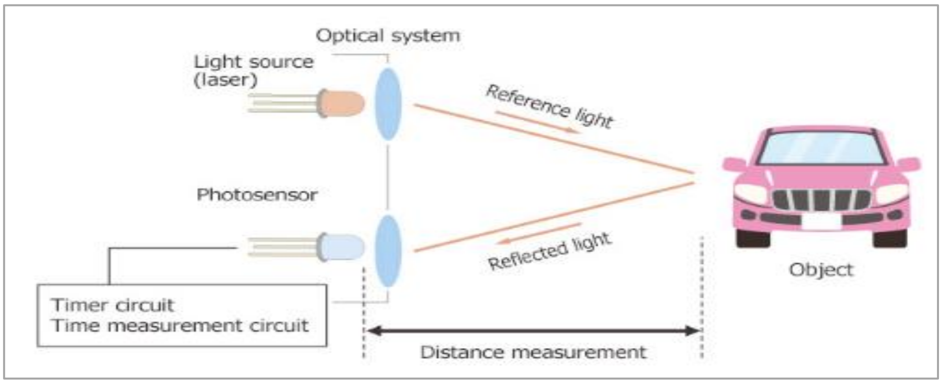


Source: www.synopsys.com

Lidar (light detection and ranging) is a remote sensing method used to measure variable distances with pulsed laser light.[18] The time it takes for the pulsed light emitted from a laser diode until it reaches the system's receiver is measured and used in distance calculations.[19] Lidar systems enable autonomous vehicles to detect other vehicles and obstacles.[20]

[18] National Ocean Service (2021) *What is lidar?* United States: NOAA. https://oceanservice.noaa.gov/facts/lidar.html
[19] Vargas, J., Alsweiss, S., Toker, O., Razdan R. & Santos, J (2021) An Overview of Autonomous Vehicles Sensors and Their Vulnerability to Weather Conditions. *Sensors 2021*, 21, 5397. https://doi.org/10.3390/ s21165397
[20] di Paolo Emilio, M (2021) *The future of automotive: electronics and EVs.* Germany: Aspencore Media GmbH. https://www.eetimes.eu/the-future-of-automotive-electronics-and-evs/

Exhibit 7: How does lidar work?



Source: www.microcontrollertips.com

Radar – This method uses radio waves instead of light. Hardware in a radar system constitutes a transmitter and a receiver. Data is collected from the scanned environment and is transformed by software to build 3D images.[21]

Cameras – AVs use cameras to view their surroundings. Cameras are favoured for feasibility, ability to portray colours and high picture resolution. They enable a 3D representation of the vehicle's surroundings. Their depth accuracies are lower than that of radar and lidar.[22]

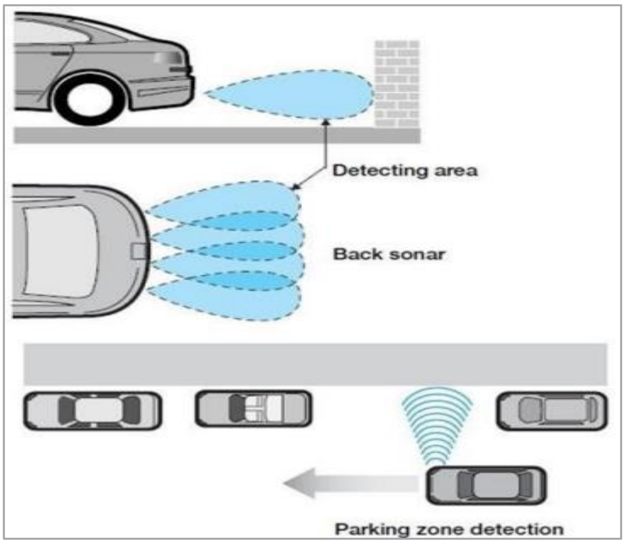
Ultrasonic sensors – Sensors transmit high-frequency sound waves to determine the distance between objects nearby. These waves imitate echolocation used by bats. The sensors relay accurate information, even in poor visibility. They complement to radar and lidar sensors.[23]

[21] di Paolo Emilio, M (2021) *The future of automotive: electronics and EVs.* Germany: Aspencore Media GmbH. https://www.eetimes.eu/the-future-of-automotive-electronics-and-evs/

[22] Vargas, J., Alsweiss, S., Toker, O., Razdan R. & Santos, J (2021) An Overview of Autonomous Vehicles Sensors and Their Vulnerability to Weather Conditions. *Sensors 2021*, 21, 5397. https://doi.org/10.3390/ s21165397

[23] Joseph Asiag, J (2021) *How ultrasonic sensor data is powering automotive IoT.* Israel: Otonomo. https://otonomo.io/blog/ultrasonic-data-automotive-iot/

Exhibit 8: How ultra sound works



Source: Vargas et al. (2021)

3.4.4 Skills Development Implications

- Knowledge of electronics is a requirement on the plant floor. Electronics are responsible for automated machinery and autonomous vehicles.
- Microprocessors and sensors are abundant in new age vehicles. Workers should be skilled to work with electronic gadgets.
- Knowledge of lidar, radar and ultrasound systems is a requirement.
- There is a digital and technical skills gap according to the High Gear Quarterly survey (NAACAM, Q1 2021). Technical and digital skills are needed to work with electronic components.
- More attention should be given to electronics in the school and post-school curricula to prepare a future workforce.

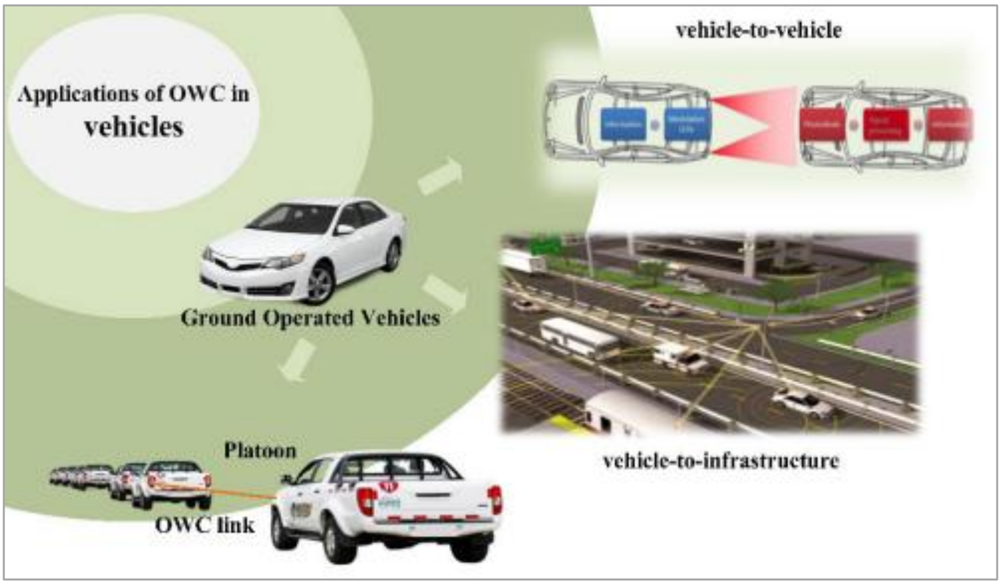
3.5 CONNECTIVITY

Connectivity is central to technological advancements. It includes remaining connected inside and outside the vehicle. Vehicles communicate and share information with other devices. Vehicles enable drivers and passengers to connect with others and network infrastructure.

3.5.1 Optical Wireless Connectivity

Optical Wireless Connectivity (OWC) enables wireless connectivity using infrared, visible or ultraviolet bands (within the light spectrum).[24]

Exhibit 9: Applications of OWC in vehicles



Source: Mei *et al.* (2020)

Conventional radiofrequency RF wireless networks for in-vehicle use include well-known Wi-Fi and cellular vehicle networks. However, RF technology has limited wireless bandwidth, high costs and spectrum resource shortages. There is a need for highly-reliable, affordable and low-latency wireless communication. OWC has emerged as a viable complementary communication technology.[25]

[24] Uysal, M. & Nouri, H (2014, July 6-10) *Optical wireless communications — an emerging technology* [Paper presentation]. 2014 16th International Conference on Transparent Optical Networks (ICTON), Graz, Austria. https://doi.org/10.1109/ICTON.2014.6876267
[25] Yamazato, T. & Haruyama, S. (2014*)* Image sensor based visible light communication and its application to pose, position, and range estimations. *IEICE Trans. Commun.*, E97.B(9), 1759–1765. cited by Uysal & Nouri (2014).

3.5.2 Types of Vehicle Connectivity

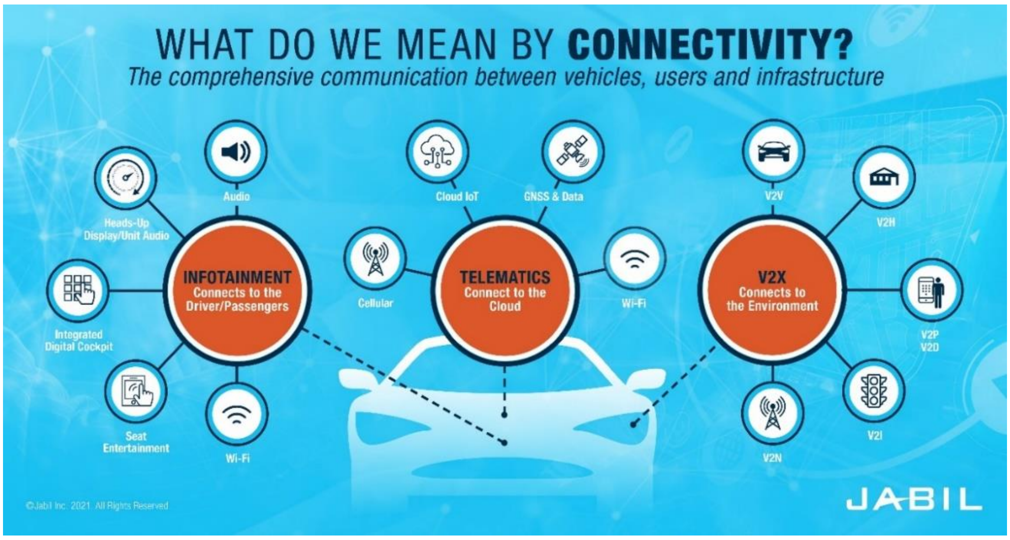
Vehicles can connect with their surroundings through:

Vehicle-to-everything (V2X) – it facilitates communication between vehicles and other vehicles (V2V), infrastructure on the road (V2I), cellular networks (V2N), pedestrians (V2P), other wireless devices (V2D) and the cloud, among others. [26]

Vehicle-to-infrastructure (V2I) allows several vehicles to share information with various devices supporting a country's highway system. These devices are included, e.g., cameras, streetlights, and lane makers. [27]

Vehicle-to-vehicle (V2V) allows communication between vehicles on the road, sharing speed and road conditions. It can prevent accidents and aid traffic flow. [28]

Exhibit 10: What is meant by connectivity?



Source: www.jabil.com

[26] Hult, R (2021) *Connected car technologies require reimagined transportation networks*. Minnesota, US: Connector Supplier. https://connectorsupplier.com/wireless-communications-in-automotive-applications/
[27] RGBSI (2022) *What is vehicle to infrastructure V2I technology?* Troy, MI: RGBSI. https://blog.rgbsi.com/what-is-v2i-technology
[28] Neumann, T (2022) *Seven automotive connectivity trends fuelling the future*. Florida, US: Jabil Inc. https://www.jabil.com/blog/automotive-connectivity-trends-fueling-the-future.html

3.5.3 Cognitive Computing and Connected Cars[29]

Cognitive computing (CC) describes technology platforms based on AI and signal processing. They entail machine learning, human-computer interaction, dialogue and narrative generation. Some industry leaders are combining the IoT with CC. Take BMW or IBM, for example. The companies are combining these technologies to create cars that communicate. They detect and associate driving patterns with the drivers' emotional responses in all situations. For example, applying brakes to prevent collisions. [30]

3.5.4 An Introduction to Telematics

Telematics is a communication technology specifically for the automotive industry. Data transmission to and from vehicles through wireless networks and wireless and location technology convergence with in-vehicle electronics. Telematics systems utilise smartphones to connect to a vehicle. It enables access to media and banking applications. This technology, however, does not come without challenges:

- Electronics product lifecycles are considerably shorter. OEMs should speed up electronics upgrades to avoid product obsolescence.
- The telematics industry is dependent on government regulations. For instance, restrictions on geographic data create difficulties.
- The influx of consumer products is the overwhelming driver. Smartphones distract drivers.[31]

3.5.5 5G

Fifth-generation wireless communication technology (5G) enables reliable vehicle communication. It enhances vehicle safety. 5G reduces latency during data transmission and enhances reliability. It enables coordinated driving and trajectory sharing.[32]

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[29] Plant Automation Technology (2022) *Top 4 automation technologies used in automotive industry.* India: Ochre Media Pvt Ltd. https://www.plantautomation-technology.com/articles/top-automation-technologies-used-in-automotive-industry

[30] Plant Automation Technology (2022) *Top 4 automation technologies used in automotive industry.* India: Ochre Media Pvt Ltd. https://www.plantautomation-technology.com/articles/top-automation-technologies-used-in-automotive-industry

[31] *Ibid.*

[32] Heineke, K., Menard, A., Sodergren, F. & Wrulich, M (2019) *Development in the mobility technology ecosystem—how can 5G help?* New York: McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/development-in-the-mobility-technology-ecosystem-how-can-5g-help

3.5.6 6G

Sixth-generation wireless communication technology (6G) is the successor of 5G. 6G networks operate on higher frequencies than 5G networks. It has greater network capacity and far lower latency. 6G technology is anticipated to launch commercially in 2030.[33]

3.5.7 Skills Development Implications

- South Africa has low maths levels. It affects digital and technological skills capacity. More attention must be given to maths and IT skills in workplaces.
- Manufacturers require skilled workers in the mentioned wireless technologies.
- Connectivity is critical in manufacturing. Communication occurs between machinery, equipment and workers.
- New technologies are essential for more seamless operations.
- 5G and 6G is rapidly unfolding. Workers should be trained to keep up with technology.

3.6 AUTOMATION & ROBOTICS

Robots have been used for many years. However, new age robots are much more sophisticated. Robots can now work with humans, and processes are automated with AI and communication technologies.

3.6.1 Global Automation and Robotics

Businesses are automating operational processes. It saves time and money. Industrial robots automate processes and reduce the human workload. COVID-19 reduced consumer demand

[33] Kranz, G. & Christensen, G (2021)

and outputs. Growth is forecast at a compound annual growth rate of 9.3% between 2022 and 2032.[34]

3.6.2 Automation Trends

There are various trends in automation and robotics:

3D Printing – Advanced welding techniques are used to weld components. 3D Printing reduces this need. Solid components can be formed over a short period.
Robotics – Robots are used to perform tedious, risky tasks. With advanced technologies, robots work with humans as 'cobots'.
IoT – IoT is instrumental in digital transformation and data-driven process automation and optimisation. IoT-enabled digital transformation connects machines.

It is also possible to integrate real-time data with other shop floor parameters. There are several benefits of the industrial IoT:

- Better monitoring and efficiency.
- Improved performance with sensors for vehicle tracking.
- Early error prevention for reduced breakdowns.
- Optimum machine operation for reduced energy consumption. [35]

3.6.3 Machine Vision

Machine vision is driven by the demand for safer, more reliable and robust vehicles. Automotive manufacturers rely on machine vision (MV) inspection technology to meet this demand. This technology uses imaging processes such as infrared, 3D and even x-ray imaging. Smart cameras or smart sensors fitted with 'frame grabbers' are used with interfaces such as Camera Link or digital cameras connected to interfaces to record or capture surface images to be inspected. These images are analysed by specialised analysis software (for conformance or irregularities). MV assists automotive manufacturers justify product market value, saving money and strengthening competitiveness. [36]

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[34] GlobeNewswire (2022) *Global automation & robotics in automotive manufacturing market is projected to grow at a CAGR of 9.3% By 2032: Visiongain Research Inc.* United States: GlobeNewswire, Inc. https://www.globenewswire.com/news-release/2022/01/18/2368630/0/en/Global-Automation-Robotics-in-Automotive-Manufacturing-Market-is-projected-to-grow-at-a-CAGR-of-9-3-By-2032-Visiongain-Research-Inc.html
[35] Fert, Z (2021) *3 automation trends in the automotive industry*. Turkey: Thread In Motion. http://www.threadinmotion.com/blog/3-automation-trends-in-automotive-industry
[36] Plant Automation Technology (2022) *Top 4 automation technologies used in automotive industry.* India: Ochre Media Pvt Ltd. https://www.plantautomation-technology.com/articles/top-automation-technologies-used-in-automotive-industry

A-frame grabber as an image processing computer board. It captures and stores image data.[37]

Some applications of MV in the automotive industry include component tracking, barcode reading, presence/absence checking, final inspections, and dimensional gauging. [38]

Exhibit 11: Machine vision applications

Source: www.microscan.com

3.6.4 Cobots

These robots assume the production steps in strenuous processes, optimising processes and improving productivity. Cobots contain sensors and cameras to reduce injuries. These enable vehicle assembly automation. A cobot reduces speed if it comes into human contact. They can operate without any protective devices, thus saving costs.[39]

There are six main types of applications, i.e., assembly, welding, material removal and polishing, painting, quality inspection and machine tending. One robot arm can be used for all six applications by changing the end-effector.[40]

[37] Engineering360 (2022) *Frame grabbers information.* Albany, NY: GlobalSpec. https://www.globalspec.com/learnmore/video_imaging_equipment/machine_vision_inspection_equipment/frame_grabbers

[38] Microscan (2021) *Machine vision for automotive.* Renton, WA: Omron Microscan Systems, Inc. https://www.microscan.com/en-us/resources/know-your-tech/machine-vision-for-automotive

[39] KUKA (2022) *Cobots: the intelligent robot as a colleague.* Germany: KUKA AG. https://www.kuka.com/en-de/future-production/human-robot-collaboration/cobots

[40] Universal Robots (2020) *6 examples of industrial robots in the automotive industry*. Denmark: Universal Robots. https://www.universal-robots.com/blog/6-examples-of-industrial-robots-in-the-automotive-industry/

Exhibit 12: KUKA cobot at work

Source: www.kuka.com

3.6.5 Skills Development Implications

- Process automation is taking over the automotive manufacturing industry. It has great benefits such as fast-tracking production, assisting with product inspection and enhancing quality control. The workforce requires sound knowledge of automation of processes for product improvement.
- There is a skills shortage for 3D printing design. Modules should be included in engineering and IT programmes to develop skilled cadres in 3D printing.
- Machine vision is becoming an integral part of automotive manufacturing. It detects miniscule mechanical defects that go unnoticed. It is a skill required by workers in the manufacturing sector, especially in quality control.
- Cobots are increasingly on manufacturing floors. They enhance the production process and reduce human workloads.
- Employees must be skilled to work with cobots in the workplace.

3.7 MANUFACTURING PROCESSES

Automotive manufacturers deal with high-value, high-complexity products. Vehicles come with optional extras which require some alterations and reconfigurations to assembly lines and processes.[41] AI is adopted to ease manufacturing processes. It includes smart robots, human-machine interaction, and enhanced quality assurance methods.[42]

3.7.1 Big Data Analytics in Manufacturing

Big Data (BD) analytics involves seeking, retrieving, collecting and interpreting data to create the correct manufacturing conditions. The analysis of automotive component production data aids technology implementation. BD increases profits by streamlining processes and testing new component prototypes. BD analytics also enables manufacturing errors to be detected and corrected quickly.[43]

3.7.2 Smart Factories

Smart factories (SFs) are manufacturing plants that leverage digital technologies to enhance productivity, feasibility, quality and service. Although advanced analytics are used for initial decision support, the ultimate objective is for the SF to reach self-optimisation in operations. The SF constantly adapts to supply/demand variations and process deviations.

These factories depend on three critical technologies for their operation.

Connectivity – IIoT is used for data collection from sensors.

Intelligent automation – the use of advanced robotics, MV, etc.

Data analytics – the use of cloud-scale data management to implement predictive analytics. [44]

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[41] ABI Research (2018) *Smart manufacturing in automotive.* New York: Allied Business Intelligence, Inc. https://www.abiresearch.com/market-research/product/1032289-smart-manufacturing-in-automotive/

[42] Slanksy, D (2021) *Manufacturing trends and technologies in the automotive industry*. Chicago, IL: PMMI Media Group. https://www.automationworld.com/business-intelligence/article/21579012/manufacturing-trends-and-technologies-in-the-automotive-industry

[43] Knauf Industries (2021) *How to effectively use big data in automotive manufacturing?* Germany: Knauf Industries. https://knaufautomotive.com/how-to-effectively-use-big-data-in-automotive-manufacturing/

[44] Capgemini (2020) *How automotive organizations can maximize the smart factory potential*. Paris, France: Capgemini. https://www.capgemini.com/wp-content/uploads/2020/02/Report-%E2%80%93-Auto-Smart-Factories.pdf

3.7.3 Automotive Part Precision Machining

Precision machining (PM) is engineering manufacturing in parts, tools, machinery and equipment creation. It is a subtractive process that utilises software, engineering tools and process steps to modify plastics, metals and composites. It is useful in manufacturing an item that contains several small parts, ensuring they fit and function correctly.[45]

Automotive component leaders adopt Computer Numerical Control (CNC) machining to manufacture more precision automotive components quickly and accurately. CNC machines are enhanced with AI sensors and tools for self-diagnosis to prevent downtime and improve quality. [46]

3.7.4 The Pultrusion Process

It is a process technology to produce fibre reinforced plastic (FRP) composites. Pultrusion combines multiple elements that offer properties and characteristics. The aim is to enhance the efficiency of the finished product. Pultrusion is a continuous controlled process producing consistent materials and quality. [47]

Exhibit 13: Pultrusion in manufacturing

Source: www.endurocomposites.com

[45] International Manufacturing Teletrading Sources (2020) *Automobile parts require precision*. Taiwan: IMTS. https://www.imts-exhibition.com/blog/automobile-parts-require-precision.html
[46] International Manufacturing Teletrading Sources (2020) *Present and future of precision auto components.* Taiwan: IMTS. https://www.imts-exhibition.com/blog/present-and-future-of-precision-auto-components.html
[47] Enduro Composites (2021) *Pultrusion process and structural components*. Texas, US: Enduro. https://www.endurocomposites.com/about-enduro/news/frp-pultrusion-process

The pultruded product benefits include:

- They are cost-effective, low maintenance and environmentally sustainable.
- They have high strength-to-weight ratios, i.e., lower weight means greater vehicle speed, lower fuel consumption and reduced emissions.
- Heat and corrosion resistance. [48]

3.7.5 4D printing

The technology involves 3D multi-material printed part production, which reacts to external stimuli (e.g., heat and moisture) and self-transforming over time. The parts regain their original shape with the relevant stimuli. 4D printing is gaining the attention of innovative science labs, tech vendors and investors. However, 4D printing has several challenges. These include the scalability of 4D printed parts. Prototypes have been manufactured successfully, but replication on a larger scale is not achieved. There is no current standard processor software for this technology.[49]

3.7.6 Digital Twins

A digital twin (DT) is a digital representation of a physical object. Due to their real-time characteristics, DTs can simulate operational systems. It enables manufacturers to monitor systems, develop models, and edit the system. DT enables entire manufacturing processes to be planned virtually before physical infrastructure is built or installed. DT allows optimisation of each process step with the aid of sensors. These capture data throughout the system, providing feedback and allowing predictive analytics.[50]

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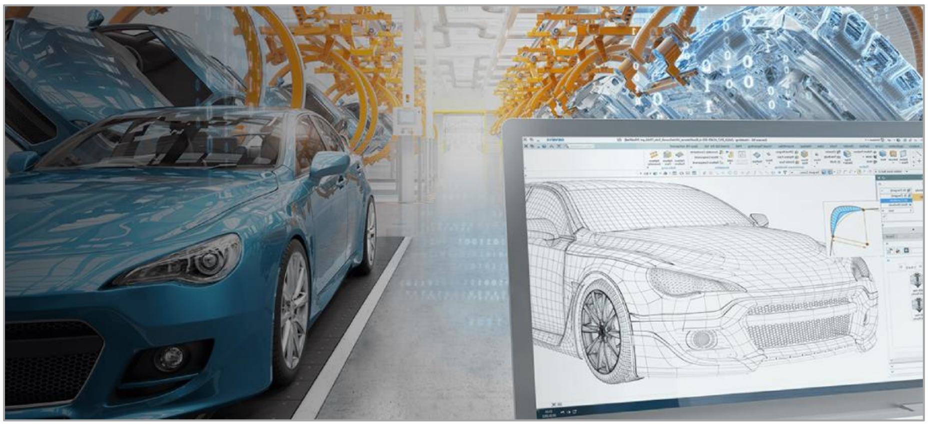
[48] Tencom Ltd. (2021) *Pultruded products drive the auto industry*. Ohio: Tencom. https://www.tencom.com/blog/pultruded-products-drive-the-auto-industry

[49] Duke, S (2019) *4D printing and the rise of smart materials.* United Kingdom: Just Auto. https://www.just-auto.com/features/4d-printing-and-the-rise-of-smart-materials/

[50] Slanksy, D (2021) *Manufacturing trends and technologies in the automotive industry*. Chicago, IL: PMMI Media Group. https://www.automationworld.com/business-intelligence/article/21579012/manufacturing-trends-and-technologies-in-the-automotive-industry

Exhibit 14: Digital twin used in the automotive industry



Source: www.challenge.org

3.7.7 Skills Development Implications

- BD analytics are a crucial part of intelligent manufacturing. There are copious amounts of data generated constantly from interconnectivity, equipment/machinery and firms. Knowledge of BD application and manipulation is necessary to enhance process and organisational control.

- Local factories are under pressure to resemble SFs to keep up with consumer demand. These factories rely on an understanding of technologies associated with electronics, connectivity and automation. Workers require skilling and upskilling in these areas to operate smart factories and smart processes.

- There is a skills gap in innovation. Firms upskill their research and development (R&D) teams to develop innovative products and experiment with new processes such as pultrusion and 4D printing.

- Digital twins benefits firms in product and system testing by saving resources and time. The technology allows projections without setting up infrastructure. ICT skills are required to apply this technology.

3.8 ADVANCED MATERIALS

The automotive industry is on the road to transformation in vehicle electrification, autonomous vehicle development, and individually-tailored products. Manufacturers' adaptability, competitiveness and success rely on innovation and technological advancements in materials engineering. [51]

3.8.1 Composite Materials

Composite materials (combined with two or more constituent materials) are used in racing cars and lower-volume, higher-end luxury vehicles. Carbon fibre is favoured. For mid-and high-volume production models, glass fibre reinforced polymers (GFRP) are used. Applications include leaf spring, body panels and frames, thermoplastic bumper frames and seat structures. The use of composites in suspension components and drive shafts is also growing. [52]

Exhibit 15: Composite suspension steering knuckle

Source: www.compositesworld.com

[51] Engineering Update (2020) *Emerging trends in automotive materials*. Oxfordshire, UK: JET Digital Media Ltd. https://engineering-update.co.uk/2020/08/05/emerging-trends-in-automotive-materials/
[52] Sloan, J (2021) *Composites end markets: automotive (2022)*. Ohio, US: Gardner Business Media, Inc. https://www.compositesworld.com/articles/composites-end-markets-automotive-2022

3.8.2 Emerging Materials Trends

New vehicles have high-strength steels, aluminium, carbon fibre (CF) composites, plastics, and natural materials (e.g., hemp). CF is the most beneficial material for car body design. However, 5 to 6 times more expensive than steel, with recycling challenges. These factors prevent market penetration. Plastics dominate car interiors for aesthetics, durability, chemical resistance, and low density. Polymer combinations are used for door panels and upholstery. More recently, car seats have become the focus for 'lightweight', discussed below. [53]

3.8.3 Light weighting

Steel in automotive is expected to decrease due to 'lightweight'. Manufacturers seek materials to reduce vehicle weight. Lightweight materials (e.g., light metal alloys) are expensive and have performance challenges. It limits market penetration. New alloys and innovative surface coatings are paving the way for more applications due to advancements in materials, technology and processes. Environmental, health, and regulatory pressures drive 'lightweight'. Consumers prefer high costs over health and environmental risks. Some materials include light metals (e.g., aluminium), composite materials (e.g., CF), and natural materials.[54]

3.8.4 Smart Materials

These are materials synthesised for deformation under certain conditions, selected due to their reactions to external stimuli (e.g., heat). They are used in 4D printing. Some examples of smart materials include magnetic shape memory alloys and temperature-responsive polymers. [55]

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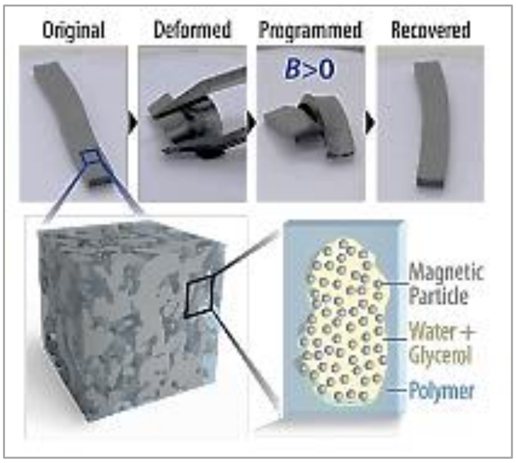
[53] Engineering Update (2020) *Emerging trends in automotive materials*. Oxfordshire, UK: JET Digital Media Ltd. https://engineering-update.co.uk/2020/08/05/emerging-trends-in-automotive-materials/

[54] Keronite (2021) *Trends in automotive materials engineering*. Haverhill, UK: Keronite. https://blog.keronite.com/trends-in-automotive-materials-engineering

[55] Haleem, A., Javaid, M., Pratap Singh, R. & Suman, R (2021) Significant roles of 4D printing using smart materials in the field of manufacturing. *Advanced Industrial and Engineering Polymer Research*, 4(4), 301-311.

Exhibit 16: Magnetic shape memory material

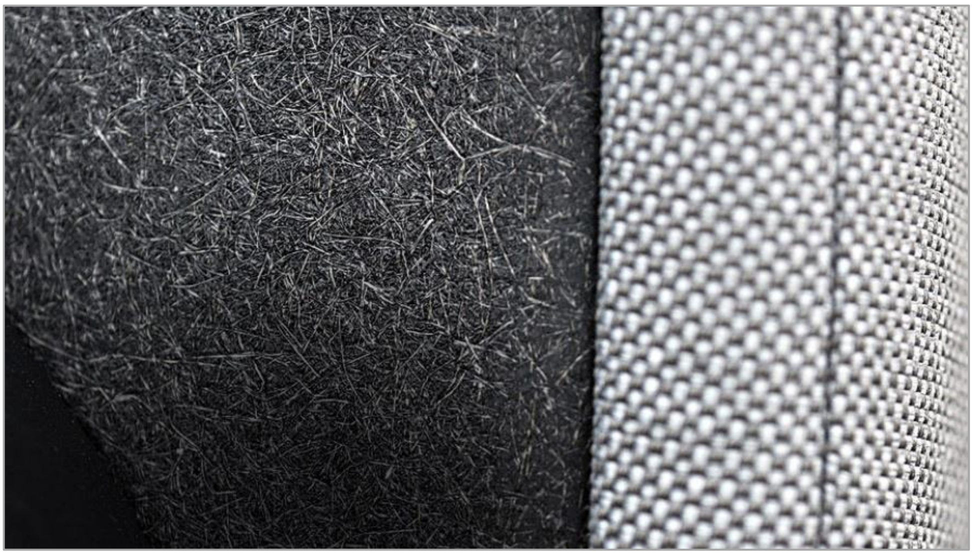


Source: mat.ethz.ch

3.8.5 Natural Fibres in Vehicle Parts

Plastics 'under the bonnet' and exterior applications are gaining popularity. Manufacturers are seeking to use natural fibres in production. For example, the BMW door panelling and instrument panel cover are made from kenaf. It is a fast-growing plant with polypropylene (PP) fibres. The fibres are thin black PP decorative film laminated to the surface. [56]

Exhibit 17: Natural fibres used in BMW i3 interior



Source: www.bmwhk.com

[56] Atkinson, K (2020) *The biggest design trends for the automotive industry 2020*. Munich: Matmatch GmbH. https://matmatch.com/resources/blog/the-biggest-design-trends-for-the-automotive-industry-2020/

3.8.6 Skills Development Implications

- There is research of enhanced materials to lower costs. The workforce requires skills in chemical and mechanical aspects of material application to leverage the most favourable materials.
- Light weighting is a challenge in the automotive industry. Firms need to find new materials and methods to construct components and cars with lower weights. Workers require the knowledge of materials and their manipulation.
- 4D printing is researched widely but there are no major breakthroughs. Investment should be made into the upskilling of R&D teams to leverage smart materials for 'printing'. Skills development can produce breakthroughs.
- Natural materials are gaining popularity in automotive interior manufacturing. The knowledge of natural materials and their sustainability is necessary for innovative products to be manufactured.

3.9 GREEN VEHICLES

There are vehicles considered to be 'green'. These include hybrid and plug-in hybrid electric vehicles, all-electric vehicles, hydrogen cars and solar cars. Green vehicles have benefits for the environment. They are capable of either zero carbon emissions or reduced emissions. This section is a discussion of each of these types.

3.9.1 Green Vehicles

Technological advancements are driving alternative powertrains. Engine efficiency improvements to reduce emissions are a focus. The improvements include:

- New coating development to reduce friction in cylinders/valves.
- Increase fuel injection pressures to obtain cleaner exhausts.

- Mild hybridisation, i.e., electric motors in vehicles that can switch off cars when they stop. [57]

3.9.2 Hydrogen Cars

The goal is to produce a new generation of less noisy cars and have harmful emissions. However, EVs need long charging times. Hydrogen could solve this problem. Hydrogen vehicles convert chemical energy into motion. Hydrogen burns directly in a hydrogen ICE vehicle (HICEV). Alternatively, it may create a reaction with oxygen in a fuel cell to produce electricity (fuel cell electric vehicle or FCEV). FCEVs are powered by electric motors with onboard power plants to facilitate hydrogen production and management. Hydrogen-powered cars have a minimal effect on the environment and emit water vapour. [58]

3.9.3 Electric Cars

Electric vehicles (EVs) are technological innovations. It is powered by an electric motor instead of the conventional petroleum engine (or ICE). It is impossible to tell the difference from the outside as they look identical to petroleum-powered cars. Yet, there are differences. The electric motor, which replaces the ICE, obtains its power from a controller. This controller, in turn, is powered by a set of rechargeable batteries. An EV car is almost silent because there is no engine.[59]

3.9.4 Types of Electric Vehicles

There are three types of electric vehicles (EVs). Hybrid vehicles require petroleum fuel for their ICEs. The EV types are depicted below. [60]

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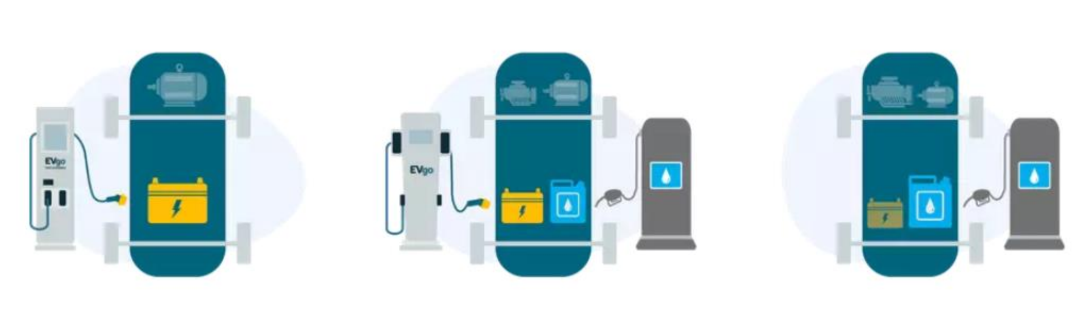
[57] Andre, F., Bollmann, O. & Neuhausen, J (2018) *Alternative fuels and powertrains: automotive strategy in a world of diverse mobility.* Germany: PwC. https://www.strategyand.pwc.com/de/en/industries/automotive/alternative-fuels-and-powertrains/alternative-fuels-and-powertrains.pdf

[58] di Paolo Emilio, M (2021) *The future of automotive: electronics and EVs.* Germany: Aspencore Media GmbH. https://www.eetimes.eu/the-future-of-automotive-electronics-and-evs/

[59] Brain, M (2021) *How electric cars work*. Georgia, US: HowStuffWorks. https://auto.howstuffworks.com/electric-car.htm

[60] EVgo (2022) *Types of electric* vehicles. Los Angeles, CA: EVgo Services LLC. https://www.evgo.com/ev-drivers/types-of-evs/#40

Exhibit 18: Electric vehicle types



Source: www.evgo.com

Battery Electric Vehicles (BEVs) are electric vehicles with rechargeable batteries. They are also called all-electric vehicles. The vehicle derives its power from its battery pack, recharged from the electricity grid. BEVs are zero-emissions vehicles.

Plug-in Hybrid Electric Vehicles (PHEVs) have ICE and an electric motor to power the car. PHEV batteries are larger than regular hybrids and plug into the electricity grid to recharge. Once its all-electric range has been depleted, a PHEV functions as a regular hybrid. PHEVs recharge their batteries through 'regenerative braking'. *Regenerative braking* is an energy recapture process. The energy spent slowing down a vehicle is harnessed when the electric motor switches into generating mode. This assists in recharging the vehicle's batteries. [61]

Hybrid Electric Vehicles (HEV) have ICE and an electric motor that power the car. The battery energy is obtained via regenerative braking. In a regular ICE, this energy is lost as heat. HEVs can travel much shorter distances than PHEVs before their ICE turns on.

[61] O'Dell, J (2021) *What is regenerative braking?* New Jersey, US: Forbes Media, LLC. https://www.forbes.com/wheels/advice/regenerative-braking/

3.9.5 The Eco-Friendliness of Green Vehicles

There are contentions regarding green vehicles – are they 'green' (i.e., eco-friendly)?

A brief discussion follows. [62]

Recharging EVs – Most EVs obtain their power by charging off the electricity grid. Electricity supply is derived from burning fossil fuels and coal or nuclear power. Each has adverse environmental effects. As the demand for green cars increases, so does electricity.

Lithium-ion battery manufacture – Another concern is the emissions produced during lithium-ion battery manufacture. These batteries are used in most EVs. Rare earth metals such as cobalt and nickel are mined and refined. High heat and sterility are required for these processes, consuming considerable energy. The fuels to produce this energy are far from "clean".

Battery recycling – Recycling is needed to alleviate the lithium-ion battery production harm. It is only viable if EVs and PHEVs dominate the market. The extraction and manipulation to recover the metals from these batteries for reuse require conventional power sources. It mitigates the intended positive effects of recycling.

3.9.6 Solar-Powered Cars

Solar cars are fitted with solar panels which allow photons (light particles) from sunlight to excite electrons. It generates an electrical current. Solar panels constitute smaller units called 'photovoltaic cells'. These cars store a portion of energy in batteries to function without sunlight (e.g., night). Solar car advantages include:

- Fuel cost savings
- Sustainability and eco-friendliness
- No excess (running) costs, except battery replacement
- Noise and air pollution

[62] CarParts.com (2022) *How eco-friendly are green cars? The main points of debate.* United States: CarParts.com, Inc. https://www.carparts.com/blog/environmental-debate-on-green-cars/

Exhibit 19: Solar panels on solar-powered cars

Source: interestingengineering.com

3.9.7 Skills Development Implications

- Automotive manufacturers and consumers are conscious of fuel emission impacts on the environment. Hence, the growing demand for alternative powertrains. The workforce requires to be skilled in technical and mechanical processes of powertrain operations.
- Hydrogen-powered vehicles are expensive. The automotive industry workforce requires skilling/upskilling in technologies that aid hydrogen vehicle production. It requires chemical and technical expertise.
- BEVs, PHEVs, and HEVs are gaining popularity. The local workforce lacks the skills to produce these cars. Workers should be skilled in EV system design and installation.
- There is solar-powered cars. Skills to work with renewable energy sources are required.

3.10 ALTERNATIVE FUELS

There are global pressures to reduce harmful emissions and conserve natural resources. It is leading to research on alternative and cleaner fuel options. Alternative fuel sources include electricity (from the electricity grid and solar power), ethanol, biodiesel, hydrogen, propane, and natural gas[63]. The price of fuel of a vehicle constitutes around 30%of ownership costs[64].

3.10.1 Legislation – A Driving Force

The French government (The Paris Agreement) aims to ban diesel cars by 2024 and petroleum by 2030. Rome plans to ban diesel cars by 2024. London is implementing fines for fossil-fuelled vehicles driven on specific streets or during peak hours. Since 2019, at least 10% of all cars manufactured in or imported to China are required to be hydrogen-powered or EVs. The Chinese government assists this process of EV registration easier. Ireland, India and Israel plan to ban new ICE cars by 2030.[65]

3.10.2 Biofuels

Ethanol and biomass-based diesel fuels manufactured using biomass materials are called 'biofuels'. They are generally blended with petroleum fuels but are suitable for use independently. Ethanol and biodiesel produce fewer emissions than petrol and regular diesel. Their differences are discussed below.

> **Ethanol** is an alcohol produced from sugars in grains, such as barley and sorghum. Research is taking place to discover whether other plant sources can produce ethanol.
>
> **Biomass-based diesel** – These fuels refer to both biodiesel and renewable diesel. They are produced for diesel engines and heating. They are manufactured by biomass or substances derived from biomass. [66]

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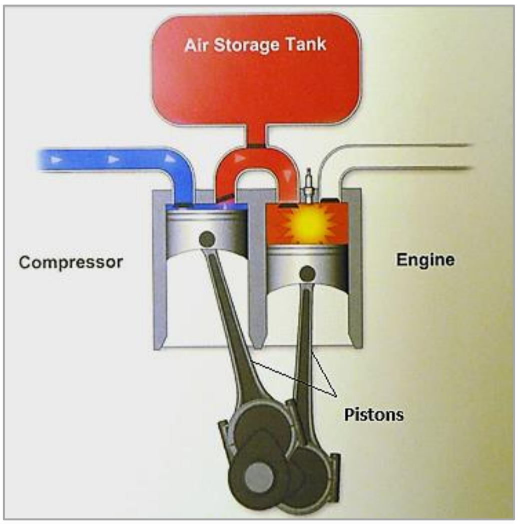
[63] Center for Advanced Automotive Technology (2021) *Alternative fuels*. United States: Macomb Community College. http://autocaat.org/Technologies/Alternative_Fuels/
[64] Andre, F., Bollmann, O. & Neuhausen, J (2018) *Alternative fuels and powertrains: automotive strategy in a world of diverse mobility.* Germany: PwC. https://www.strategyand.pwc.com/de/en/industries/automotive/alternative-fuels-and-powertrains/alternative-fuels-and-powertrains.pdf
[65] Andre, F., Bollmann, O. & Neuhausen, J (2018) *Alternative fuels and powertrains: automotive strategy in a world of diverse mobility.* Germany: PwC. https://www.strategyand.pwc.com/de/en/industries/automotive/alternative-fuels-and-powertrains/alternative-fuels-and-powertrains.pdf
[66] U.S. Energy Information Administration (2020) *Biofuels explained.* United States: USEIA. https://www.eia.gov/energyexplained/biofuels/

3.10.3 Air as an Emerging Alternative Fuel

Some vehicles can run on compressed air. As the air expands, it drives the pistons of a modified piston engine, i.e., the air is delivered via an injection system. It powers the car, producing only chilled air as exhaust emissions. During summer, this air can be utilised for cooling purposes. The technology requires further R&D. [67]

Exhibit 20: Compressed air engine



Source: contest.techbriefs.com

3.10.4 Compressed Natural Gas

Compressed natural gas (CNG) is gaining global popularity. CNG is produced by compressing natural gases. Natural gas forms in the lower layers of the earth when organic matter transforms naturally (e.g., undergoes decomposition) over millions of years. It is a preferred fossil fuel due to its eco-friendliness and affordability. CNG use is expected to increase as crude oil reserves are depleted. [68]

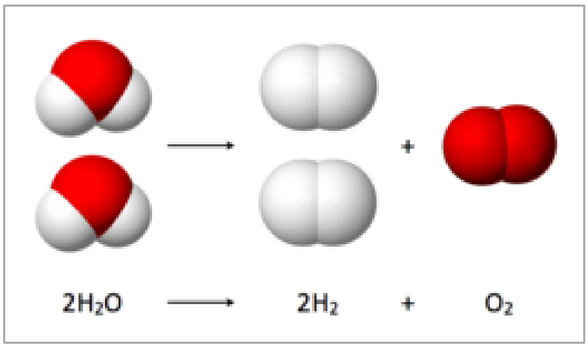
[67] The Automotive Training Centre (2022) *Emerging alternative fuels in the automotive industry*. Surrey, Canada: Automotive Training Centre. https://www.autotrainingcentre.com/blog/emerging-alternative-fuels-automotive-industry/
[68] Doğan, B. & Erol, D (2019, October 11-13) *The future of fossil and alternative fuels used in automotive industry* [Paper presentation]. IEEE 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT), Ankara, Turkey. 10.1109/ISMSIT.2019.8932925.

3.10.5 Hydrogen as an Alternative Fuel

Hydrogen-powered vehicles have a minimal effect on the environment. The challenge is to produce hydrogen. The environmental impact of its production depends on the energy source used to produce hydrogen. Despite hydrogen being a promising future fuel, renewable solutions for its production need to be found. There are two types of production, i.e., hydrogen reforming and electrolysis, discussed below.

Electrolysis - This method requires electricity to split water (H_2O) into hydrogen (H_2) and oxygen (O_2) via a chemical reaction. Though it does not emit pollutants, the process requires large amounts of energy (rendering it costly).

Exhibit 21: The production of hydrogen



Source: wikipedia.com

Hydrogen reforming entails crude oil extraction refining and requires transportation. Hence, it has a greater environmental impact.[69]

3.10.6 Propane

Renewable propane is not classified as a fossil fuel. It is derived solely from organic sources such as vegetable oils, plants and animal fats. It is shipped in gas and compressed liquid forms and is suitable for transportation. Propane is deployable at scale using existing infrastructure.[70]

[69] di Paolo Emilio, M (2021) *The future of automotive: electronics and EVs.* Germany: Aspencore Media GmbH. https://www.eetimes.eu/the-future-of-automotive-electronics-and-evs/

[70] Wishart, J (2020) *Three sustainable alternative fuels*. Washington, DC: Propane Education & Research Council. https://propane.com/environment/stories/three-sustainable-alternative-fuels/

Dimethyl Ether[71]

It is produced from organic waste, biogas and natural gas. Dimethyl ether (or DME) is both biodegradable and non-toxic. It burns clean. DME is easy to store and handle, rendering it suitable for a replacement fuel source. Legacy diesel engines require a few modifications to run on DME. A major limitation is a cost. Methanol is an intermediary product formed during DME production. Methanol is a biofuel.

3.10.7 Skills Development Implications

- More research and development is needed in alternative fuel technology.
- The automotive industry workforce requires skilling/upskilling in alternative fuels.
- Alternative fuel technology courses should be offered at universities.

3.11 CIRCULARITY

The automotive sector contributes over 10% of industrial emissions. The industry must seek life cycle decarbonisation solutions to achieve the goals set out by The Paris Agreement. Decarbonisation efforts have focused mainly on electrifying powertrains. But this is not the only solution. Emissions embedded in-vehicle materials also require attention. [72]

3.11.1 Toward a Circular Economy

We are faced with resource depletion, waste and increasing carbon dioxide emissions. There is an urgency to transition from the conventional linear economy to a circular economy. The difference is the waste output. While the linear economy follows the outdated "take, make,

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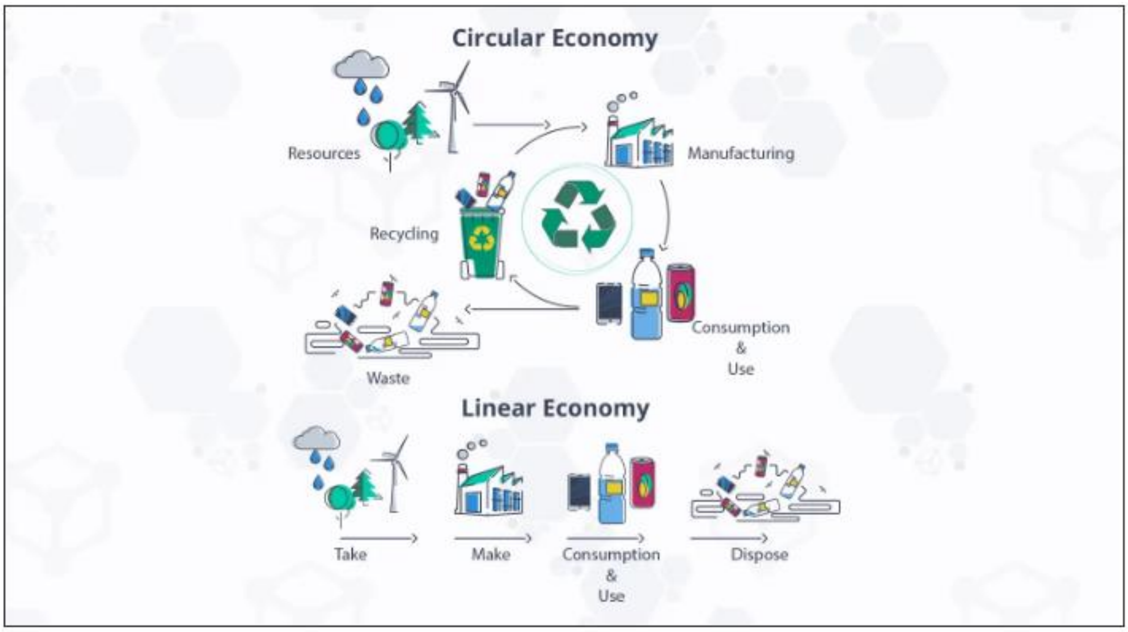
[71] Wishart, J (2020) *Three sustainable alternative fuels*. Washington, DC: Propane Education & Research Council. https://propane.com/environment/stories/three-sustainable-alternative-fuels/

[72] World Economic Forum (2022) *The circular cars initiative*. Geneva: WEF. https://www.weforum.org/projects/the-circular-cars-initiative

use and dispose of" sequence, a circular economy mitigates waste. It is achieved through reusing, reducing, recycling and remanufacturing products and materials.[73]

Exhibit 22: Circular economy vs linear economy



Source: matchmatch.com

Reusable materials include transition materials such as titanium and steel, post-transition metals such as aluminium, alkali metals such as lithium, and plastics such as polyethene terephthalate or PET. Common recyclable engineering materials include steel, aluminium, PET plastic, HDPE (high-density polyethene), and glass. [74]

3.11.2 The Paris Agreement

The Paris Agreement is a legally binding treaty that sets out long-term goals guiding nations toward addressing climate change and its adverse effects. It was developed in December 2015 by world leaders during the UN Climate Change Conference (COP21) in Paris. The European Union, along with 192 countries, have signed the Agreement.

[73] Matmatch (2022) *The complete guide to sustainable materials selection*. Munich: Matmatch GmbH. https://matmatch.com/guide/sustainable-materials-selection
[74] Matmatch (2022) *The complete guide to sustainable materials selection*. Munich: Matmatch GmbH. https://matmatch.com/guide/sustainable-materials-selection

The three main goals are:

- Significantly minimise greenhouse gas emissions to suppress the global temperature increase during this century to 2 degrees Celsius while making further efforts to limit the increase to a further 1,5 degrees Celsius.
- Review the different nations' commitments every five years.
- Provide financial aid to developing nations to minimise climate change, enhance resilience, and improve adaptability to the impacts of climate change.

3.11.3 A Circular Economy Approach in Automotives

A circular economy approach in the automotive industry will decrease the carbon emission lifecycle per passenger kilometre by up to 75% by 2030. This approach is pivotal as raw materials and resources are depleting. The increase in global demand leads to increased costs. Circularity in manufacturing begins at the design stage. Disassembly and recyclability are required in the product development cycle to apply the closed-loop (i.e., circular) approach successfully. The application of AI and machine learning aid businesses with circular production methods.[75]

3.11.4 A Circular Car

In a statement by Axel Schmidt, Accenture's senior managing director, Circular cars are said to be a key element in meeting the increasing demand for mobility. It is achieved while reducing resources and carbon emissions. While cars will never truly be entirely circular, the automotive industry requires increasing its efforts toward achieving circularity. A 'circular car' can be defined as a theoretical vehicle with maximised material efficiency and zero waste and pollution during production, use and disposal.

Joss Bleriot of the Ellen MacArthur Foundation hypothesises a "multimodal shared mobility system". It offers several modes of transportation. There would be fewer cars on the roads if they were shared as a service. Cars would be used for extended periods, having the benefits of reducing road congestion, air pollution and maintenance costs. [76]

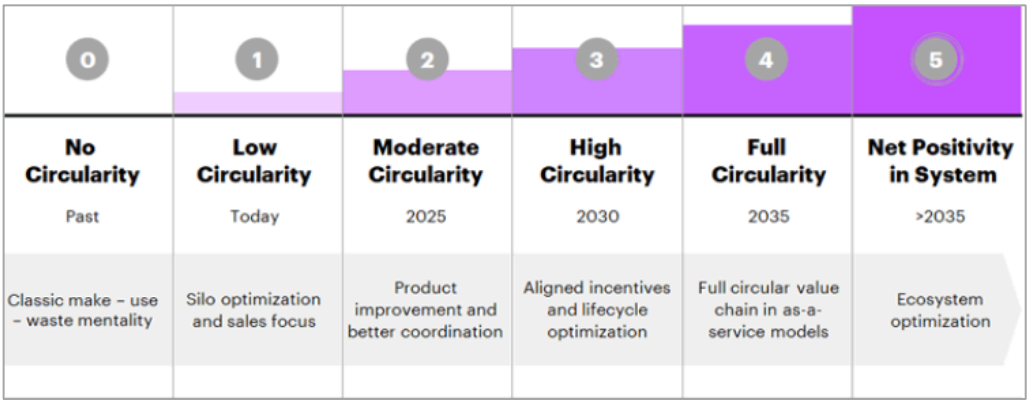
[75] Singh, P (2021) Opinion: Paving the way to a more sustainable automotive manufacturing industry through circular economy. India: ETAuto.com. https://auto.economictimes.indiatimes.com/news/industry/opinion-paving-the-way-to-a-more-sustainable-automotive-manufacturing-industry-through-circular-economy/84195355

[76] Totaro, A. I (2021) *What does it take to make a car truly circular?* California, US: Greenbiz Group Inc. https://www.greenbiz.com/article/what-does-it-take-make-car-truly-circular

3.11.5 The 5 Levels of Automotive Circularity

Manufacturers of automotive vehicles have aspirational goals to achieve carbon neutrality in 30 years. They have aligned their business strategies with electrifying their product portfolios. However, efforts over and above vehicle electrification and dispensing of the ICE are required. Businesses need to work toward leveraging more circular strategies to transform their products. It will be the second step toward achieving net-zero emissions. In cohesion with Accenture, the World Economic Forum proposes a five-level taxonomy for achieving a circular car. The taxonomy will assist with launching a transformational approach and provide a universal language required by the value chain to guide and gauge progress. [77]

Exhibit 23: A taxonomy guide- the five levels of automotive circularity



Source: Accenture

[77] Accenture (2021) *A new roadmap for the automotive circular economy.* Dublin, Ireland: Accenture. https://www.accenture.com/za-en/insights/automotive/roadmap-circular-economy

3.11.6 Skills Development Implications

- There is a need to develop skills that enable the use of resources in a sustainable way throughout the processes of automotive manufacture, use and to enable recycling/reuse.
- Skills in advanced material development and recycling materials are a necessity for the circular economy.
- Waste disposal and treatment in more eco-friendly ways also require attention for circular economy. The workforce requires reskilling and upskilling.
- Skills associated with advanced design and manufacture of 'recyclable' vehicles are needed. These skills are hinged on mechanical, chemical and technical expertise. These skills should be the focus of reskilling and upskilling.
- There are regulations and legislation for governing manufacturing/recycling processes. Compliance to regulations/legislations and incorporation of more eco-friendly processing methods are required to achieve more circularity.

SECTOR FOUR: INTERVIEW AND GROUP DISCUSSION FINDINGS

4.1 MASTERPLAN AND SKILLS DEVELOPMENT

The Masterplan recognises the importance of skills development for achieving its objectives:[78]

Enabler: An automotive sector growth enabler is incentives for asset-enabling activities for training/skills development, industrialisation (testing), R&D, and industry-specific infrastructure.

Growth Targets: Growing South African vehicle production from 0.68% to 1% of global output would take domestic vehicle production to between 1.3 million and 1.5 million units by 2035. Four key industry objectives should be achieved: local content should be substantially increased, employment (and associated skills) should be grown, industry competitiveness should be substantially advanced, and greater broad-based societal inclusion in the automotive value chain should be secured.

Employment: Improving employee skills and labour productivity should influence emerging industry business models and utilise capital intensification. It should drive increased employment in the industry.

New Technologies: The South African automotive industry's ability to achieve substantial growth by 2035 depends on its ability to attain competitiveness comparable to leading international competitors. It straddles costs, quality, delivery reliability and operational flexibility. The less obvious are process and product innovation and the development of skills capable of absorbing new industry technologies that are likely to dominate vehicle and automotive components production through to 2035 increasingly. The global automotive industry's skills requirements are advancing with technology advances. It requires a fundamental shift in the number and skills level of personnel in the industry.

Transformation: The industry's ability to contribute to the transformation of the domestic economy lies in its fiscal contributions, employment of Black South Africans, enterprise development, and the deepening of skills and technology spill-overs.

[78] Department of Trade & Industry (2018) *South Africa's automotive industry masterplan to 2035*, 18 December. DTI: Pretoria.

Skills: Due to the automotive industry's advancing skills requirements, employee education and skills development will remain a priority, ensuring that technical and advanced management skills are transferred into the South African economy.

Roadmap: The local automotive industry must develop a technology and an associated skills development roadmap to support the industry's evolution. South Africa requires an EEV technology roadmap focusing on likely changes to the domestic, regional, and international markets supplied by the local industry and the associated technology developments that will shape its future growth.

Competitors: South Africa's global automotive competitors are developing skills in advance of industry requirements to ensure that skills bottlenecks do not stunt the growth and development of their industries. The local automotive industry must partner with the government and the social partners to follow a similar model.

4.2 TECHNOLOGY, SKILLS AND EMPLOYMENT

According to Mashilo[79], there is a contradictory relationship between economic and social (labour) upgrading in the automotive assembly sector. OEM investments in automation and robotisation, lean manufacturing and restructuring of production systems have led to employment decline.

There was an average yearly reduction of approximately 1% in the assembly from 1995 to 2017. The assembly sector reduced direct assembly sector jobs through process upgrading involving an increased machine-labour ratio. It was achieved with intensified automation and robotisation and new, more efficient work and production coordination methods.

There was a 1.41% employment gain in the components sector. Increased volumes and exports drove the growth in components sector employment. The increases in output absorbed the aggregate employment increase from 60 800 in 1995 to 80 000 in 2017. The fall in components manufacturing sector employment between 2007 and 2009 in part underlines the importance of high production to employment sustenance and growth in the context of continuous process upgrading

The average worker output in the assembly sector in volume terms doubled from 10.1 CBU vehicles in 1995 to a peak of 20.4 CBU vehicles in 2014. The average increase in the assembly sector productivity was made possible by process upgrading, automation, robotics, and new production systems with lean production principles.[80]

[79] Mashilo, AM (2019) Auto production in South Africa and components manufacturing in the Gauteng province. Working paper no. 58, September, Global Labour University (ILO): Berlin. *Accessed at www.ECONOSTORE.EU*
[80] Ibid.

The OEMs increased output per worker and reduced overall employment. Increased worker output without a sufficient increase in volume to maintain existing employment levels or employ additional workers leads to workforce reduction and job losses.

4.3 SKILLS TRAINING

A Decent Work Survey was conducted by Mashilo[81] , covering 184 workers in 16 automotive components firms in the Gauteng Province. The survey found the following:

- 36.4% of workers never attended work-related training after receiving the necessary training to perform the jobs.
- 14.7% of workers attended training in the last five years.
- 7.6% of workers attended training more than five years ago.
- 41.3% of workers attended training in the last 12 months.

Workers, on average, spent eleven working days in training. Mashilo concludes that while firms were pursuing continuous improvement strategies, the same could not be said about skills training, especially training that leads to nationally recognised qualifications. Factory floor workers can enrol for a National Certificate in Automotive Components: Manufacturing and Assembly at NQF level 2 and 3. In 2015, out of a workforce of 82 100, 289 graduated at NQF Level 2 and 69 at NQF level 3. These graduate numbers are significant since 74% of the automotive components manufacturing sector is at the operator level.[82]

[81] Ibid.

[82] Ansara, D (2018) Motor Industry Skills of the Future - Research project to investigate the relevance of occupations and skills for the South African motor industry. Benchmarking and Manufacturing Analysts SA: Durban.

4.4 SKILLS MATRIX

The following skills matrix identifies current, and future skills need at different occupational levels. They have been obtained from the literature review and interviews.

Skills Needs	Manager	Professional	Supervisor	Artisan	Operator
Management and Production					
Lean manufacturing	X	X	X	X	X
Kaizen	X	X	X	X	X
Strategy	X	X			
Financial management	X	X			
Financial management for Non-Financial Managers			X	X	X
Operations / Production management	X	X	X	X	X
Leadership and team-building	X	X	X	X	X
Conflict management & negotiation	X	X	X	X	X
Communication Skills	X	X	X	X	X
Leadership and management	X	X	X	X	X
Risk management	X	X	X	X	X
Human Resources Management		X			
Visual management and communication boards	X	X	X	X	X
Computer/Digital					
Computer literacy / ICT	X	X	X	X	X
Computer Modelling		X			
Advanced computer skills (e.g. programming/system design)		X			
Artificial intelligence		X			
Data Management		X			
Data Science		X			
Digital Automation and Analytics		X			
Cloud Computing		X			
Quantitative Skills					

Skills Needs	**Manager**	**Professional**	**Supervisor**	**Artisan**	**Operator**
Advanced Mathematics		X			
Data analytics (e.g. Big Data and Machine Learning)		X			
Technical Skills					
Robotics and Automation		X	X	X	X
International quality standards, e.g. ISO14000	X	X	X	X	X
Regulatory compliance	X	X	X	X	X
Advanced process monitoring techniques		X	X		
Mechatronics		X	X		
Process control techniques		X	X	X	X
Health, Safety & Environment	X	X	X	X	X
Material Science		X			
Electronics		X	X	X	X
3D printing		X	X		
Tool Making			X	X	
Core Tools Training					X
Computer Aided Engineering		X			
Robotics		X			
Welding				X	X

4.5 INTERVIEW FINDINGS

Interviews were held with fifteen key informants for the ACM sector, including some representatives willing to participate in the interviews. These were key informants that had good insights into the dynamics of the sector. We provide a summary of the interview discussions.

Change drivers: The key change drivers in-vehicle technology are electronics, electric (EVS), alternative fuels, automatics, materials science, green, circularity and digitalisation. It will impact the production plant and workforce skills.

Skills Gap: The automotive sector requires skilled and versatile workers who can adapt to change. Although the primary skill on the production floor is manual dexterity, it is changing with automation and digitalisation. Firms want people who can interpret data, read charts and make decisions. They also want workers who can work in teams, take the initiative and handle multiple jobs. There is a growing gap between current worker skills and future worker skills.

New technologies in powertrain, joining and assembly, and electronics, coupled with faster product cadence, will drive skills changes. In skilled trades, we will see fewer classifications, more cross-skilling, and more skill needs in electrical, electronics, and software areas. A production line operator or a maintenance operator must master new digital tools and applications.

Vehicles are becoming more complex, with more and more onboard electronic systems and power electronics. There is a growing trend toward so-called mechatronic or plastronic parts, i.e. those incorporating electronics. The transition from foundry-type methods to additive manufacturing will affect the design and production professions.

Autonomous vehicles are expected to be on the road by 2030, requiring an entirely new skill set in machine learning, computer vision, sensor processing, and more to design the guiding intelligence of autonomous cars. Electric vehicles, too, will continue to have a big impact on the automotive industry.

Artisan Skills: There is a dire shortage of artisan skills in the core trades such as tool and dye-maker, millwright, fitter, turner, electrician, PLC technician and mechanic.

Data analytics: There is a need for data analytics training for employees at all levels based on their tasks. Operators and technicians should be able to navigate software systems, capture and interpret data. The older operators tend to have little understanding of data.

Soft skills: There is an emphasis on "soft skills." Production line workers are expected to be communicators, team workers and problem solvers. They must be able to "think on their feet". They must understand the "big picture" – why are they doing, what they are doing and how it fits in the internal and external value chains. Moreover, what happens to the firm and workers when things go wrong. Workers must take greater responsibility for quality.

Occupations: There is also a shortage of skilled machinists, operators, artisans and technicians. These are the "foot soldiers" on the production floor and determine whether to expand operations and product range. More workers should be trained in Automation, robotics, and Artificial Intelligence.

The global automotive value chain trend is hiring engineers, computer scientists, software developers, data analysts, and IT specialists to design and manufacture the next generation of vehicles with infotainment systems, electronic controls, digitalisation, and safety systems.

Transformation: There is an ecological transition in the energy mix favours hybrid, electric (battery and hydrogen) and NGV engines. It will require reskilling in the ACM sector to manufacture a new range of products.

SECTION FIVE: FINDINGS AND RECOMMENDATIONS

5.1 TRANSFORM MASTERPLAN INTO AN ACTION PLAN

Findings: The South African Automotive Master Plan is the strategy for all role-players in the automotive value chain in 2035. It is developed by the automotive sector for the sector and supported by the government.[83]

The Master Plan specifically references skills development with broad statements about sector growth enablers, growth targets, localisation, production volumes, employment, new technologies, transformation and competitiveness.

Several targets have direct skills development implications:

- Increasing local content from 38.7% to 60% by 2035.
- Growing South African vehicle production from 0.68% to 1% of global output.
- Increasing domestic vehicle production to between 1.3 million and 1.5 million units.
- Developing an EEV technology and skills roadmap.
- Increasing Tier 2/3 Black-owned supplier contribution to 25%
- Increasing employment in the value chain to 224 000.

The above targets are impossible without understanding that workforce skilling and reskilling are the most important factors in achieving Master Plan objectives.

The industrial success of the SA automotive sector is due to its value chain approach. Therefore, training success should also involve a value chain approach, occurring within value chain segments through vendor specifications.

Recommendations:

- Transform the Masterplan skills development statements into actionable programmes adopting SMART (specific, measurable, achievable, realistic, timebound) with a value chain approach.
- Establish an implementation structure with financial and human resources to manage the skills development programmes of the Masterplan.
- Ensure that programmes address the training, beneficiaries, timelines, targets, funding, training providers, etc.
- Engage MERSETA to ensure that the mandatory and discretionary skills development grants align with the Masterplan skills development priorities.

[83] Although the term "plan" is used, SAAM is a strategy rather than a plan.

5.2 IMPROVE THE TRAINING RATE

Findings: The training rate (the ratio of employees trained as per the total employee population) in automotive components manufacturing is very low. Likewise, the graduation rates for operator level NQF qualifications as a proportion of the total workforce is low. These findings were drawn from the Mashilo paper discussed in the previous section.

Technology advancements and the changing face of the global automotive value chain that will emerge with the mass commercialisation of EEVs and hybrid vehicles require a retooling of plants and reskilling of employees. Employees require more training more frequently. The recommendations below apply to ACM firms.

Recommendations:

- Improve the employee training rate in the sector.
- Conduct employee training needs surveys and feedback sessions on current skills supply, demand and mismatches.
- Investigate different training and education modalities that can be implemented in the firm.
- Survey the industry to understand the current, ongoing, and relevant skills challenges to ensure that future focus and funding are directed towards the highest priority skills sector needs.

5.3 FOCUS ON SKILLS DEVELOPMENT

The primary role of the ACM Chamber is to promote skills development in the sector to develop a highly-skilled workforce and globally competitive firms. It is to be achieved by increasing access to skills training, learnerships, apprenticeships, internships and bursaries for tertiary students. In addition, the Chamber develops skills development projects that are relevant to all ACM firms.

There are 21 SETAs covering all SIC codes in the economy. There are discrepancies in all SETAs regarding SIC code allocation. These have come about for consolidation purposes and to ensure a viable number of SIC codes per SETA to make them viable. Even within MERSETA, there are imperfections in the allocation of SIC codes. A reallocation of SIC codes will upset the equilibrium of the MERSETA structures, lead to unnecessary quarrels and delay skills acquisition.

It is mentioned in Section A that it is not plausible to transfer SIC codes from existing chambers to the ACM chamber and vice versa because:

- The other chambers would not allow it (dead-end debate), nor is it advisable.
- It will disrupt the MERSETA chamber, governance and staffing structures.
- The other chambers specialise in tyre assembling, plastics, metals and auto manufacturing. Therefore, they are best placed to drive skills development in those areas.
- The ACM firms comprise 2% of the MERSETA registered firm. The Chamber should not reduce its SIC codes, e.g., 38200.

Recommendations:

- Keep the Chamber focused on the following:
  - Improving the training and graduate rates of the workforce.
  - Making training accessible for the workforce (those that need and want training should be trained)
  - Ensuring that training is responsive to employer demand.
- Maintain the ACM Chamber SIC code status quo (SIC codes 38200, 38300 and 38710).

5.4 ADOPT FLEXIBLE TRAINING MODALITIES

Findings: Our national skills system is "hard-wired" to recognise full qualifications registered on the NQF as the only legitimate form of learning. It is a misconception. People learn in diverse settings and in different ways. For instance, the production plant is a learning institution that deserves due recognition. The NQF system is slow, rigid, inflexible and unresponsive to a fast-changing world. NQF qualifications are time-consuming, cost-ineffective and engulfed in bureaucracy.[84] Hence, the low training and graduate rates in the sector.

[84] We are not encouraging the demise of the NQF but merely pointing out that it has limitations that should be overcome by the recognition of other learning forms.

There are diverse learning forms that should be given legitimacy and recognition. Our conception of what constitutes learning should be broadened and incorporated into the MERSETA and automotive value chain.

Recommendations

- Recognise and incentivise other non-formal and informal learning forms to reskill, upskill, and increase the training rate.
- Encourage different learning delivery modalities such as full-time, part-time, correspondence, e-learning, micro-learning leading to digital credentialing, and blended learning.
- Conduct a feasibility study of how micro-learning and digital credentialing can fit into the training mix.

5.5 MAKE AUTOMOTIVE ATTRACTIVE TO TALENTED YOUTH

Findings: One of the concerns articulated during interviews is that young talent tends to veer towards "sexy" sectors such as finance, IT, engineering, law and medicine. These sectors pay above-average salaries to first-time job entrants. Generally, there is a tendency to look away from manufacturing jobs.

Youth may not be aware of the attractiveness of the automotive sector, which can accommodate diverse occupational types, including finance, IT, law, logistics and engineering. The sector accommodates youth with trade-related skills for which there is global demand. Moreover, jobs are comparatively of better quality in Automotives than in other sectors such as services or retail. There are low, middle and highly skilled occupations in the sector. The sector is gender-neutral. The benefits of working in automotive are not sufficiently communicated to schools, teachers and learners. In contrast, accounting and auditing firms trawl the schools and monitor potential talent in grades 11-12.

The sector should develop attractive career pathways for youth and existing employees at all occupational levels.

Recommendation:

AREA	PROBLEM	NOW	SOLUTIONS	FUTURE	BY 2030
School Graduates	Auto not seen as attractive	Learnerships			Skilled employees
TVET / tertiary graduates	Underused in supply chain	Learnerships	Skills programmes	Talent management	Skilled technicians / professionals
Plant Operators	Basic skills	Learnerships	Skills programmes		Supervisors / artisans / technicians
Artisans/technicians	Technology	Management / Technical / Technology skills programmes			Professionals
Professionals	Technology Management	Executive management / Technology skills programmes / visits to main plants			Future leaders / managers
Managers / Executives	Technology Management	Global perspectives Economics			Mentors and coaches

5.6 THINK DIGITALISATION

Findings: Digitalisation of manufacturing processes is a "no-brainer." We have conducted extensive international and local literature reviews of the sector. Our findings reveal that firms have little option but to embark on the digitalisation transformation journey, regardless of size, products and services offered.

Data is flowing rapidly, and its volume is increasing exponentially. The trend is towards digitalisation. International studies show that manufacturing firms are moving towards digitalisation. As OEMs digitalise, they will compel suppliers to upgrade. Firm-level success will depend on digital investments, infrastructure, implementation of technological change and workforce skilling. The two critical assets for digitalisation are technology and skills.

Recommendations

- Assess the digital maturity level of individual firms.
- Develop a digital transformation strategy focusing on infrastructure, skills development, data analytics and implementation.

- Invest in "tech-savvy" (younger) talent and leverage the knowledge of the legacy workforce to fit digital technologies into the production system.

- Capacitate employees with basic, intermediate and advanced data analytics courses.

CONCLUSION

In response to the question of whether the automotive components manufacturing sector is ready for Industry 4.0, the following should be noted:

- ACM firms respond to the OEMs' current product and service needs per vendor specifications.
- ACM firms cannot retool for future products and services that they do not know. The OEMs will specify what is required, when and in what volumes. ACM firms respond to client demand.
- No firm can reasonably aspire to adopt a state-of-the-art infrastructure because "state-of-the-art" is sure to advance by some degree when new infrastructure is installed.
- The future of automotive components manufacturing is likely to be the digitalisation of manufacturing processes—converting materials to products. However, data flow further, faster, and more significantly than before. The automotive sector is moving towards digitalisation. The best that firms can do is prepare the workforce with entry, intermediate and advanced digital skills to anticipate product and service innovation.
- Digitalisation is not and cannot replace mechanical processes. It should not be viewed as a discrete process divorced from mechanics. It simply optimises mechanisation.
- There is a good reason to pursue digitalisation. Data is becoming as valuable as the product. Currently, the value of data is yet to be realised in local firms.
- The adoption of digitalisation in manufacturing is a journey and a continual improvement process. It is not a singular event.
- The benefits of digitalisation for firms are:
    - Better serving the customer
    - Keeping up with competitors
    - Improving the bottom line
    - Obtaining value from data
    - Environmental sustainability
- ACM firms should assess its digital maturity level and devise a digital transformation strategy to achieve its goals.

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ANNEXURE A: LIST OF INTERVIEWS AND FOCUS GROUP DISCUSSION

NO	FIRST NAME(S)	POSITION	ORGANISATION
1	Justin Barnes	Automotive Sector Expert	B&M Analysts
2	Alex Mashilo	Automotive Sector Expert	Independent
3	Ruth Ntlokotse	Deputy Chair: ACM Chamber	NUMSA
4	Hedley Judd	TEPA Director	RMI
5	Louis Van Huyssteen	Training	RMI
6	Renai Moothilal	Executive Director	NAACAM
7	Beth Dealtry	Analyst	NAACAM
8	Simanga Tsotetsi	Labour Representative	NGK
9	Natalie Nelson	Consultant	Tetelestai Holdings
10	Gerald Naidoo	Plant 2 Director	Smith Engineering
11	Glenn Geldenhuis	CEO	AUTO-X
12	Naresh Maharaj	Head of IT, South Africa	Mahle Behr South Africa
13	Naeem Manga	Process Engineering	Mahle Behr South Africa
14	Vincent Lameire	CEO	Gruppocln
15	Christo Rootman	CEO	Natal Gaskets
16	Christoph Ewers	Chief Commercial Officer/Director	Atlantis Foundries
17	Dato Kevin Pather	Managing Director	Pasdec Automotive Technologies
18	Carlien Van der Merwe	HR Manager	MAHLE Behr SA
FOCUS GROUP DISCUSSION			
19	Andre Swartbooi	Commercial Director	Acoustex
20	Asatuwi Mafunzwaini	Process Engineer	Acoustex
21	Hennie Venter	CEO	Formex
22	Joubert Dupreez	Industrial Engineering Manager	First National Battery
23	Stephan Blom	Logistics Manager	Q Plas