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Applying Industry 4.0 in the Automotive Sector

Dissertation

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List Of Abbreviations

Abbreviation	Definition
5Ps	Privacy, Pervasiveness, Prediction, Performativity & Purposelessness
ACES	Autonomous Driving, Connectivity, Electrification & Shared mobility
ADAS	Advanced driver-assistance system
AGI	Artificial General Intelligence
AI	Artificial Intelligence
AIV	Autonomous Intelligent Vehicles
ANI	Artificial Narrow Intelligence
AR	Augmented Reality
ASI	Artificial Super Intelligence
CC	Cloud Computing
CE	Circular Economy
CPS	Cyber Physical Systems
CS	Cloud Systems
DLT	Distributed Ledger Technologies
ERP	Enterprise Resource Planning
EV	Electric Vehicle
FMS	Flexible Manufacturing Systems
GHG	Greenhouse Gases
GSC	Green Supply Chain
GVC	Global Value Chains
I4.0	Industry 4.0
ICE	Internal Combustion Engine (Vehicle)
IIoT	Industrial Internet of Things
IoT	Internet of Things
JIT	Just In Time
KPI	Key Performance Indicators
M2M	Machine to Machine
MID	Modularity in Desing
MIP	Modularity in Production
MIU	Modularity in Use
NFC	Near Field Communication
OEM	Original Equipment Manufacturer
PdM	Predictive Maintenance
QR	Quick Response (code)
RFID	Radio Frequency Identification
SCSR	Supply Chain Sustainability Risk
V2I	Vehicle to Infrastructure
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle

1 Abstract

Industry 4.0 and its methodologies have the potential to create significant paradigm shifts within the Automotive Industry, from design, manufacturing, vehicle use, customer services, business models and beyond. This dissertation will focus primarily on the impact of OEMs moving towards the Circular Economy, the adoption of Artificial Intelligence and integration with the Internet of Things. Sustainability, Smart Systems and Cloud Computing will play significant i4.0 related supporting roles in these key areas.

There are significant challenges and pitfalls for OEMs wishing to adopt i4.0, however those that change too slowly could risk becoming the Kodak or Blockbuster of the car industry. Whilst the optimal route to i4.0 may not be clear; this dissertation will aim to highlight examples of OEMs that are embracing these future trends and highlight key foundational areas that should be focused upon to achieving this next step in industrial evolution.

As well as being a research study this dissertation will also consider key questions that have arisen in the automotive industry in recent years. These include examining how 'green' and sustainable Battery Electric Vehicles are when compared to their Internal Combustion Engine counterparts. A practical study into the used and applications of AI in the automotive sector will also be explored.

This dissertation will aim to provide a broad scope of research to the reader in order to provide a comprehensive understanding of i4.0 with the car industry today whilst also considering future uses and applications.

2 Introduction

This research-based study will examine the application of Industry 4.0 in the Automotive Sector. Due to political, societal and resource pressures car makers have increasingly pivoted towards being more environmentally friendly and sustainable. This case study will highlight ways in which OEMs are applying i4.0 and Circular Economy methodologies to achieve climate-based targets and critically evaluate their Sustainability claims. Paradigm shifting technological advances through AI, Smart Systems, The Cloud and the IoT will be assessed with a focus on their uses and effects on manufacturing, processes, business models and vehicle usage.

3 Aims & Objectives

The aim of this dissertation is to gain a deeper understanding of industry 4.0 application within the Automotive Sector. Case studies will be compared, and a practical examination of AI based tools will be applied. Based on these findings' predictions on future uses and applications of i4.0 in the key related areas, The Circular Economy, AI and The IoT, will be made.

3.1 Sustainability and the Circular Economy

The emphasis within the industry on sustainability has led to EVs rapidly increasing in sales. Circular Economy methods to reduce carbon impact and improve sustainability will be investigated. A critical evaluation into EVs full life cycles will explore if the net impact is positive when compared to Gasoline and Diesel (ICE) cars. The following statements and questions will be answered:

- Understand how i4.0 can improve data on the sourcing and sustainability of materials.
- Can i4.0 achieve Design for Sustainability via the Circular Economy?
- Understand the total environmental impact of ICE vs EV.
- Critically evaluating OEM claims regarding "green" cars factoring in customer preferences.

3.2 AI and Smart Systems

Significant breakthroughs in AI have shown a surge in the adoption of this technology, case studies of its application within the automotive sector will be explored. The impact Smart Systems in conjunction with AI on design, engineering, manufacture, use, customer service and existing business models will be evaluated. This section will gain a greater depth of understanding and answer the following questions:

- Understand how AI and Smart Systems are being utilised in self-driving, ADAS, vehicles.
- Can AI and Smart Systems optimise design, manufacturing and vehicle use?
- Could AI be used to render design concepts and create personalised adverts?
- Is AI advanced enough to produce engineering documents and be used for customer services?

3.3 The Cloud and the IoT

The impact of The Cloud and the IoT will be appraised in order to predict future applications and uses of these technologies within the automotive sector. This section will investigate the following uses for The Cloud and IoT:

- Understand how the IoT improves manufacturing communication and optimisation.
- How Smart ID technologies can use the IoT for components and vehicle traceability.
- Can the Cloud store Digital Twins to display a car and its component histories?
- Learn how Smart factories use Cloud systems and Big Data to form the IIoT.

4 Literature Review of Industry 4.0 within the Automotive Industry

This literature review will provide a general picture of i4.0 currently being applied within the automotive industry, focusing on the key subject areas of this dissertation; sustainability, the CE, AI, Smart Systems, The Cloud and the IoT.

The Fourth Industrial revolution signifies paradigm shift within the Automotive Industry, Figure 1. From design, sourcing and manufacturing through to usage and end of life, every aspect of the industry could witness significant changes to the existing structures and business models.

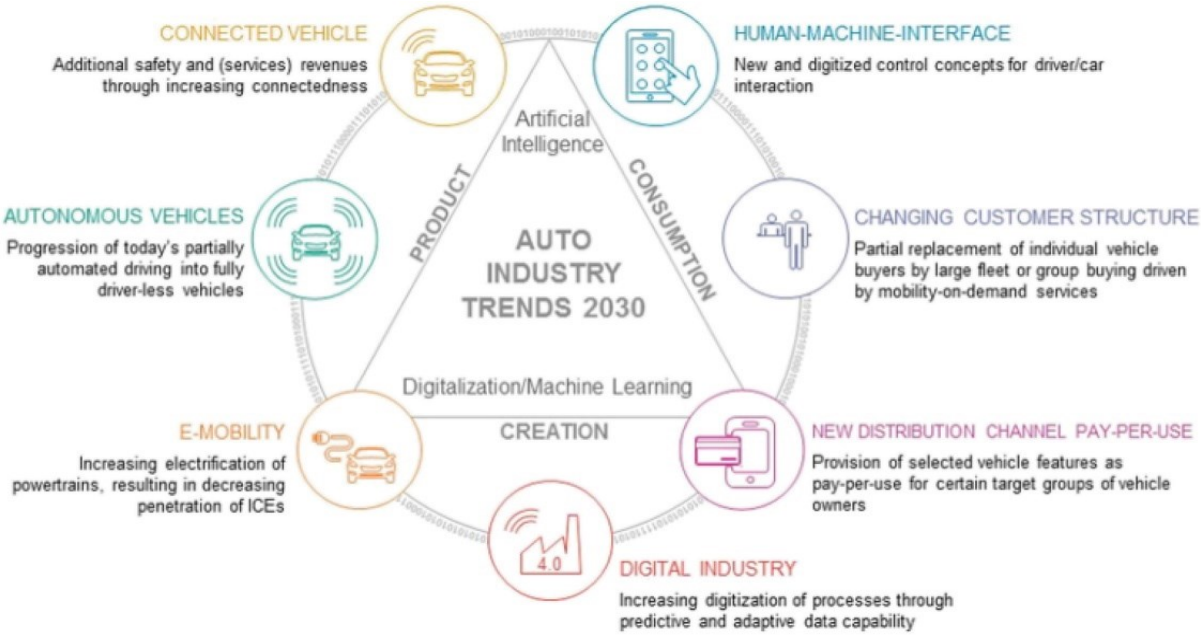


Figure 1, Automotive Trends related to industry 4.0 (Yu, et al., 2021)

The key enabling components of i4.0 are defined by (Bányai, et al., 2022) below:

- Cyber Physical Systems (CPS), the combination of physical and computational processes, a virtual environment to simulate a physical process via a virtual twin. CPS leads to faster processing, decision making, optimisation and preventative maintenance. CPS does have security concerns from hacking of data theft of the online connected system.
- Cloud Systems (CS), virtual server online storage and data management systems. CS requirements can be scaled up or down as required and reduce costs. CS allow 'Big Data' management solutions for communication between sites.
- Machine to Machine (M2M) communication, allows devices to directly communicate in order to enable smart vending, connected vehicles and remote service management.
- The Internet of Things (IoT), the connection between the internet and physical devices such as machines, electronics, buildings or vehicles to gather and share information automatically. The Industrial IoT (IIoT), improves manufacturing opportunities by optimising processes, resources and creating sophisticated autonomous machines and systems.
- Augmented Reality (AR) can produce virtual models of existing processes, they can then be used to optimise processes or train personnel in a virtual environment.

- Smart Factories or Smart Manufacturing refers to the move towards automation and digital systems. Smart factories need minimal human input with robots working autonomously. Smart Factories rely on i4.0 cornerstones such as Big Data, M2M, CS, IoT, IIoT and CPS.
- Big Data, i4.0 promotes data capture and sharing leading to vast amounts of information not suitable for manual human processing. Machine learning can mine the data to extract useful information for processes optimisation or to inform decision making.
- Intelligent Robots will enable labour to be decoupled from humans, robots today are largely static and perform a specific task continuously. Intelligent robots could be humanoid and perform multiple unique tasks and be capable of learning new tasks.
- Enterprise resource planning (ERP) efficiently organises resources in Smart Factories using Big Data via Cloud systems. ERP can automate forecasting to suppliers, production and sales and help with transparency resource optimisation and order tracking using real time data.

4.1 Sustainability and the Circular Economy Literature Review

Sustainability and the Circular Economy are key motivators within the Automotive Industry's shift towards i4.0. From the very start of the manufacturing process Green Supply Chain (GSC) management is highlighted by (Ghadge , et al., 2022) as important for achieving greater sustainability, they note the importance of implementing the IoT, blockchain and CPS to achieving GSC's. Sustainable development is explored by (Bai, et al., 2020), their research suggests that nanotechnology, mobile technology, simulation and drones would have the highest impact on sustainability in the automotive industry. This is contrasted by (Gonzalo, et al., 2021) who claim that the eco-innovation of products has a higher importance than that of processes or management.

The immutability of the recorded data via Distributed Ledger Technologies (DLT) can ensure that "greenwashing" (WWF, 2023) or the opaque ethics of material sourcing and labour (Frankel, 2016) are eliminated. Data governance is also identified by (Singh Bhatia & Kumar, 2022) as the critical success factor as it affects the four key performance outcomes, operation, product, economic and responsiveness. This enables OEMs to be well informed in decision making, ensuring that legal aspects of supply are covered with greater clarity.

Technologies such as 3D printing are allowing OEMs to become more independent at the initial prototype phases, from this they can quickly manufacture and test prototypes in house to ensure fit and function before outsourcing to suppliers (Bányai, et al., 2022). Whilst additive manufacturing can be more energy intensive than other manufacturing methods, in-house 3D printing reduces the overall carbon footprint when considering the traditional supply chain as a whole.

Refurbishment and remanufacturing are key components of the CE, the challenges of implementing this in the automotive industry are highlighted by (Kalverkamp & Raabe, 2017). These include a lack of government policy, differing competencies of dismantlers and recyclers in each country/region and legal rights in terms of property ownership. This challenge is further explored by (Schulz , et al., 2021), they address the key stakeholders for CE and the four key decision contexts that CE relies upon. These contexts are 1. Product Development and Supply Chain, 2. Supply Chain and End of Life, 3. Product Development and End of Life, 4. Business Models and End of Life.

In order to rationalise the remanufacturing process within the automotive industry (Kanellou, et al., 2021) have formalised the Key Performance Indicators (KPI's) that should be monitored. These KPIs are classed as 'Horizontal' that affect all actors involved within the automotive value chain and 'Specific' KPIs that are only relevant for some actors depending on their activities. 'Horizontal' KPI's

include broad aims such as reducing emissions, increasing life expectancy of components and European re-industrialisation to create jobs and reduce transportation emissions. The 'Specific' KPIs focus on improving performance, disassembly and re-use or recycling of key component areas such as batteries, electronics & mechatronics, techno-polymers and textiles.

However as (Ghadge , et al., 2022) note, there is currently scarce literature combing industry 4.0 and green sourcing within the automotive context, this is in part due to this relationship being in its infancy. This sentiment is echoed by (Bai, et al., 2020), therefore, at this stage a lot of the research is based on theoretical relationships between the paradigms of i4.0 and GSC management and sustainable development. It becomes clear that there is no consensus yet on what area to focus on, in order to achieve greater circularity, attention must be given to all key areas within the car life cycle.

4.2 AI and Smart Systems Literature Review

Artificial Intelligence and Smart Systems will provide significant improvements in manufacturing, processes and vehicle use, Figure 2. AI advances can be broken down into 3 categories "*operation intelligence*", "*prediction intelligence*" and "*detection intelligence*" (Vermesan & et al., 2021). Operational intelligence delivers real time analytics for machines via process data, AI then uses this data to make automated or manual decisions/actions. Prediction intelligence uses learned historical comparisons and real time data to predict patters and autonomously act accordingly. Detection intelligence identifies abnormalities from pre-determined target conditions, this data can be gathered via sensors and acted upon.

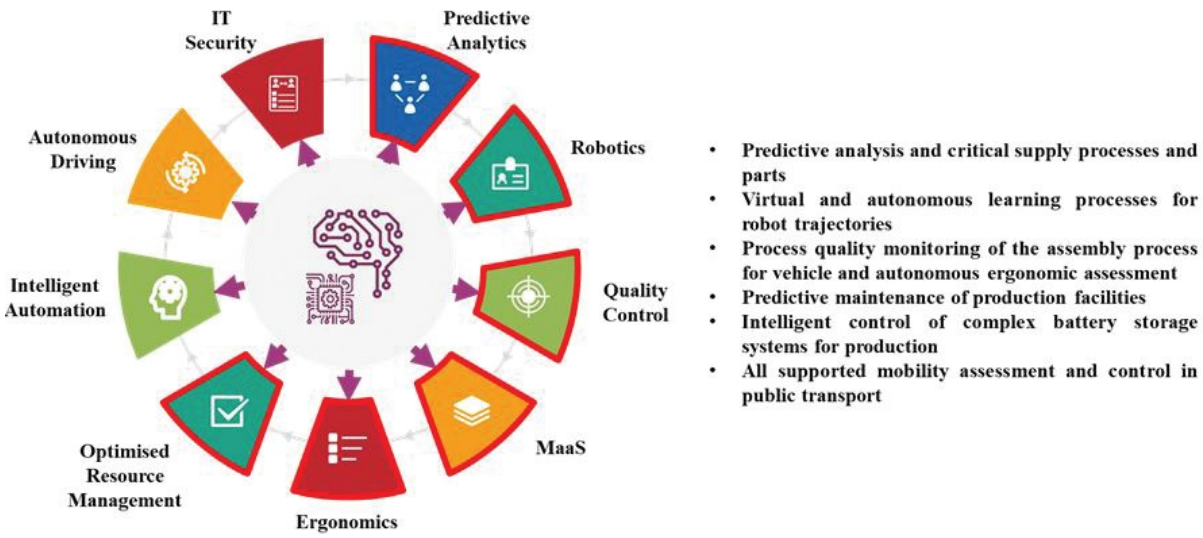


Figure 2, (Vermesan & et al., 2021) AI application within the Automotive Industry.

Real time predictive maintenance (PdM) can be used within manufacturing and assembly/disassembly facilities. By combining PdM AI systems with the IoT and Big Data the data processing across multiple facilities globally can become more intelligent by sharing information in real time (Vermesan & et al., 2021). AI systems used in ADAS can improve autonomous driving capabilities via shared data between networked vehicles and road infrastructure. However, OEMs should express caution as network hacking could compromise ADAS systems (Wasner & Traxler , 2019), therefore businesses must ensure security by utilising tools such as blockchain.

The increase in availability and affordability of Smart Systems, sensors and radars have enabled basic ADAS systems, Figure 3, to become viable. Currently to achieve ADAS 4 and 5 larger and more

expensive UDAR sensors, radar arrays and onboard digital processing are required, these systems can be expensive and take up a lot of room. However, as (Oculii, 2021) explain, advancements in AI software could overcome these cost obstacles, improving the resolution of cheaper hardware by via internet connectivity and CC.

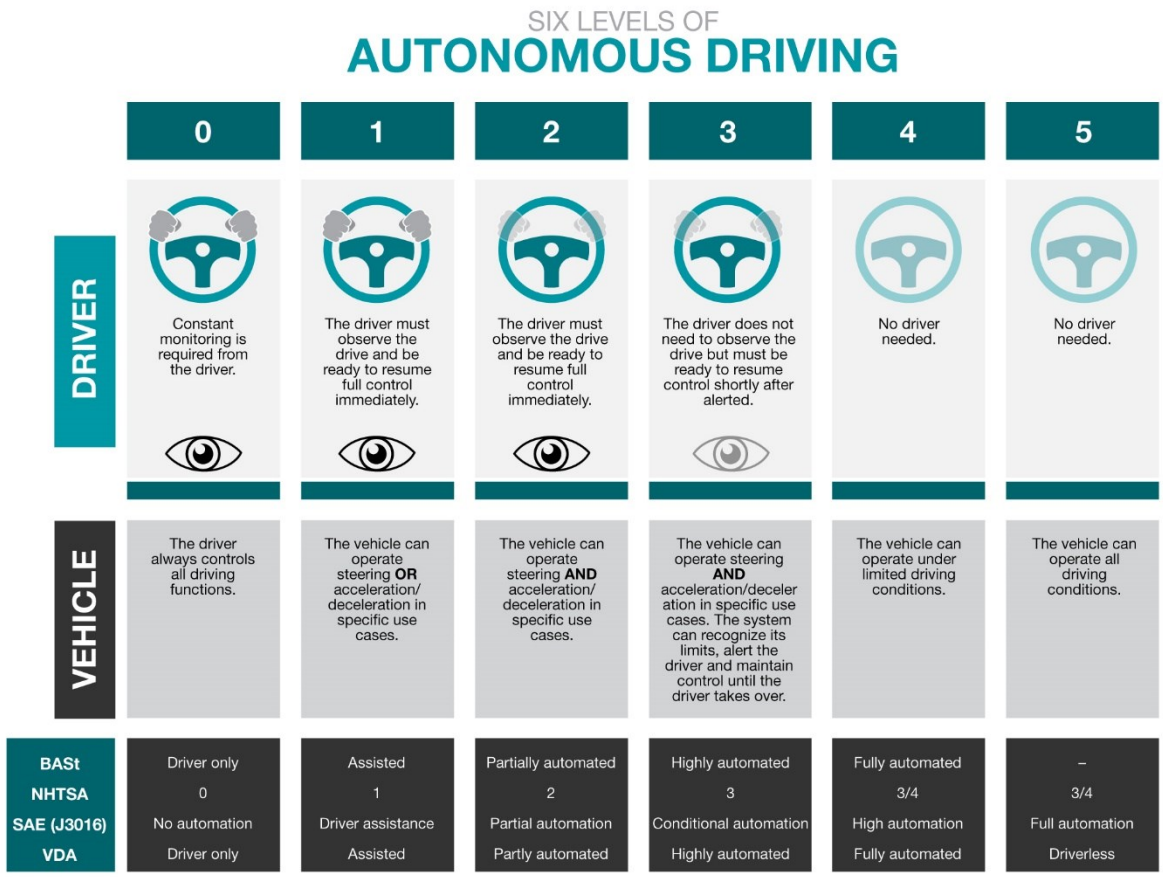


Figure 3, ADAS levels defined by regulatory bodies BASt, NHTSA, SAE and VDA (Estl, 2018)

4.3 The Cloud and The IoT Literature Review

The Cloud and the IoT are key components to industry 4.0 by enabling interconnectivity between companies, machines and components. This relationship is demonstrated by (Tihanyi, et al., 2021), they detail the impact of digital twins using Cloud integration within ADAS and traffic management systems in real time. Smart vehicles could then tailor routes based on real time data to find optimal solutions in terms of energy use or journey time.

Vehicle integration with the IoT is also discussed by (Kim, et al., 2017), they look at home to vehicle connected service scenarios via smartphones. A secure blockchain connection can enable 'user to vehicle' interfaces via voice recognition software to execute tasks whilst driving (Freeman, 2023).

For production, the Industrial IoT (IIoT) will enable Flexible Manufacturing Systems (FMS) to be applied. As (Cronin, et al., 2019) note, FMS via IIoT communication will allow OEMs to regularly change and update their processes in small ways to retain competitiveness whilst avoiding delays, downtime and costs from larger but less frequent wholesale updates. The Cloud and IIoT enable OEMs to communicate autonomously in real time between different departments or production facilities,

improving data clarity and aiding desilofication. This could be extended to suppliers to enable efficient production and validation of components.

The emergence of CC has allowed OEMs to reduce their IT hardware costs whilst maintaining and improving processing power. This enables OEMs to become more agile and allows resources to be directed towards R&D (Wang, et al., 2021).

4.4 Conclusion of literature review

I4.0 offers many avenues of exploration to improve current business models and practices. What is perhaps most noticeable is the significant overlap between these systems, particularly online. Due to its innate nature in data sharing I4.0 will mean stepping away from 'silofication'.

This does pose challenges for automotive companies, adopting i4.0 will require both capital and personnel investment. OEMs will need to hire expertise in and re-train staff in order to exploit the benefits of i4.0, significant changes and investment in machinery and processes will also be required.

An issue with assessing i4.0 within the Automotive Industry is that a lot of it is currently hypothetical. The majority of sources are from the last 5 years and mostly reference the possibilities of i4.0 with real examples being relatively few and small scale. This dissertation will aim to delve further into this area but also go beyond it.

The human factor within i4.0 and resistance to change will also need to be considered. Currently management structures within OEMs may be reluctant to radical change in case of job security fears. The significant paradigm shifts of i4.0 will not occur unless the culture within the automotive industry changes.

However, as some companies and whole industries failed to adopt advancements in previous industrial revolutions, so too may some OEMs fall behind if they are too slow to adopt i4.0.

5 Applying the Circular Economy & Sustainability in the Automotive Industry

Since the phasing out of leaded gasoline in the 1970's (Ritchie, 2022), there's been an emphasis towards making the cars less pollutant, *"the combination of cleaner fuels and vehicles can reduce emissions by more than 80%"* (UN environment programme, 2021). Government policy has aided the trend, in the early 2000's this included encouraging UK drivers to buy diesel vehicles (Rosenbaum, 2017). However, whilst lowering C02 output, Diesels were found to be more damaging to people's health than Gasoline with respect to particulate emissions.

The Automotive Sector has made strives to develop fuel efficient and less particulate emitting vehicles. ULEZ, introduced in London in 2019 (Transport for London, 2017), has also pushed consumers towards cleaner vehicles. Since the Diesel emissions scandal in 2014 (Connett, 2015) onlookers may be sceptical towards the claims by OEMs regarding the credentials of "greener" vehicles. In this study, the full life cycle emissions of comparable electric and gasoline vehicles will be compared, and sustainability claims by OEMs will be critically evaluated.

To adopt Circular Economy methodologies and improve sustainability whist reducing emissions, OEMs will need to become integrated with i4.0. This segment will explore how car materials, manufacturing methods, serviceability, usage, ownership as well the recycling and reusing of components will need to be re-evaluated in the i4.0 gaze.

5.1 Defining the Circular Economy

5.1.1 What is the Circular Economy?

The Circular Economy (CE) can best be described by Figure 4, it is the philosophy of reusing and remaking products and materials in a sustainable way that ultimately eliminates waste and pollution. The CE contrasts to the typical linear economies that; take, make and waste, ultimately causing pollution (A&A Packaging, 2023).

Linear economies are characterised by having short-term outlooks, whilst this can be improved with the 3R's (reduce, re-use, recycle), CE differs by having multiple long term life cycles that are inherent from the design process.

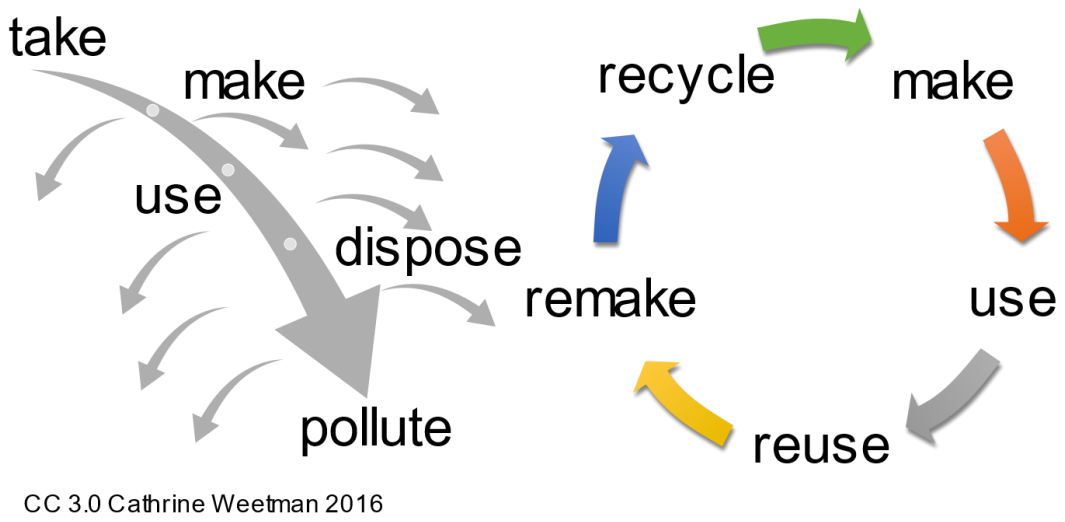


Figure 4, The Circular Economy (Weetman, 2022)

5.1.2 How does i4.0 tie into industry the CE?

By integrating the CE with i4.0 greater levels of sustainability can be achieved. Big Data can be harvested through smart systems and CPS, stored via the IoT and processed with CC. This data can then be used to optimise design, logistics, sourcing and remanufacturing processes to reduce carbon emissions and waste (Rajput & Singh, 2019). I4.0 tools such as the IoT, CPS and Big Data will aid CE production, repair, re-use and remanufacture of vehicles and components.

From the perspective of GVC, it is noted by (Awan, et al., 2022) that the CE will be largely supported by digitisation and i4.0 implementation. This view is also supported by (da Silva & Sehnem, 2022) "*These technologies can positively influence sustainable production and CE capabilities, as I4.0 and sustainability integration is still at its initial stages*". However, this area of research is in its infancy, limited to peer review studies and economic theory models rather than relying on tangible practical examples.

With i4.0 integration, new CE compatible business models could be established with shared vehicles paid for per use or via subscription services. This would result in fewer vehicles built and sold but an increase in use per vehicle.

5.1.3 What does the CE mean in the context of the Automotive Industry?

Recent trends, namely electrification (Edwards, 2023), have seen Automotive OEMs design cars with sustainability in mind, however this often just considers the output from the vehicle during use.

To go a step further and achieve CE synergies, OEMs must consider the supply chain (SC) and manufacturing of the vehicle, the use, re-use and serviceability of the car and its components as well recycling or the use of recycled materials.

Current linear car lifecycles result in significant waste, whilst components such as wheels, tyres and body panels may be removed and re-used via scrapyard networks, there is very little CE design in cars today. The majority of cars are crushed and shredded, 65% of a car is made of steel which is recyclable (National Scrap Car, 2023). Therefore, its core materials rather than components that being re-used.

It's noted by (Yu, et al., 2021) that i4.0 plays a positive role in the implementation of the CE and that it is both operationally and economically advantageous for OMEs to embrace the CE.

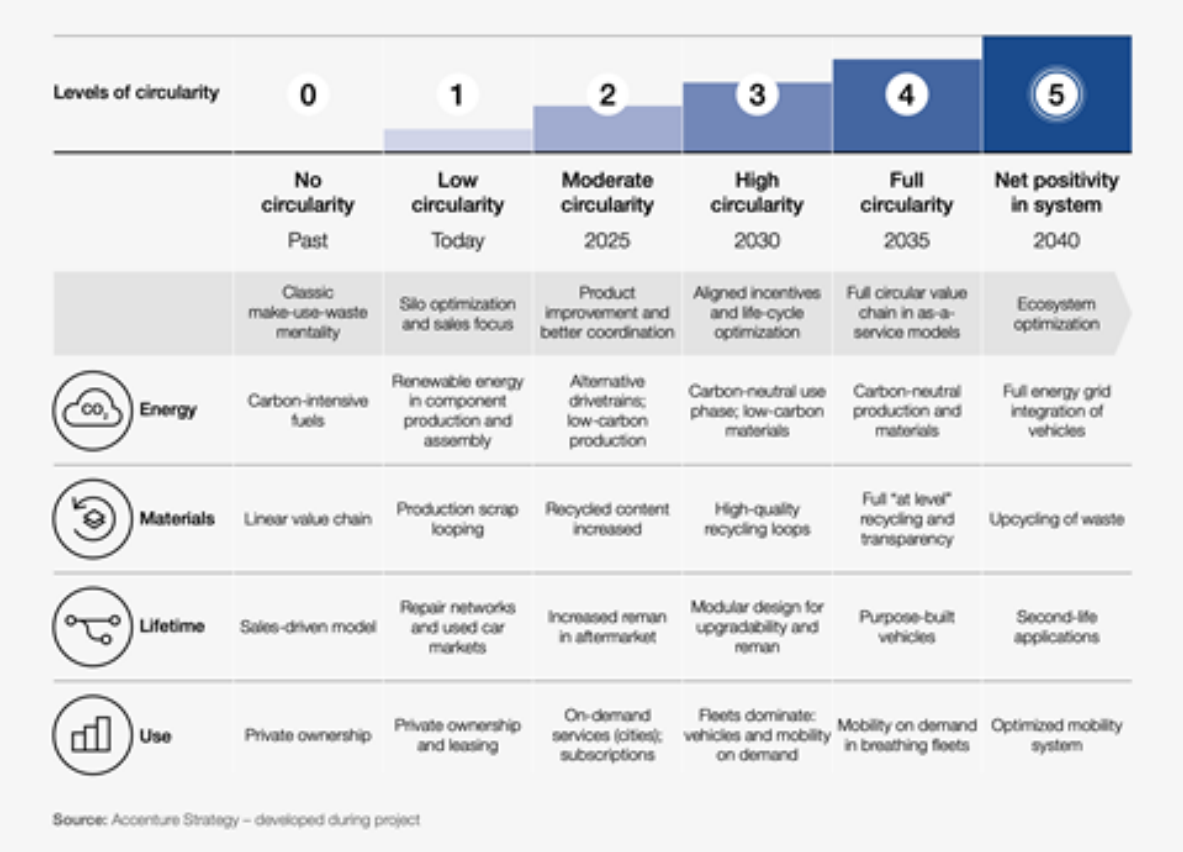
5.2 Examples of how OEMs can adopt Circular Economy methodologies.

5.2.1 Incorporating the CE into Automotive manufacturing

By pivoting their manufacturing towards CE methodologies OEMs can become more sustainable. This will require involving the whole supply chain and radically changing current business models. As Figure 5 from (Automotive Manufacturing Solutions, 2022) shows, it is better for OEMs to approach circularity in an iterative approach to enable energy and material suppliers as well as customers' time to adapt to the changes. Figure 5 demonstrates that there are only low levels of circularity in car production today, with some renewable energy use, material recycling and cars being maintained and leased to extend their use and lifespan.

Mazda explain in (Automotive Manufacturing Solutions, 2022) that they aim to ensure that all of their production facilities are carbon neutral by 2035 and for the entire business to reach carbon neutrality by 2050. In order to become truly carbon neutral OEMs must work closely with Suppliers to ensure that sustainability is considered down the supply chain. Stellantis look to take this further by not just focusing not just on materials and parts but by also incorporating the machinery and robots from production facilities into their CE ethos, *"Many of our plants have developed the skills to transform and adapt robots for reuse"* (Automotive Manufacturing Solutions, 2022).

Renault Group are targeting re-manufacturing, relying on a "*reverse logistics ecosystem of partner companies*" (Ellen MacArthur Foundation , 2023) in order to become more circular. Their aim is to extend the life of their vehicles, find secondary uses for EV batteries, dismantle and re-use the parts from end-of-life vehicles and to innovate and share knowledge about the circular economy.



Levels of circularity	0	1	2	3	4	5
	No circularity Past	Low circularity Today	Moderate circularity 2025	High circularity 2030	Full circularity 2035	Net positivity in system 2040
	Classic make-use-waste mentality	Silo optimization and sales focus	Product improvement and better coordination	Aligned incentives and life-cycle optimization	Full circular value chain in as-a-service models	Ecosystem optimization
Energy	Carbon-intensive fuels	Renewable energy in component production and assembly	Alternative drivetrains; low-carbon production	Carbon-neutral use phase; low-carbon materials	Carbon-neutral production and materials	Full energy grid integration of vehicles
Materials	Linear value chain	Production scrap looping	Recycled content increased	High-quality recycling loops	Full "at level" recycling and transparency	Upcycling of waste
Lifetime	Sales-driven model	Repair networks and used car markets	Increased reman in aftermarket	Modular design for upgradability and reman	Purpose-built vehicles	Second-life applications
Use	Private ownership	Private ownership and leasing	On-demand services (cities); subscriptions	Fleets dominate: vehicles and mobility on demand	Mobility on demand in breathing fleets	Optimized mobility system

Source: Accenture Strategy – developed during project

Figure 5, Levels of Circularity (Automotive Manufacturing Solutions, 2022)

5.2.2 Are OEMs using sustainable materials or sourcing ethically?

By implementing the 3R's OEMs can become more sustainable. Renault Group note the economic benefits, estimating that remanufactured and re-assembled parts are 40% cheaper than new ones whilst still undergoing the same quality checks and tests (Ellen MacArthur Foundation , 2023). Renault Group also estimate that remanufactured parts use; 80% less energy, 88% less water, 92% less chemical products and 70% less waste (Ellen MacArthur Foundation , 2023).

Additionally, whilst OEMs are making efforts to recycle materials, the source of the materials is becoming important in the public and political agenda, particularly EVs which are viewed as a more environmentally friendly mode of transport. The source of the materials that make the batteries has become a topic of discussion, *"Furthermore, the rare earth metals used in batteries, like cobalt, are sourced in enormous mines that destroy local habitats and are often linked to child labour, inhumane working conditions and conflict"* (Automotive Manufacturing Solutions, 2022).

For companies to be considered both green and ethical, efforts will need to be made to ensure that materials are sourced in a clean and non-exploitative manner. I4.0 can provide solutions in this area, by using Big Data and the Cloud, it could be mandated that all raw materials sourced are sold with a digital footprint, which could be transferred to the various production sites via the IoT before the material reference is attached to the car sold. This level of data will enable auditors and governments traceability of the raw material processes to ensure that good ecological and humanitarian practices

are enforced. This system could work in a way similar to how 'Fair Trade' foods practices are labelled and enforced.

5.2.3 Design of vehicles with the CE

A key driver for OEMs becoming aligned with the CE will be the design ethos of future vehicles, whilst cars today can be recycled and repaired, they are still not fully aligned with the CE.

Citroen have shown how a new approach could look with their 'Oli' concept electric vehicle, the Oli aims to use fewer and lighter materials than current cars. By reducing the vehicle weight the Oli's range can be increased, or a smaller battery can be used resulting in fewer raw materials required to travel similar distances. Being a smaller EV, the Oli requires less materials to produce the end product, resulting in lower manufacturing emissions and less total energy use in the vehicles life. The Oli uses "honeycomb cardboard" body panels that Citroen claim are stronger than steel whilst being half of the weight (Parrott, 2023). The interior is designed with the CE in mind, the lightweight 3D printable seats are made of recyclable thermoplastic polyurethane.

Reducing weight and size in order for cars to become more sustainable is echoed by (Rodeffer, 2023) *"because powertrain efficiency and vehicle weight also have a significant effect on a car's environmental impact, some hybrid and gasoline vehicles outperform some EVs".*

Cars considered to be 'green' are not necessarily the same as cars compatible with the CE in terms of sustainability. Due to producing fewer emissions at use, EVs and Hybrids can be considered 'green' and at circularity levels 1 to 2 in terms of Figure 5. However significant steps are required to reach sustainability level 5 in terms of energy (in production), materials (upcycling waste), lifetime (secondary applications) and use (optimised usage system).

From a design perspective, i4.0 tools such as AI and generative design via CC can be used to optimise the design of key components. 3D printing can also be used to produce lighter, stronger and more complex components to save on weight, materials and transport. By designing for longevity and serviceability modern cars may become more modular. This will enable key parts to be easily refurbished or replaced, identification via QR or RFID systems could enable live and up to date data to be stored in the cloud and the IoT.

5.2.4 Serviceability and then End of Life recycling re-use, refurbishment.

Cars today can expect a lifespan up to 200,000 miles or 12 years, this is a significant improvement in terms of longevity and reliability as in the past 100,000 miles was considered significant (CascadeCollision, 2020). However, whilst cars can be expected to reach these milestones it is largely dependent on regular maintenance and servicing, the actual average life expectancy of a new vehicle is 150,000 miles (~241,402km) or 8 years (Weisbaum, 2006). Whilst a car may function beyond these milestones, it is often left to the consumer or insurance companies to determine if it is economically viable to keep a car running. The introduction of carbon credit schemes could be an option for governments to ensure that cars are kept on the roads for longer.

Whilst cars have improved in terms of reliability over the decades (Progressive , 2022), CE alignment will require serviceability and maintenance of vehicles to improve this further still. Refurbishment of cars is being considered by major OEMs, Toyota plan to re-manufacture vehicles up to three times in order to extend lifespan and profit (Smith, 2022). Stellantis also aim to extend vehicle lifespans to 15 years, from the 12-year average, to reduce emissions and better align with the CE (Gibbs, 2023).

Vehicles will inevitably reach an end-of-life point despite improved serviceability and refurbishment. The recycling and re-using of components that are still road worthy is one way to reduce overall

environmental impact. A video by (Smith, 2023) details the efficiency of modern breaker yards, with vehicles booked onto a database, stripped, inspected, parts packaged, photographed, stored and listed for sale online within a matter of hours. The aim of this is to improve the profitability of "scrap" vehicles and to prevent useful and saleable components from being needlessly wasted or destroyed.

Greater circularity can be achieved by also finding new applications for parts, such as repurposing EV batteries. As (Vaughn, 2023) shows, older EV batteries can be given a second life by being used to store electricity generated from solar panels, these can be used commercially or domestically and help in reducing peak energy demand.

5.3 Critical evaluation of 'Green' vehicles in the automotive sector

This section will evaluate the full life cycle of a vehicle, noting the emissions and environmental impact of their manufacture and use. This will primarily compare ICE to EVs to give a full and rounded scope of vehicles on the market today. It will consider the impact per year and the typical useful life span of a vehicle before being scrapped. Hybrid and Hydrogen cars have not been considered in this analysis due to the significant variance in powertrain types and lack of data available for a full lifecycle analysis.

To provide a picture of how sustainable or 'green' a car is (GreenCars.org, 2023) use a metric based on fuel economy, emissions and pollutants as well as estimating pollution from vehicle manufacturing and the production and distribution of fuel. From this cars are graded on a "green score" from 0 to 100 with 100 being the best possible score, in 2023 the average score was 43 with the top scoring Mini Cooper SE Hardtop 2 door achieving 67 and the worst being the Dodge Ram 1500 TRX 4x4 with 22 (Rodeffer, 2023) & (GreenCars.org, 2023).

The overall lifetime of a car must be considered when evaluating how 'green' or sustainable they are. The bar chart in Figure 6, (The Manufacturer, 2022), shows the lifecycle emissions between ICE and EV cars. According to their findings cited from (capgemini, 2020) the switch to EVs would cut lifetime GHG's (Greenhouse Gases) by 37% and the operating footprint (fuel) by 75%. It should be noted that the (capgemini, 2020) calculations, Table 1, assume a vehicular lifespan of 150,000km (93,000 miles).

Table 1, total emissions over 150,000km / 93,206 miles ICE vs EV (capgemini, 2020)

Overall lifecycle GHG emission analysis (g.CO2 eq/km)	**ICE**	**EV**
Fuel combustion	208	0
Power production/fuel production	50	67
Battery	0	72
Maintenance	9	9
Production of body/components	37	43
Total (g.CO2 eq/km)	**304**	**191**

In reality the useful lifespan of an ICE is currently typically greater than an EV due to battery degradation. Whilst EV's have fewer moving parts and typically require less maintenance, most OEMs battery warranty runs out after 8 years or 100,000 miles (Gorzelany, 2022), after this the range can be reduced by 20 to 30%. This range reduction may make the EV redundant for typical usage resulting in otherwise premature replacement or scrappage. By contrast (Progressive, 2023) note that modern ICE vehicles that are well maintained can be expected to run for 200,000 to 300,000 miles. Whilst

300,000mi is on the higher end compared to the (Weisbaum, 2006) 150,000mi average it is worth considering as OEMs aim to extend vehicular life for CE compatibility.

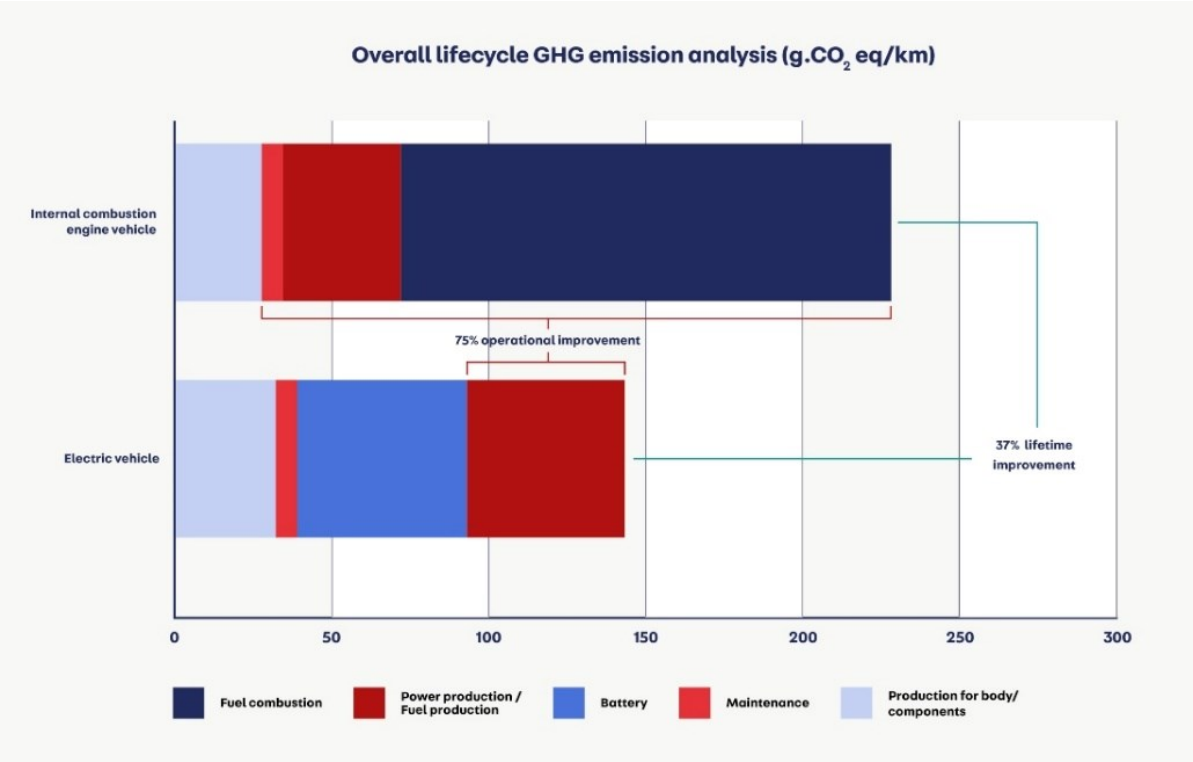


Figure 6, Overall lifecycle emissions analysis (The Manufacturer, 2022)

The following calculations are based on the (capgemini, 2020) data comparing like for like EV and ICE cars, for full details see Appendix 1 Workings for lifetime vehicle emissions comparison. The average EV range when new is 236.25 miles, less than half of the ICE 540.5 miles. Battery range also decreases over time, estimated by (EV Connect, 2022) by up to 2.3% per year, extrapolating this over 30 years (300,000 miles assuming 10,000 miles per annum) the range of an EV becomes drops to an estimated 117.55 miles compared to an ICE 488.94 miles (assuming age related efficiency losses). These calculations assume ideal EV running conditions with regards to temperature and driving style, in reality this range could be much lower. By contrast a well-maintained ICE vehicle can be expected to run with minimal efficiency or range losses.

Table 2, expected range from new to 30 years / 300,000 miles of use ICE vs EV.

Expected Average Range	ICE	EV
Avg Range in miles (full tank/battery) new	540.5	236.25
Avg Range in miles (full tank/battery) 10 years / 100,000 miles	540.5	187.21
Avg Range in miles (full tank/battery) 20 years / 200,000 miles	514.08	148.34
Avg Range in miles (full tank/battery) 30 years / 300,000 miles	488.94	117.55

In a poll by (Jenkins, 2021) only 7% of consumers would consider an EV with less than 200 miles range. Whilst EV early adopters may be willing to accept a reduction in total range many drivers will not. Table 2 shows that the average EV range reduces to 187 miles after 10 years. Therefore, consumers

would need a new EV every 7 years (70,000 miles) in order to maintain a practical minimum range of 200 miles.

Price also needs to be considered with the EVs costing on average £40,501 compared to the average ICE price of £17,195 (capgemini, 2020). Using the 70,000-mile figure, then the typical owner would require up to four EV's (£162,004 not adjusting for inflation) in the space of one ICE car to cover close to 300,000 miles of usage.

When extrapolating the data from (capgemini, 2020), Table 3, then up to four EVs (~280,000 miles total) result in a carbon impact of 764g.CO2 eq/km. For a single ICE vehicle, the total carbon impact is 838g.CO2 eq/km, assuming 279,618 miles, close to the 300,000 miles maximum estimated lifespan. At this point the carbon impact of 4 EVs compared to 1 ICE comes close to parity, albeit subsequent scrap waste emissions are not factored in.

Table 3, approximate total emission over 28-30 years of practical car use.

ICE	**10 years est**	**20 years est**	**30 years est**		**Total**
Fuel combustion	208	208	208		624
Power production/fuel production	50	50	50		150
Battery	0	0	0		0
Maintenance	9	9	9		27
Production of body/components	37	0	0		37
Total (g.CO2 eq/km)	304	267	267		**838**
EV	**7 years est**	**7 years est**	**7 years est**	**7 years est**	**Total**
Fuel combustion	0	0	0	0	0
Power production/fuel production	67	67	67	67	268
Battery	72	72	72	72	288
Maintenance	9	9	9	9	36
Production of body/components	43	43	43	43	172
Total (g.CO2 eq/km)	191	191	191	191	**764**

It is worth noting that these calculations are based on idealised circumstances and omit major considerations, primarily these are cost, driving style and weather. The data for the ICE also assumes an idealised maximum lifespan of 300,000 miles rather than the average of 150,000mi.

Cold weather can significantly reduce the range of a battery EV, a report by (Burn, 2021) found that the Honda E states a range of up to 120 miles, but this reduced by ~33% to 80 miles in cold weather. In one instance, due to a combination of colder weather and driving style, the Honda E's range decreased by 50% to 60 miles. A report from (Tracy, 2023) also found that a 12-year-old Nissan Leaf (73-mile range when new) with less than 70,000 miles had only a vehicle predicted range of 35 miles and in reality, could only travel 25 miles before requiring recharging. Table 2, and Appendix 1 Workings for lifetime vehicle emissions comparison, show a battery degradation of 2.3% per 10,000 miles however the evidence of a used Nissan Leaf would suggest a 10% degradation per 10,000 miles based on vehicle predicted range and 14% degradation based on actual driven range.

When factoring in weather and driving styles, EVs with up to 400mi range would be required to comfortably achieve 200mi in sub-optimal conditions. Currently few EVs are capable of ranges greater

than 350 miles (Wilkinson, 2023) and those that can are expensive, putting them out of reach for many consumers. However, this would need to be considered on a case-by-case basis, with not all parts of the world experiencing colder weather conditions.

Table 4, total emissions factoring in average ICE use, average ICE age and average useful EV battery life (considering climactic conditions & driving style).

ICE (replaced every 15 years / 150,000 mi)	**15 years**	**15 years**			**Total (30 years)**
Fuel combustion	312	312			624
Power production/fuel production	75	75			150
Battery	0	0			0
Maintenance	13.5	13.5			27
Production of body/components	37	37			74
Total (g.CO2 eq/km)	437.5	437.5			**875**
ICE (replaced every 8 years / 80,000mi)	**8 years**	**8 years**	**8 years**	**6 years**	**Total (30 years)**
Fuel combustion	166.4	166.4	166.4	124.8	624
Power production/fuel production	40	40	40	30	150
Battery	0	0	0	0	0
Maintenance	7.2	7.2	7.2	5.4	27
Production of body/components	37	37	37	37	148
Total (g.CO2 eq/km)	250.6	250.6	250.6	197.2	**949**
EV (replaced every 3 years / 30,000mi to retain min range >200mi)	**3 years**	**(30 years)**			**Total (30 years)**
Fuel combustion	0	(0)			0
Power production/fuel production	22.11	(221.1)			221.1
Battery	72	(720)			720
Maintenance	2.97	(29.7)			29.7
Production of body/components	43	(430)			430
Total (g.CO2 eq/km)	140.08	(1400.8)			**1400.8**

Taking into consideration data 'noise' the results are recalculated, Table 4, over the same 30-year (~300,000mi) span, making necessary adjustments to the original data. The average ICE lifespan is stated as 8 years or 150,000 miles by (Weisbaum, 2006). If replaced every 8 years (assumed 80,000mi) then 4 ICE cars in total would be required, over 30 years, with total emissions of 949 g.CO2 eq/km. If replaced after an average ICE usage of 150,000mi (~15 years) then 2 ICE vehicles would be required with a lifetime output of 875 g.CO2 eq/km. The EV range from new is reduced by 10% to account for temperature fluctuations and driving style. From these assumptions EV range (including annual battery degradation of 2.3%) would drop to 198.3 miles after 3 years (30,000mi). Therefore 10 EVs would be required over 30 years with total emissions of 1400.8 g.CO2 eq/km. This would suggest that EVs would have a greater negative environmental impact that ICE under current technological and consumer led constraints.

In a CE both EVs and ICEs would be more environmentally friendly due to re-use and remanufacturing of components and vehicles. However, the CE not yet established and some of the omissions from the (capgemini, 2020) data include non-emissions related pollutants and also emissions from vehicular scrappage.

The mining of materials such as cobalt and lithium, used in EV batteries, needs to be taken into account to understand the full picture.

"*Though emissions deriving from mining these two elements are lower than those deriving from fossil fuels production, the extraction methods for lithium and cobalt can be very energy intensive – leading to air and water pollution, land degradation, and potential for groundwater contamination*" (Zheng, 2023).

Extracting and processing these toxic metals can contaminate the waterbed and be harmful to both humans and local biodiversity. The mining process in Figure 7 highlights the scale of the impact, it is noted by (Campbell, 2022) that this can lead to soil degradation, damages to local ecosystems, losses in biodiversity, water shortages, air contamination and an increase in global warming.

"Lithium can be described as the non-renewable mineral that makes renewable energy possible - often touted as the next oil." (Campbell, 2022).

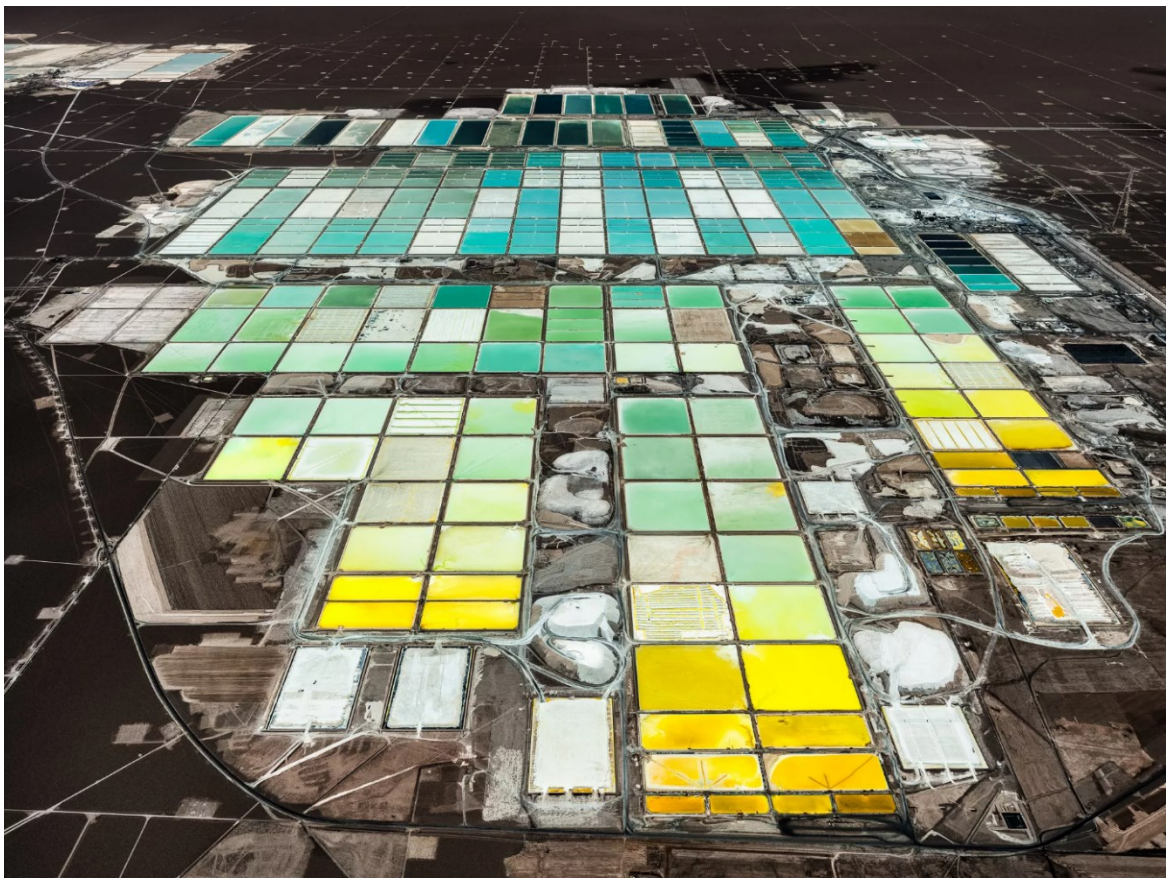


Figure 7, Lithium Fields' in the Salar de Atacama salt flats in northern Chile by Tom Hegen (Campbell, 2022)

Leaks at the end of use of these toxic metal contaminants are also frequent with (Gemes, 2021) noting that 95% of lithium-ion batteries make it to landfill (this statistic includes batteries from electronic devices). This can lead to underground fires and environmental damage from direct emissions and groundwater contamination.

However, the current status quo of battery technology will not last and efforts to move away from lithium-ion batteries are underway, (Campbell, 2022) illustrates that research is being conducted into salt, silicone, iron, magnesium and even hemp as alternative material-based batteries.

"One of the key challenges is the degradation of parts and materials, particularly when considering EVs. Estimates vary based on the materials and production methods used, but according to the Massachusetts Institute of Technology (MIT), emissions created during the production of the 80kWh lithium-ion battery found in a Tesla Model 3, for example, could range between 2400kg (almost two and a half metric tons) and 16,000kg (16 metric tons)." (Automotive Manufacturing Solutions, 2022)

Generally, EVs are cheaper to run than ICEs, particularly when charged at home, they also produce fewer direct usage emissions helping improve air quality in urban environments. However, for most consumers initial cost and range degradation are important limiting factors to be considered.

5.4 Summary and Evaluation

This analysis shows that OEMs are making tentative first steps into embracing the CE and employing i4.0 technology to achieve this. The scale-up of smart technologies will see this trend improve over the next decade with (Automotive Manufacturing Solutions, 2022) predicting full circularity by 2040. However, significant progress is still to be made with Figure 5 showing only a low level of circularity being applied currently.

In terms of manufacturing and design OEMs are still in the concept phase with cars such as the Citroen Oli offering a glimpse into the future but not being a production intent vehicle. Manufacturing will need a radical i4.0 inspired re-think in order to improve both efficiency and compatibility with the CE. Whilst Mazda focusing on manufacturing carbon neutrality and Renault focusing on re-used materials are positive steps, so far, no major OEMs are fully embracing the CE. Targets such as 2040 may seem far away but for the automotive industry this is only a few design cycles into the future, significant shifts in attitudes and perhaps governmental policy will be required to force change more quickly. Sluggishness in CE adoption is perhaps reflected in the sources referenced, often predicting or commenting on future and planned trends but rarely showing circular methodologies being presently applied.

OEMs will need to do more to take into consideration the full life cycle of the vehicle in a circular rather than linear context. Whilst cars have generally become more reliable and efficient, thus aiding the environment in terms of overall impact, significant steps are needed to completely re-develop the end-of-life cycle for vehicles. OEMs will need to follow the example of Toyota by refurbishing or remanufacturing used vehicles to increase their useful lifespan. Whilst the scrappage has become more efficient thanks to online databases improving information, traceability and the availability of components, OEMs will need to do more by utilising i4.0 to ensure that components can be easily identified, removed and re-used. The re-purposing of EV batteries is still niche and more work in required in this area to improve EV sustainability.

A big consideration for customers is cost, Appendix 1 Workings for lifetime vehicle emissions comparison shows comparable EVs to be more than double the cost of ICE cars on average. Initial cost is not the only consideration, depreciation affects all vehicles however in the current market EV's are typically depreciating at a higher rate than ICE's. Findings from (Hardigree, 2023) show that in 2023 the average car retained 66% of its original value whereas EVs retained only 45%. If a consumer decides to lease rather than buy then they are insulated from direct depreciation, however car dealers will raise the lease prices or interest rates according to market conditions in order to remain profitable.

EV's may suffer steeper depreciation than ICE vehicles, partly due to range anxiety induced by degradation but also due to higher initial cost vehicles typically depreciating more steeply than cheaper vehicles (Hardigree, 2023).

This research also highlights that the 'green' credentials of EV's can be met with some scepticism. Whilst they do emit less directly, the reduced practicality due to range means that on average they will be replaced by consumers more frequently than ICE vehicles as the calculations in Table 4 highlight.

However, the rate of battery development is significant, cleaner, lighter and cheaper batteries with improved ranges are emerging (Vinkhuyzen, 2023). With EV ranges improving concerns over battery degradation, whilst still an issue, can be mitigated and battery swap systems such as those employed by NIO (Ryan, 2023) can remove anxieties altogether. Early adopters will often take the brunt of the R&D costs and whilst EVs may not currently be a practical for all or be truly 'green', this is not to say that they won't be in the near future.

Whilst OEMs can rightly claim that EVs are 'greener' than ICE in terms of roadside emissions consumers should be able to take into account the full life cycle when making their decisions. As shown in this analysis, work is required to make the whole lifecycle of vehicles cleaner, sustainable and ethical. OEMs are making strives to produce cars that are more compatible with the CE, however currently there is no common tool or metric to measure these claims. It may take an external auditor to produce a framework to certify and measure the CE credentials of vehicle, much in the same way that NCAP benchmark the safety of a vehicle and the EU set the European Emissions Standards to measure vehicle pollutants.

6 Applying Artificial Intelligence & Smart Systems to the Automotive Sector.

This section will delve into how AI and Smart Systems can be applied within an automotive industry context to gain a full understanding and opportunities and limitations.

6.1 What is Artificial Intelligence?

AI is defined by (McKinsey & Company, 2023) as "*a machines ability to perform the cognitive functions we associate with human minds".* In 'big tech' there is growing consensus around the following categories of AI, they are defined by (Saracco, 2023) as follows.

- Artificial Narrow Intelligence (ANI) "better than humans in one specific task, e.g autonomous driving".
- Artificial General Intelligence (AGI) "capable like humans in every task".
- Artificial Super Intelligence (ASI) "better than humans in every task".

AI in Automotive use is generally confined to specific areas such as ADAS. Autonomous Driving (ADAS) is already advancing with trials and government approval pending for further development, integration and adoption. However, there are ongoing discussions and concerns about safety from trial cities such as San Francisco (Shepardson, 2023).

As (McKinsey & Company, 2023) shows, generative AI could also be used for personalised marketing, technical sales content as well as generating text, images and videos. In terms of engineering generative AI can be used in CAD to optimise models from strictly defined parameters as well as being used to review code and write technical documents. The AI currently proposed for use in the automotive industry generally falls into the ANI category.

6.2 What are Smart Systems?

Smart Systems are defined by (SSi, 2023) as "miniaturised systems, combining data processing with multi-modal (optical, biological, mechanical) sensing, actuation and communication functions".

Smart systems can be understood as the physical manifestation or hardware interface between digital software and computing advancements such as AI, The Cloud and the IoT. Smart Systems enable tangible interconnectivity between the cyber and the physical (CPS), allowing theoretical gains to become reality in both manufacturing and vehicle usage.

In an automotive context Smart Systems can be used to aid communication between self-driving vehicles and smart cities whilst also improving performance between autonomous manufacturing systems, robots and M2M learning in smart factories. With advancements in technology and reducing costs it is now easier to implement human to robot interfaces with real time AI based responses.

Smart factories can employ Wi-Fi and 5G connected Smart Systems such as sensors and cameras for live feedback and data. Modular and flexible layouts enabled by Smart Systems will allow production to continue with minimal disruptions through unforeseen downtime. Modularity in factories, machinery and car design will also reduce complexity, costs and improve servicing.

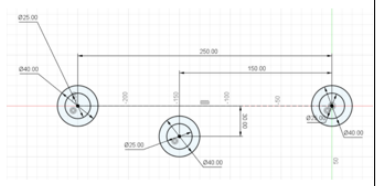
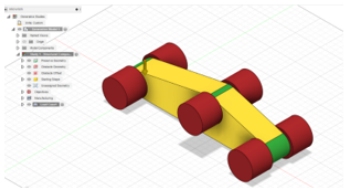
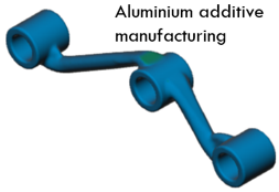
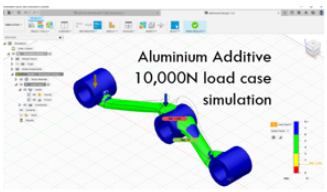
6.3 Uses for AI and Smart Systems within Automotive Design and Manufacture

The following examples show how AI and Smart Systems can be used within the Automotive Industry for Design, Engineering and Manufacturing.

6.3.1 Generative AI for Engineering

Generative AI embedded in CAD software can be used to optimise the design, development and engineering of components such as the example in Table 5. Within defined parameters set by the engineer iterative simulations via Cloud processing can find the optimal shape and design of a component. These parameters may include criteria and limits such as weight, strength, material, size, machining or manufacturing processes and costs (PTC, 2023).

Table 5, Control arm iterative design, created by Nefyn Roberts for a UWTSD MSc exercise in the Generative Design Module.

Process of an Iteratively designed control arm using Autodesk Fusion 360.		
First the contact points are sketched in 2D CAD and extruded in 3D. Next limits are set (red), the preserve area is stated (green) and space for generative design is defined (yellow).		
Parameters such as strength, weight, material, cost and manufacturing process are set. The software then iteratively develops optimised concepts, several solutions may be offered.		
FEA simulations can then be run to determine the suitability of the shape and materials for the task required of the component. In this instance a vertical force of 10kN is directed on the centre.		
The most suitable concept for the pre-defined parameters is then selected for prototyping, testing and manufacturing.		

6.3.2 Generative AI for Design

Generative AI can also be used for design to create images based on a set of user defined prompts. For the automotive industry it could be used early in the design process to quickly generate concepts and ideas to base a new model. If the design is more advanced, then it could be used for marketing materials to show a vehicle in a given context without the need for travelling to a specific location with the vehicle and a photographer.

Bings image creator is powered by Open AI's DALL-E, regarded by (Guinness, 2023) as one of the best for AI image generators and Gencraft is a competitor platform. Table 6 and Table 7 compare Bing and Gencraft from the same prompts (see Appendix 2 Interior Design Generative AI Data and Appendix 3 Exterior Design Generative AI Data for higher resolution). Each systems results may be refined by altering the prompts, however for the purpose of this experiment the prompts were kept the same.

Bing creates 3 to 4 low resolution images from each prompt whilst Gencraft creates 2 high resolution images for each prompt.

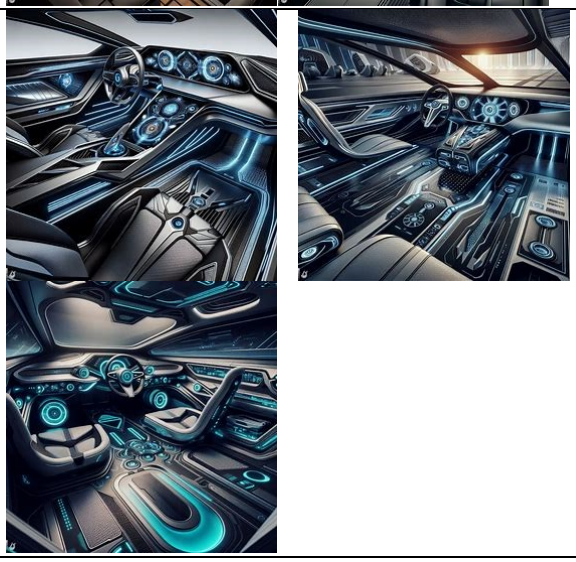
6.3.2.1 Car interiors Generative Design

Gencrafts AI comes closest to convincingly replicating automotive interiors, particularly example 1, 2 and 5 although it is largely down to mimicking existing ideas instead of showing genuine creativity. For examples 1, 2 and 5 Bing also draws from existing interiors whilst adding its own modifications, however this can come across as cluttered and impractical. When prompted to follow defined styles such as Art Deco (3) or Bauhaus (4) Gencraft AI comes up with interesting concepts rooted in vintage car interior design whilst Bings interpretations are more conceptual (4) and steampunk inspired (3).

For initial mood boards and idea generation, generative AI has its place and can save artists and designers hours of labour in conceptual art. Overall Gencraft does a better job in interpreting the prompts and creating feasible car interiors, whilst Bings designs may work better in a more conceptual environment. At this stage real artists, designers and engineers would still be required to work collaboratively to ensure that designs are functional, practical and feasible.

Table 6, AI generated interior concepts.

Interior Design Prompts	Bing AI image generator	Gencraft AI image generator
1. An expensive and modern car interior for a luxury Range Rover using leather, oak wood and brushed aluminium materials.		
2. A cheap car interior for a budget brand using grey plastics and a minimalistic layout.		

3. A car interior inspired with art deco design influences.		
4. A car interior inspired with Bauhaus design influences.		
5. A futuristic car interior inspired with science fiction design influences.		

6.3.2.2 Car exterior Generative Design

For the exteriors, Bing does a superior job interpreting a 'modern' interpretation of an E-type in example 'A', with Gencraft being closer to an exact copy of the original. For prompt 'B' both are closer in shape to the VW Golf rather than the Renault Clio although more elements can be seen in Bings interpretations. The abstract prompts create the biggest differences in output, in 'C' and 'D' Gencraft creates designs based on vintage cars. Bing draws from steampunk styles in 'C' whilst for 'D' takes influences from Audi and VW in car shape whilst transposing Bauhaus paint schemes onto them. With example 'E' Bing creates examples in an exaggerated concept art style whereas Gencraft's designs are more akin to current production vehicles.

It is worth noting that generative AI is still in its infancy, and it is likely that this is the most primitive that it will ever be. From this perspective AI can offer fascinating and exciting development opportunities in the near future. With refinement to prompts and commands and an iterative approach users could achieve results close to their preferences and expectations.

Table 7, AI generated exterior concepts.

Exterior Design Prompts	Bing AI image generator	Gencraft AI image generator
A. A modern reimagining of the Jaguar e-type retaining the classic shape.		
B. A budget brand hatchback car with modern styling similar to a VW Golf and a Renault Clio.		

C. A car exterior inspired with art deco design influences.		
D. A car exterior inspired with Bauhaus design influences.		
E. An SUV exterior inspired with modern design influences rugged off-roading abilities.		

6.3.3 Generative AI for Technical Documentation

Open AI's Chat GPT and Googles Bard are regarded by the some of the most advanced and sophisticated AI chatbot systems (Abdullahi, 2023). The AI systems were set identical prompts to role-play scenarios (tabulated in Appendix 4 Technical Documentation Generative AI Data (tabulated and edited)), to create automotive related technical documentation (see Appendix 5 Technical Documentation Chat GPT Generative AI Data uneditedand Appendix 6 Technical Documentation Bard Generative AI Data unedited.for the raw data).

In Scenario 1 Chat GPT and Bard create a technical document for fitting a vehicle door. Both systems quickly produce detailed step-by-step guides whilst also creating lists of equipment needed and specifying due diligence via quality checks at the end of the process. Scenario 2 asks the AI to produce a health and safety documents for factory visitors, both produce thorough and professionally set out documents that could be readily edited and modified according to specific needs. Both systems successfully create DFMEA (Design Failure Mode and Effects Analysis) templates in scenario 3, a standard engineering document used during design and development. The DFMEA tables can suitable to be used immediately by the user and Chat GPT even sets out the structure of the DFMEA process.

The prompt in scenario 4 asks for the creation of user manual for car seat adjustment. Chat GPT creates a succinct and useful guide that covers the main features of the seat and advises the user with how to proceed. Bard performs similarly but adds more detail and includes images to help guide the user. However, Bard also includes links that aren't necessarily useful or relevant such as one to seat adjuster for sale on eBay and one of the pictures uses an office chair which is not relevant for a car seat.

Scenarios 5 and 6 ask the AI to create code for adjusting the duration of a vehicles exterior lighting, prompt 5 is broader with 6 specifying Python. In scenario 5 Chat GPT suggests using the infotainment system as a suitable access point and creates an example Python script. Bard does not fully understand the initial request and produces no code, instead advising connecting to the vehicle ECU to adjust settings. In scenario 6 Chat GPT creates code different from the first example, in both instances ChatGPT recognises that a specialised tool or interface would be required to adjust these settings. Bard does produce code in Python in scenario 6, as specified in the request, and also recognises that ECU connectivity via software or a tool would be required. Both systems are able to create code, and both recognise that driver user interface intermediaries are required to adjust these settings. However, Engineers should be cautious that the code offered by these AI services may not be correct and can vary depending on the prompt so would need to test them first in order to achieve optimal results.

6.3.4 Predictive Maintenance (PdM),

PdM can be achieved by integrating Smart Systems with AI, as (Lakshmanan, 2021) notes, the cost of scheduled or unscheduled downtime can cause serious financial setbacks. By using PdM industrial equipment can be monitored in real time and the probability of failures can be predicted, once a machine passes a predetermined threshold replacement parts or servicing can be scheduled.

These examples by (Andersson, 2023) show both the advantages and challenges of incorporating PdM.

6.3.4.1 PdM Advantages

- Increased 'uptime', with proactive measures and repairs. Algorithms learn patters from past breakdowns and predict when equipment will likely fail.
- Cost savings by reducing 'downtime', preventing expensive reactive repairs and reducing scrap and delays from breakdowns and failures.
- Improved safety, by reducing failure risks potential safety hazards can be avoided.

- Increased efficiency, PdM plan optimisation can reduce the resources and time needed to repair equipment.
- Extended Equipment lifetime by identifying problems early before significant damage through failure modes.

6.3.4.2 PdM Challenges

- High cost, to implement PdM investment in sensors, software and data gathering equipment plus testing and verification are required.
- Complexity, the significant data and analytics required can be difficult for users to interpret.
- Data accuracy, the validity of data can be compromised by numerous factors. Unless filtered incorrect data could result in unnecessary servicing or repairs.
- Limited expertise, PdM requires specialised training or external experts for the recommendations to be interpreted accurately.
- Long implementation time, months or years' worth of data may be required for a sufficient PdM sample size. If machinery or processes are changed then the cycle restarts.

6.3.5 Manufacturing optimisation

AI can be utilised to improve productivity within the smart factories through production line optimisation, defect detection and quality control (Wizata, 2023). Digital Twins can be created with Big Data to find optimal solutions for process routes and factory layout. It's noted by (Mitchell, 2023) that AI can be used to make better decisions in real-time such as production planning, resource sharing and product development. Smart Sensors and CPS combined with the IIoT will gather large amounts of data, AI can then filter this to suggest productivity or process improvements. As AI becomes more sophisticated the re-designing of components to improve cost, quality or manufacturing time as well as suggestions for optimised processes, factory layout or new machinery may become possible.

6.4 How can AI and Smart Systems be used by Automotive Users?

6.4.1 ADAS

Perhaps the most obvious use for AI in the Automotive Industry is via Advanced Driver Assistance Systems (ADAS). Through a combination of AI integration with smart sensors, 5G, Big Data and CPS cars will be able to autonomously navigate with minimal to zero driver assistance.

6.4.2 Customer Service

AI could be used as a customer service tool, making suggestions or assisting customers based on the feedback provided or queries made.

Due to the broad scope of AI, it can often draw answers from anywhere on the internet. However, AI results can be fine-tuned via "Few-Shot Learning" (Sheer, 2023), effectively creating a wall around the search criteria so that the data drawn upon is narrowed down. This can enable customer queries to be delt with accurately and if a query is not covered or recognized by the initially outlined criteria, then the customer can be passed on to a human customer service employee.

AI will help filter queries to the correct departments more efficiently or answer questions without the need of human-to-human interaction. The examples in Appendix 7 Customer Service Generative AI Data (tabulated and edited show how effective AI systems ChatGPT and Bard, instructed to act on behalf of Jaguar Land Rover (JLR) customer service, can be in this role.

In the first example the 'customer' asks the AI to recommend a family friendly JLR vehicle for less than £50,000. Chat GPT provides and accurate and succinct reply whilst Bard goes into more detail and even provides pictures and links to the vehicles. However, Bard erroneously recommends a Defender that retail over £50,000 (Landrover, 2023).

For the second prompt the AI is asked to recommend a JLR sports car or sports saloon between £50,000 and £65,000. Once again ChatGPT responds succinctly whilst Bard is more comprehensive and detailed.

The third prompt asked the AI to book a customer's existing Range Rover Evoque for a service close to their home (Flint, North Wales). For this both systems correctly note that they are not capable of booking on behalf of the customer but recommend nearby approved garages. Chat GPTs garage recommendation is closer than Bards however Bard does provide a Google map link and image of the location.

In the fourth prompt the customer reports an issue with their cambelt and requests for their Evoque to be booked into a nearby garage whilst also asking an approximate quote for the repair. ChatGPT doesn't recommend a local garage, advising instead seeking out an approved JLR dealership or a trusted local mechanic, it also doesn't provide an estimated cost. Bard does not recommend a local dealership and even encourages going to an independent garage to save costs. Bard does however provide approximate part and labour cost which would be helpful for the customer.

The fifth example was made to be deliberately ambiguous to simulate non-technically minded customers describing a dashboard light appearing, Figure 8. For this the customer describes it as resembling a 'red genie lamp', in both instances ChatGPT and Bard fail to interpret the description correctly. ChatGPT indicated that it may be a charging issue or problem with the electrical system and Bard identifies it as an engine overheating issue or various electoral failures.

Figure 8, dashboard light (LAND ROVER ENGLEWOOD, 2023)

The final prompt asks the AI to identify a mechanical failure based on the approximate location, sound and feel described by the customer. In this case both ChatGPT and Bard correctly identify it as a suspension related issue and recommend getting it inspected by a qualified JLR dealership and technician.

Overall, both AI systems work remarkably well in their given roles providing mostly detailed and accurate answers. If OEMs choose to use AI in future for their customer services, it will be relatively easy for them to include features such as booking functionality. OEMS will also need to ringfence the

possibilities of answers to refine the system and employ few-shot learning before allowing a full-scale rollout. These examples show that he possibilities of AI are just scratching the surface and in the near future could be entirely capable of replicating humans for such interactions.

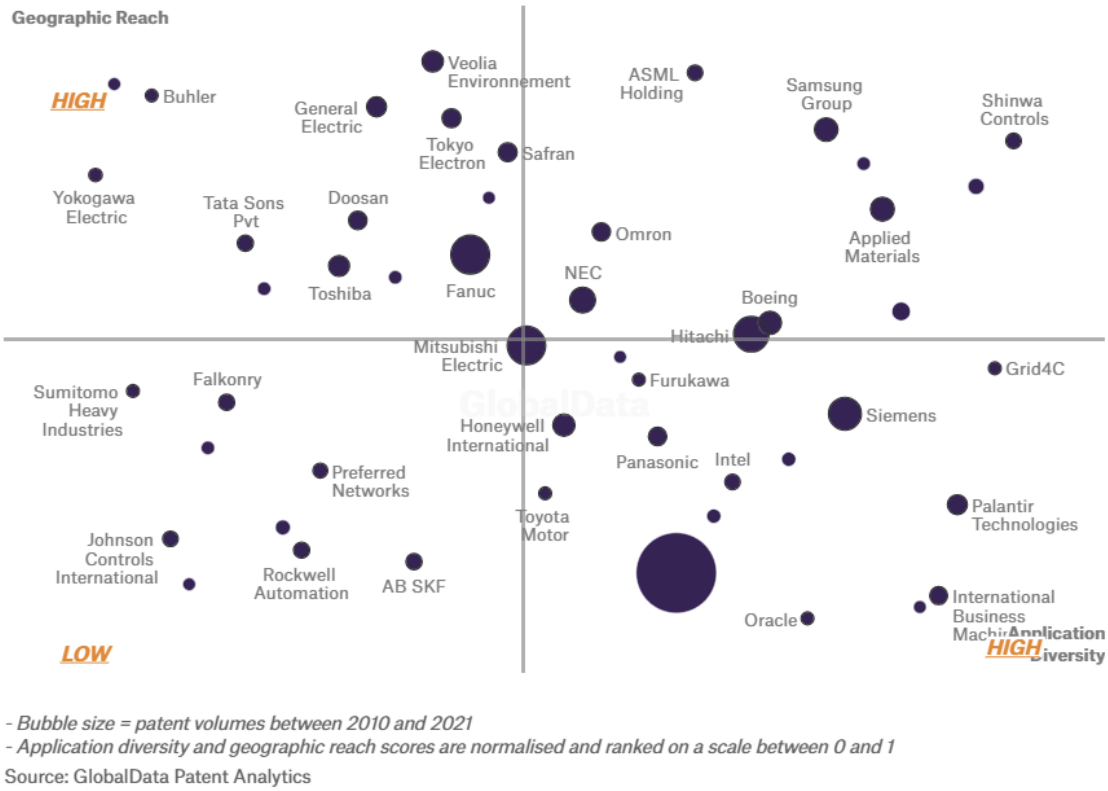
6.4.3 Diagnostics

Smart systems and sensors can be used to perform detailed vehicular diagnostics in real time (Martinez, 2021), an improvement on the currently dashboard warning light that can be vague. AI can be utilised to communicate with the driver to make recommendations, answer any questions and provide additional details, it could also pre-emptively contact the dealer or recommend local garages. This free's the driver from checking the handbook and finding a garage to diagnose the issue.

UVeye an external car inspection service powered by AI and backed by General Motors has been developed (Gastelu, 2023). A car travels through an MRI style scanner and, using deep learning, can inspect 70% of the standard multi-point inspection areas on a vehicle and produce a service report within seconds. The technology can detect tread depth and interpret steering alignment based on uneven wear. Oil leaks, broken or worn parts and stress fractures can also be identified quickly though these scans.

6.4.4 Vehicle Predictive maintenance

Rather than cars just sensing faults as they occur AI could be utilized within vehicles to predict wear and failure based on a combination of mileage, sensors, driving style and big data via The IoT. As noted by (Lakshmanan, 2021) PdM in vehicles can recommend or schedule repairs and checks for the customer before breakdowns occur. As (GlobalData, 2023) highlights, Figure 9, a number of companies ranging from 'big tech', Automotive OEMs and Tier 1 suppliers are investing in PdM systems that use a combination of past service records data, M2M learning, smart sensors and the IoT to establish accurate predictions for users and manufacturers.



- Bubble size = patent volumes between 2010 and 2021
- Application diversity and geographic reach scores are normalised and ranked on a scale between 0 and 1

Source: GlobalData Patent Analytics

Figure 9, Predictive Maintenance Patents 2010-2021 (GlobalData, 2023)

6.4.5 Automated smart charging

With EV's becoming more prevalent the charging duration and time of charging are becoming more important. Home chargers are already switching off at peak times to avoid blackouts (Mullen, 2021), and by using AI and the IoT the time to charge overnight can be arranged between vehicles and networks to coincide outside of peak hours to reduce electricity costs and also demand on the grid.

When in use EV's can identify the nearest charging points, by having internet connectivity this could be taken a step further to identify optimal charging stations enroute and even pre-book charging station slots to avoid the driver needing to wait for a space or from stopping prematurely due to range anxiety.

6.4.6 Customer vehicle interface

Whilst voice recognition is not new in vehicles it has been limited to simple tasks such making calls or changing radio stations. These voice commands often require clunky predetermined phrases, and the system can be "*distracting and unreliable*" (Nelson, 2014). Google and Continental are proposing to improve this through AI which will allow drivers to talk more naturally with their vehicles (Crosse, 2023). JLR have recently adopted Amazons AI based Alexa to be built into their vehicles Pivi Pro infotainment systems (Landrover, 2023), enabling drivers to control aspects of the cars user-interface hands free with greater reliability and functionality than older systems. Internet connected systems such as Alexa have significant benefits as they can be regularly updated and improved.

6.5 Future Scope for AI uses within an Automotive Industry

6.5.1 Personalised and targeted Advertising.

With data gathering through apps becoming more prevalent targeted adds are now commonplace for many social media users (Meta, 2023). Automotive companies can tap into this trend by not only advertising to prospective customers directly through apps but by also using AI to personalise ads specifically to the intended target audience. The examples in Table 8, and Appendix 10 Personalised Advertising Generative AI Data, generate personalised advert images based on a social media users lifestyles, circumstances and preferences.

The first prompt asks Bing and Gencraft to create family relevant advert images for Volvo. Bing creates a concept closer to the intended theme whereas Gencraft, quite worryingly, shows children about to walk in front of a car. However, the Gencraft depiction of the Volvo X90 is more accurate.

The second example targets a British person interested in a sports car, both AI systems interpret the limited prompt well with Bing's representation closer to a Mazda MX5 and Gencrafts images more representative of a Jaguar F type. These examples show how specifically identifying the target car can ensure a more accurate generation as per the requirements specified in prompts 1, 3 & 5.

Prompt 3 targets a metropolitan worker interested in a sports coupe, specified as an Audi A5. Gencraft shows more accuracy in terms of vehicle shape and also varies the colours and city details in its examples whereas Bing's examples are generic and focus on the city as much as the car.

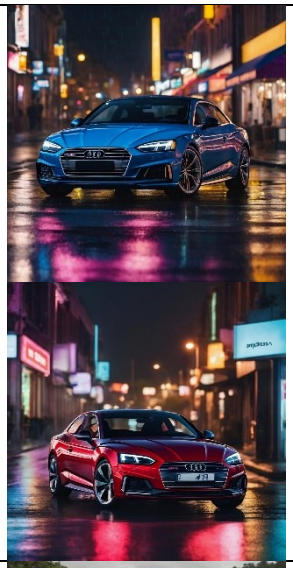
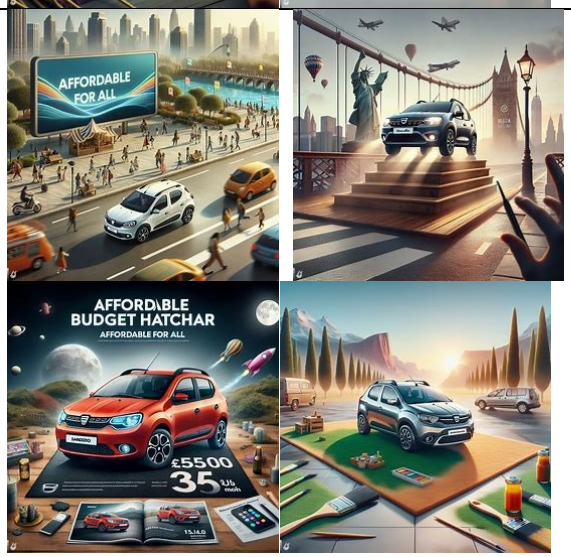
Prompt 4 targets a farmer interested in a 4x4 or pickup truck. Gencrafts interpretation is close to the brief by focusing on the vehicle in a farm environment. Whereas Bing focuses more on the farmer than the vehicle, so the advert purpose is not immediately obvious. The prompt didn't specify a vehicle brand or age, so it is interesting to note that Bings examples look modern whereas Gencrafts prompts are inspired by older vehicles.

Currently image generators are not yet well refined at generating text, however the fifth prompt attempts to add a slogan onto the advertisement as well as a targeted image. Whilst not perfect and displaying grammatical errors Bing interprets these prompts better than Gencraft, which ignores the tag line altogether, and creates what at quick glance appears to be a passable advert.

These examples show that personalised AI advertising may not be far away. AI with predetermined and specific prompts combined with data mining and fine tuning via "Few-Shot Learning" (Sheer, 2023) will see adverts generated for specific target audiences. With further advancements generative text AI may be combined with generative image AI to create accurate adverts with up to date and relevant information and data.

Table 8, AI generated personalised advert concepts.

Advertising Prompts	Bing AI image generator	Gencraft AI image generator
i. A mother picking up her young children from school in her Volvo XC90.		
ii. A convertible sports car driving in the English countryside at sunset.		

iii. An Audi A5 in a neon lit city at night in the rain.		
iv. A 4x4 or pickup truck advert targeted at a farmer.		
v. Create an advert for a modern budget hatchback such as the Dacia Sandero with the strap line “affordable for all”.		

6.5.2 Automated Vehicles (ADAS level 5)

ADAS level 5 is a paradigm shift in the automotive industry that enables cars to drive completely autonomously. Companies such as Uber and Waymo are investing significantly in these technologies and trials of ADAS level 4 driverless taxis are being trialled in San Francisco (Bhuiyan, 2023).

ADAS Level 5 could see the model of car ownership becoming a thing of the past, much in the same way that the music industry has been transformed with steaming services. There are examples today in cities where cars can be rented for short periods, such as Zipcar and Uber-rent (Ocasio, 2023), however these cars are not autonomous and have to be picked up and dropped off from specific locations. With level 5, the cars could autonomously drive back to a charging or service depot or onto the next customer. According to (Barter, 2013) cars spend 95% of the time parked, such a system would allow OEMs to produce fewer vehicles whilst increasing usage and profitability per vehicle. OEMS could introduce a subscription service with customers able to upgrade the vehicle they use or the number of hours of usage depending on their subscription package.

6.6 Summary and Evaluation

This research has shown that AI and Smart systems are gradually being adopted by OEMs with significant advances and applications i4.0 on the horizon. There are instances of OEMs of using smart systems and AI within factories and vehicles, however they are often sporadic and in isolation.

Generative AI has shown that it is already very capable at quickly creating technical documents and refining engineering CAD models. AI tools can also be a good starting point for coding; however, at this stage experienced programmers are still required to verify proposed solutions. Likewise, AI image generation and design results are impressive but are not yet ready for commercial or design use.

With adequate ringfencing and refinement AI systems have displayed enough capabilities to suggest that they are already advanced enough for customer service and interface tools. However, users must be cautious with these AI tools, exact and specific prompts are required in order to receive consistent and repeatable results, and this can vary from one AI system to another.

The emergence of powerful AI technologies may be the catalyst required to create i4.0 'Smart Factories'. Advancements in analytics, diagnostics and PdM using Smart Systems and AI will be crucial for improving upon established and successful manufacturing models.

OEMs will need to embrace AI, Smart Systems and i4.0 more generally or be at risk of being left behind, however it is not yet clear what specific areas need to be targeted first in order to maximise potential.

7 Applying the Cloud and the Internet of Things to the Automotive Industry

This section will examine how The Cloud and the IoT can be utilised in key automotive sector such as supply chain, sourcing, manufacturing and vehicle use.

7.1 Vehicle Use

One of the most obvious applications for The Cloud and the IoT is within vehicle use. With 5G vehicle connectivity, Vehicle to Vehicle communication (V2V) and ADAS advancements a "*wide range of possibilities*" (Martinez, 2021) will be on offer. V2V communication enables cars to pool processing and data gathering, becoming a hive of live data and information rather than single unconnected nodes.

7.1.1 ADAS

ADAS vehicles could use V2V data to optimise their routes, speeds, parking location and allow the creation of intelligent cities and highways (Martinez, 2021) via the IoT. The data can allow ADAS cars to safely maintain their speed and distance from others via adaptive cruise controls and help to reduce emissions and energy usage (Gautam, 2023) and if taken further could allow vehicles to safely draft one another, reducing air resistance and improving efficiency.

7.1.2 Vehicle connectivity

The 5G Automotive Association (5GAA) is a combination of telecoms companies, major OEMs and technology companies designed to create the infrastructure for vehicular internet connectivity (Martinez, 2021). This will enable V2V, V2I and V2P (vehicle to vehicle, vehicle to infrastructure and vehicle to pedestrian) connectivity via The Cloud and IoT, allowing the creation of smart cities and the advancement of smart vehicles. Tesla already have internet connectivity to their vehicles via Wi-Fi, this allows updates to software and vehicle features to be downloaded (Tesla, 2023) to improve performance and user experience.

7.1.3 Subscription services

Audi and BMW have been exploring "on demand" purchase upgrades or subscription services to their vehicles such as heated seat subscriptions (Hull, 2023). Such schemes are not without their critics and after significant backlash following the proposal BMW has made a U-turn on this idea (Charlton, 2023). However, that is not to say that such services will not exist in the future. As OEMs look to improve both the lifespan and profitability of their vehicles similar services could be offered and enabled by Cloud and IoT connectivity.

7.1.4 Digital Twins

Siemens use digital twins optimise vehicle product development to aid performance and efficiency without needing physical testing or prototyping (Siemens, 2023). Taken a step further, an online digital twin with a unique blockchain ID could be assigned to a vehicle, data collected via the IoT could then keep an online record of service life and use (Nishanth, 2023). This information could also feed into a centralised OEM databases to aid PdM. Vehicle data could also be shared to the owner and to prospective purchasers to confirm validity of servicing, vehicle mileage, age and condition.

7.2 Smart Factories

Cloud and Industrial IoT (IIoT) integrated Smart factories are the nest logical next step for OEMs in i4.0 manufacturing development. Smart Factories can also be managed and controlled 'remotely' from a central hub of operations, Tesla as noted by (Cook, 2021) are key proponents of this innovation.

7.2.1 Manufacturing Flexibility

With implementation of the IIoT in the automotive industry, Flexible Manufacturing Systems (FMS) offer opportunities to move away from traditional linear or cellular process routes towards in order to maintain profitability and competitiveness (Cronin, et al., 2019).

CPS are integral for IIoT and i4.0 implementation as they allow the collection of real time data. Through the use of sensors, Autonomous Intelligent Vehicles (AIV), robots and IIoT frameworks smart factories can autonomously ramp up or down production based on demand. OEMs and suppliers must incorporate horizontal and vertical integration systems in order to have the capabilities to adapt quickly and release new products in cost effectively way. Such a radical approach is a challenge (Cronin, et al., 2019) but is required to provide greater flexibility to customers and smart manufacturers.

The key element to achieving Smart Manufacturing as cited by (Cronin, et al., 2019) are IIoT and The Cloud use of Big Data analytics, AI, 5G, AIV's, CPS and Digital twins. By combining all of these key component's aspects of manufacturing can becomes interconnected and integrated to a centralised hub whilst also adapting independently in real time. Smarter and more flexible manufacturing methodologies also reduce the cost impact of design changes to either the vehicle or the implementation of new machinery into the plant.

Smart sensors combined with Cloud stored data can aid in improving quality and reducing scrap. AI can be used to analyse live data to quickly and form a Failure Mode Element Analysis (FMEA) on a particular process or processes in order to determine the cause of a defect. An Alert can then be raised to the engineering team and system operators in order to fix the problem or find a solution to the quality issue.

7.2.2 Modular Manufacture

Three modularity concepts in the automotive industry are defined by (Pandremenos, et al., 2009) as Modularity in Design (MID), Modularity in Use (MIU) and Modularity in Production (MID).

- MID, a products physical and functional architecture.
- MIU, consumer driven satisfying ease of use and individuality.
- MIP, factory floor modularisation, components assembled off-line and then brought together for final assembly.

Reducing costs in technologies can also enable factories to become 'smarter' more flexible and modular (MIP). Automated trollies Figure 10, developed by (Toyota Forklifts, 2023), can carry components around the autonomously around smart factories.

EV start up Arrival is planning on installing several "*micro-factories*" around the world (Arival, 2023), with MIP scalability and repeatability being key components. Arrival state that their micro-factories decentralise production and claim that local supply chains can reduce environmental impact whilst being profitable from lower volumes. This is break from the traditional large 'centralised' and fixed manufacturing hubs from established Automotive OEMs.

Tesla with their planned Giga factories in Mexico and Germany, expected to cost $10 billion and $5.5 billion respectively (Rapier, 2023), may sound antithetical to MIP. Teslas "unboxed" system uses MIP

by building modularly in parallel rather than the traditional series production line *"pioneered by Ford"* (Weber, 2023) and their 'giga presses' use MID to eliminate individual stamping and fabrication processes.

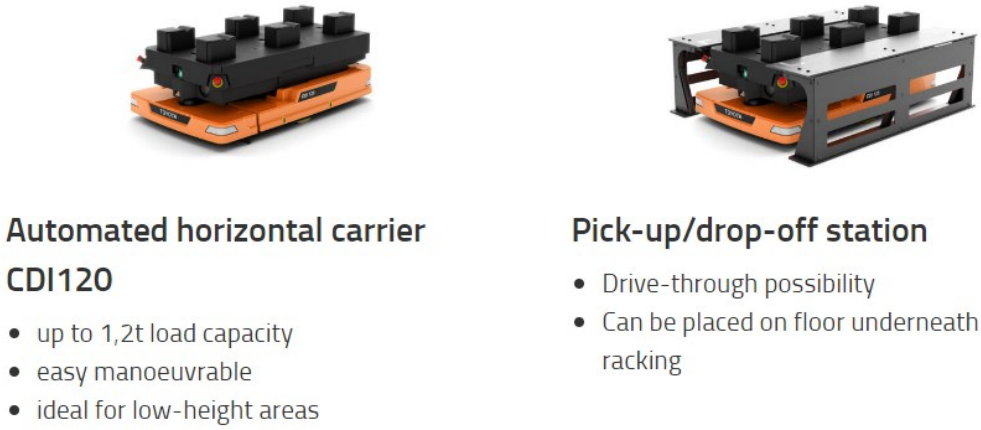


Figure 10, Automated Pallet Carriers and dock (Toyota Forklifts, 2023).

A growing MID trend within the industry is to modularise chassis', drivetrains and components so that OEMs can produce vehicles of different models or brands on the same production line per. MIP utilising Cloud Connectivity and the IoT can deliver components right on time for specific makes, models as per the MIU customer specification. An example of this is the partnership between Peugeot, Citroen and Toyota with the same plant in the Czech Republic producing the 107, C1 and Aygo which share around 70% of their parts (Gill, 2014). Likewise, VW Audi group have used a modularised MQB and MEB architectures, Figure 11, to produce cars for VW, Audi, Skoda, SEAT and Cupra (Shah, 2021).

By adopting these modular synergies OEMs can offer greater levels of MIU at lower cost as cars can share components, software and features across multiple platforms and specification types.

Figure 11, VW Group modular architecture (Shah, 2021).

7.2.3 Digital Twins

For Automotive manufacturing digital twins can be a precise virtual model of a vehicle or a production plant (Cook, 2021). This can allow designers to visualise the layout and material flows digitally whilst identifying bottle necks. Digital Twins can also be used to show the impact of design changes to either the vehicle, assembly or the factory, they can then simulate various scenarios to eliminate physical trials and reduce the need for physical prototyping. There are 3 types of digital twins identified by (Cook, 2021), product, production and performance. By integrating them OEMs can create a 'digital thread' that combines data from all product and production lifecycles.

7.2.4 Surveillance Capitalism

Whilst i4.0 implementation offers productivity improvements and can help in identifying hidden factories it is not without its sceptics and critics. It is highlighted by (Cook, 2021) that there are concerns regarding smart factories defined as the 5P's by Zuboff in '*The age of surveillance capitalism*' which can lead to the dehumanisation of employees, the 5Ps are as follows.

1. Privacy, the human experience can be greatly affected by the IoT and coercive networks.
2. Pervasiveness, identity in 'Smart Factories' can be rendered as information control.
3. Prediction, the core of surveillance capitalism turns data into control creating digitally informed views that the individual mimics.
4. Performativity, as thesis that assumption-based models affect what they purport to describe creating a cycle of data aligned more to theory than the reality.
5. Purposelessness, demotivated employees deprived of agency lacking in motivation due to the implementation of AI robotics.

7.2.5 Part Identification

With factories becoming smarter and more automated it is crucial that both CPS and humans can quickly identify parts correctly. Most Part Identification Systems use local software for readers to identify the corresponding component. By having 'smart' identification systems linked to The Cloud via 5G, parts and assemblies can be accurately followed within the manufacturing process, they can also have a unique digital twin counterpart that can be used to create a full digital twin model vehicle thus incorporating them fully into the IIoT.

Different technologies can be used to identify parts, outlined by (Yuldashev & Solovev, 2023), these include:

7.2.5.1 RFIDs

Radio Frequency Identification (RFID), wireless communication via radio waves to uniquely identify objects. RFID systems require a reader, a tag and software that stores the received data. As RFIDs work through radio waves they don't need direct line of sight to be identified by the reader and the tags can be detected when stationary or moving.

7.2.5.2 NFCs

Near Field Communication (NFC), evolved from RFIDs NFC uses magnetic transmitters rather than radio waves. Similarly, NFC requires a reader, a target (tag, sticker, fob etc) and embedded software. NFC's are shorter range than RFIDs and can only be read 1 at a time, however they benefit from 2 way communication and can convey more complex data, Figure 12.

7.2.5.3 Barcodes

Barcodes have traditionally been used to quickly identify objects and are very cheap. Barcodes require an optical scanner with a direct line of sight. Disadvantages of barcodes can be labels getting damaged, lost or misplaced and that the data conveyed is limited.

7.2.5.4 QR codes

QR codes use vertical and horizontal space so can convey more data than barcodes via optical scans, however QR codes suffer many of the same disadvantages as barcodes.

7.2.5.5 Wired ID chips

Wired ID Chips work in a closed loop system making them more secure and can be used as an RFID and NFC alternative, however they cannot be read remotely and require smart cards or touch memory devices to be read.

7.2.5.6 Wi-Fi

Typically used for more local systems than tracking devices, Wi-Fi receivers have a long range but require more energy than passive systems such as RFID and NFC tags.

7.2.5.7 Bluetooth

Normally used for connecting smart devices such as home entertainment, Bluetooth beacons suffer the same disadvantages as Wi-Fi in terms of energy usage.

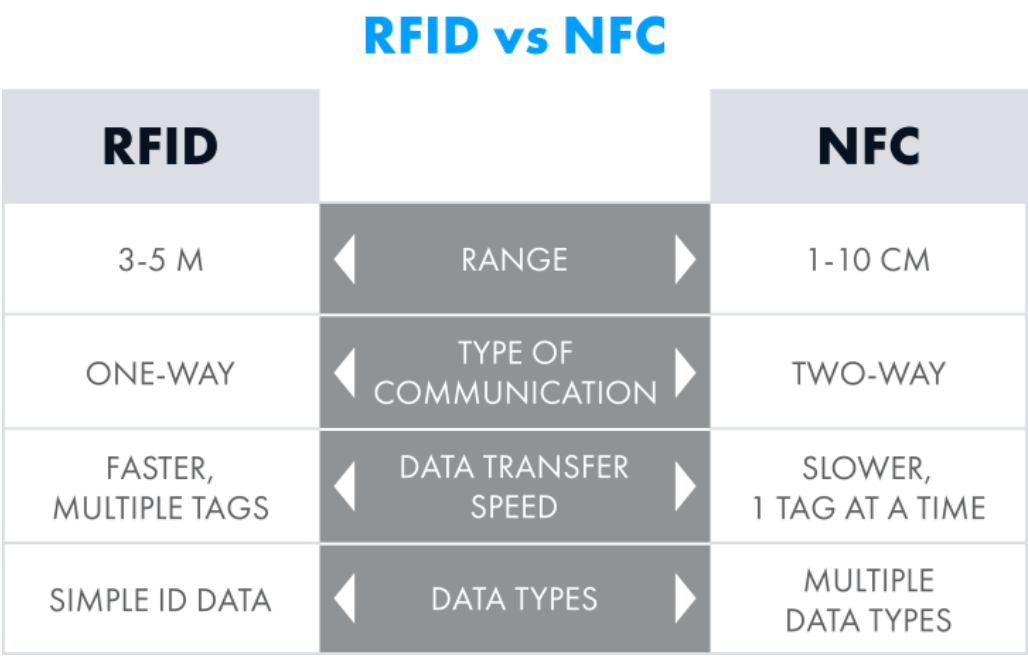


Figure 12, RFID vs NFC (Yuldashev & Solovev, 2023)

Easily identifiable components have benefits later in a vehicle's life. Once scanned the data can be stored into the cloud as part of a full vehicle digital twin, service life and use of a part can then be digitally tracked. This feeds into PdM, enabling decisions to be taken with a greater level of available data. Smart Identification via the IoT will give OEMS, dealers and customers a greater understanding of the history, age, condition and specification of the components within a vehicle.

7.2.6 Part tracking

Part Identification systems can also be used to track components throughout the manufacturing process from raw material processing, assembly to packaging and shipment (Yuldashev & Solovev, 2023). Using a combination of QR codes, RFIDs and NFCs individual products or pallets of products can be tracked with their location updated with 5G connectivity to the IoT. This information can then be communicated in real time to ensure that parts are compliant with Just in Time (JIT) methodologies and moved to the correct location at the correct time for assembly.

This greater level of data can be used to understand an accurate picture of a vehicles total environmental impact. Tracking systems used throughout a vehicles life can contribute to the improvement of a vehicles serviceability, recyclability or re-useability by digitally recording this data allowing lessons to be learned for future iterations. OEMs can the use this data to proactively change their designs or processes to incorporate different suppliers or materials to improve their CE credentials and a vehicles overall sustainability. Part tracking and i4.0 can offer solutions via different technologies to solve the paradox of sustainability and profitability (Bányai, et al., 2022).

7.2.7 Sourcing

The ethics of raw material sourcing and manual labour practices may come under more scrutiny with the improved depth of data made available by the IoT and smart tracking systems. Information, detailed by (Sharma, et al., 2023), related to time and date, participant identification, manufacturer, manufacture location, batch number, shift pattern etc can be recorded into each shipment via 5G connected scanning systems. Manufacturers will have a greater level of understanding towards the source of their materials and components and with this, pressures may lead to improvements in working conditions and living standards in developing countries.

7.2.8 Supply Chain

A comprehensive report into these opportunities is detailed in '*Supply Chain: Recent Advances and New Perspectives in the Industry 4.0 Era*' by (Bányai, et al., 2022). The IoT can improve clarity of communication between parties from sourcing through to manufacturing and final assembly.

Supply Chain Sustainability Risk (SCSR) poses a threat to OEMs as they have limited visibility of their suppliers and their operations. Unforeseen events such as wars and Covid-19 have highlighted vulnerabilities within global supply chains for OEMS, the scarcity of certain components and materials, most notably semi-conductors, greatly impacted operations within the Automotive industry (Burak, et al., 2022).

Lack of visibility can cause inefficiencies impacting lead time, supply and cost delaying builds or require OEMs to build additional storage for contingency stock. Blockchain and the IoT can be used to provide greater visibility by adopting Distributed Ledger Technologies (DLT). This allows immediate live traceability of products and their condition within the production cycle to better optimise ordering and shipping (Bányai, et al., 2022).

The IoT and blockchain are identified by (Krasmir & Pavel, 2020), in their study of 12 automotive industry experts, as the key enablers for overall production visibility and improving logistics and supply chains. They do however caution that cybersecurity and faulty data are potential pitfalls and challenges within this area.

By combining 'smart' tracking systems and DLT, parts and materials can also be followed autonomously worldwide. For this OEMs and Suppliers will need closer integration through 5G and Cloud systems that feed into a shared but blockchain encrypted and secure IIoT (DHL, 2023).

This cohesive and collaborative approach is supported by (Bányai, et al., 2022), in their chapter "*The Tenets of the Next Generation of Supply Chain Management*", the current linear approach can instead be looked at in a three dimensional vertical, horizontal and diagonal dimension. If an IoT connection between suppliers and consumers can be achieved, a supply web that works in three dimensions can be enabled. The benefits over a supply chain are improved clarity and visibility with the aim of reducing wastes such as costs, shipping, time and emissions.

7.3 Future Scope

Due to the broad capabilities of i4.0 and the seemingly inexhaustible uses of both cloud computing and the IoT it can be difficult to predict what will come next in terms of advancing the automotive industry. However, some such as (McKinsey, 2022) have attempted to explore this area, they determine that 5G and Edge computing will create opportunities in 'ACES' trends, Autonomous Driving, Connectivity, Electrification and Shared mobility.

Autonomous Driving will require intelligent 'Connectivity', Figure 13, as a key enabler, this will include 5G connectivity and communication with other vehicles, roads, signage and more generally the IoT in order to navigate safely through smart cities and more suburban and rural areas.

Advances in connectivity and computing may unlock many new use cases for the automotive sector.

Example use cases, not exhaustive

Autonomous driving | Connectivity | Electrification | Shared mobility

Autonomous vehicles
- autonomous driving level 1/2 (L1/L2)
- autonomous driving L3/L4
- robo-taxi L4/L5

Autonomous-driving infrastructure
- training data for L3/L4
- over-the-air updates
- virtual vehicle-to-vehicle platform
- teleoperated autonomous-vehicle (AV) control centers
- remote monitoring services for all AVs

Infotainment
- infotainment platform, including voice control
- map enhancements (eg, traffic, parking)
- cloud gaming platform

Connectivity-based technologies
- smart traffic
- vehicle-to-everything

Emergency services (notifications)
- automatic crash notification
- emergency vehicle approaching
- warnings: emergency brake, lane change, roadwork ahead

Emergency services (monitoring)
- recognition of slow or stationary vehicles
- intersection observation with automatic warnings

Connected services
- data monetization platform
- payment solutions (eg, toll, parking, charging)
- insurance: usage based, accident data storage
- remote diagnostics and predictive maintenance
- dashcam solution
- theft prevention, including intrusion detection
- fleet solutions
- trunk solution for mail
- bookable upgrades

Electric vehicles
- charging-station solution
- charging-infrastructure-footprint optimizations

Shared-mobility solutions
- seamless mobility application
- mobility service offerings
- secondary authentication through mobile phone
- car-sharing profile broker
- location data that can be sold to mobility provider

Source: McKinsey Center for Future Mobility

Figure 13, (McKinsey, 2022)

Electrification continues to advance and will be best suited for autonomous vehicles as fewer mechanical parts in EVs compared to ICE. This reduces the amount of maintenance required whilst also allowing vehicles to comply with localised emissions laws. Autonomous cars can also take advantage of ever-improving charging networks and if the vehicle is used for 'shared mobility' then users will no longer need to fill up the vehicle at traditional liquid fuel stations.

Of the ACES trends is perhaps 'shared mobility' that is the biggest paradigm shift to the automotive industry by opening up new business models and revenue streams. Generally, customers will lease or buy a car whereas in the future short-term vehicle renting of only hours or days at a time could become the norm. To be practical shared mobility will require autonomous driving, IoT connectivity and electrification as building blocks that once enabled will completely transform the traditional automotive landscape. Vehicle ownership may become a thing of the past and vehicle use will become democratised allowing users to rent based on preferences or immediate requirements. OEMs will no longer rely on car sales but car subscriptions.

7.4 Summary and Evaluation

Industry 4.0 can be an amorphous concept, but it is clear that The IoT and The Cloud are essential cornerstones in its foundation. Without the IIoT factories cannot become 'smart' and without cloud-based computing and storage the sheer quantity of data required for i4.0 could overwhelm localised 'in house' systems.

Manufacturing modularity and flexibility can only be aided via smart tracking systems that autonomously gather data that is stored in the IoT and processed via the Cloud. The processing power of Cloud computing enables Digital Twins to be formed for individual vehicles, their parts and also factory machines and processes. VR built around these digital twins can then be used to role-play and optimise processing routes and techniques.

Developments in EV technologies have seen disruptive innovators such as Arrival and Tesla enter the market and attempt to change established manufacturing methodologies modular approaches however this has not yet guaranteed success.

For the automotive industry to become compatible with the Circular Economy and integrate AI the IoT will be required as a hub for this data. Greater Smart systems and part tracking devices combined with 5G connectivity can greatly improve the clarity of parts sourcing and tracking to develop a better understanding of a vehicles, their parts and their carbon footprint. This data can be used throughout the vehicles life to ensure appropriate servicing, refurbishing or recycling are performed and assist in recording data for collaborative and localised tools such as PdM and diagnostics.

8 Conclusion

8.1 Summary of findings

From this research it is evident that elements of industry 4.0 are being applied within the Automotive Industry. There are plans by OEMs to embrace Circular Economy methodologies and AI advancements can radically change a multitude of aspects from production, design, use and customer services. IoT and Cloud interconnectivity will enable factories, processes and vehicles to become smarter, and i4.0 as a whole proposes to drastically change the status quo.

However, it is also clear that these are the primordial stages of adoption and currently no major OEM can claim to be fully i4.0 incorporated. 'Big Tech' backed 'unicorn' start-ups like Arrival aim to be modular and i4.0 integrated but are struggling with finances and the realities of mass manufacturing (Webster, 2023) and established disruptive innovators Tesla are still several years away from significant productivity gains with their 'Giga' factories.

Whilst technology companies can be agile in their implementation of i4.0 the nature of mass vehicular manufacturing means a slower roll out due to pressures from customers, costs and regulatory obligations. The architecture of EVs being so different to ICE allows companies like Tesla to re-think the order and methods of vehicle production. Whilst the current the cost of i4.0 adoption is high and requires a radical re-think and re-fitting of factories, OEMs that are too slow may become be overshadowed and outmanoeuvred by disruptive innovators. With technologies reducing in cost and improving in capability i4.0 adoption will become an inevitability. However, it will cause significant shifts in the industry and the human experience must also be factored in, from both an employment and customer perspective.

8.2 Were the aims and objectives achieved?

For the Circular Economy the aims were to understand how data can be used to improve OEMs carbon footprint, learn if i4.0 can be used to design for sustainability, understand the environmental impact of ICE vs EV and critically evaluate if 'green' car claims are true. Whilst design for sustainability is often mooted, with concepts such as the Citroen Oli being a notable example, there is little evidence yet of major OEMs manufacturing vehicles today that are CE compliant. Broadly this dissertation has met the remaining aims and highlighted examples of how increased data enabled by i4.0 can provide clarity to current processes and improve sustainability. The study on ICE vs EVs has been particularly insightful in understanding the full life cycle and how sustainable 'green' cars are when taking into account often-neglected human needs and market forces.

With AI and Smart Systems, the objectives were to better understand the integration of these systems in ADAS, design, engineering, manufacturing and services. The findings highlighted the current uses for ADAS and planned advancements to achieving full autonomy (level 5) whilst also speculating on future trends and applications. Particularly exciting were the findings in generative AI's ability to interact in hypothetical customer scenarios and likewise its aptitude for producing technical engineering documentation with minimal prompts. For car design and advertising AI is still some years and optimisation away from practical use, however the opportunities and uses that lie ahead are immeasurable.

This research achieved its aims by understanding the opportunities for the IoT and Cloud Systems to be employed within smart factories, manufacturing optimisation, supply chain and vehicle use. Both the IoT and the Cloud will be important tools for i4.0 key areas within automotive, namely ADAS, Big Data, Digital Twins and generative AI. Improved interconnectivity (5G) will be vital for the CE, GVC's and keeping records of a vehicle condition, location and carbon footprint.

8.3 What has been learnt?

This dissertation has learnt that currently EVs may not be as 'green' as they claim to be when the full picture is taken into account. However, it must be noted that battery technology is improving at such a rapid pace that these fears may be obsolete within the next decade.

This dissertation has discovered that AI tools, freely available online, are already capable of aiding and even replacing humans within the automotive industry. Nevertheless, this should be tempered with some pragmatism, whilst these AI tools are powerful and can greatly increase productivity, they also need to be handled with caution.

Ultimately i4.0 will play a significant role within the automotive industry, AI, IoT, CE methodologies and a host of other components will be key tools for building the new automotive landscape. However, uptake varies between companies and no OEM is yet fully i4.0 compliant.

8.4 Areas for further research

Whilst the aims and objectives have largely been met this is not to say that definitive answers have been found for all questions.

The findings have raised questions towards how best OEMs can implement i.40 with no clear answer to what areas or technologies should be prioritised first. Further research into smart factories could yield more examples of 'smart systems' implementation and provide a clearer pathway for full i4.0 adoption. Improving battery technology will mean that the calculations comparing EV's to ICE and establishing how 'green' cars are could be re-done within the next decade with very different results.

Further reading into the recycling and re-using of automotive parts would be an area of great interest as this impact is somewhat underreported. Areas of AI adoption that were previously unheard of could become more mainstream and its impact on the Automotive Industry will be followed with interest. AI advancements make this field extremely dynamic and shortcomings in systems today may be completely rectified with this technology.

With many of the cited examples hypothesising changes it will be important to re-visit these subjects in the next 5-10 years to ascertain how much progress has been made with regards to i4.0 adoption. Recent technological advancements pose both exciting challenges and possibilities, in particular the areas of machine learning, big data and automation.

8.5 Recommendations

The key recommendations for this dissertation will be for OEMs to focus particular attention on low hanging fruit, namely the adoption of AI and implementing CPS and the IoT for Smart Factories. The sooner OEMs automate data collation the better their understanding will be to identify areas for improvement via i4.0.

With a full re-evaluation of their assembly and manufacturing processes, particularly in light of new EV architecture, significant gains to productivity and cost can be found, as evidenced by Tesla's Giga factories. A fresh look at their processes and improved data gathering capabilities can also result in a re-evaluation of designs, supply chains and end of life processes with regards to the Circular Economy.

Advancements towards ADAS levels 4 and 5 will mark a new dawn in the Automotive landscape and its business models, OEMs will need i4.0 in order to become more agile, adaptable and modular in their products and processes to survive these shifting market dynamics.

References

Gonzalo, M.-G., Jose Arturo, G.-R. & Yesenia, P.-C., 2021. Eco-innovation and the circular economy in the automotive industry. *Benchmarking: An International Journal,* 28(2), pp. 621-635.

A&A Packaging, 2023. *A&A Packaging.* [Online]
Available at: https://www.aandapackaging.co.uk/how-is-a-circular-economy-different-from-a-linear-economy/
[Accessed 11th June 2023].

Abdullahi, A., 2023. *eWeek.* [Online]
Available at: https://www.eweek.com/artificial-intelligence/best-ai-chatbots/#:~:text=Microsoft%20generative%20AI%20tool%20Bing,creative%2C%20balanced%2C%20and%20precise.
[Accessed 20th December 2023].

Andersson, K., 2023. *Timbergrove.* [Online]
Available at: https://timbergrove.com/blog/predictive-maintenance-advantages-and-disadvantages
[Accessed 20th October 2023].

Arival, 2023. *Arrival.* [Online]
Available at: https://arrival.com/card/why-arrival-microfactory
[Accessed 23rd October 2023].

Automotive Manufacturing Solutions, 2022. *Automotive Manufacturing Solutions.* [Online]
Available at: https://www.automotivemanufacturingsolutions.com/lean-manufacturing/adopting-circular-economy-principles-in-car-production/44012.article
[Accessed 14th June 2023].

Awan, U., Golgeci, I., Makhmadshoev, D. & Mishra, N., 2022. Industry 4.0 and circular economy in an era of global value chains: What have we learned and what is still to be explored?. *Journal of Cleaner Production,* Volume 371, pp. 1-9.

Bai, C., Dallasega, P., Orzes, G. & Sarkis, J., 2020. Industry 4.0 technologies assessment: A sustainability perspective. *International Journal of Production Economics,* Volume 220.

Bányai, T., Bányai, Á. & Kaczmar, I., 2022. *Supply Chain : Recent Advances and New Perspectives in the Industry 4.0 Era.* 1 ed. s.l.:IntechOpen.

Barter, P., 2013. *Reinventing Parking.* [Online]
Available at: https://www.reinventingparking.org/2013/02/cars-are-parked-95-of-time-lets-check.html
[Accessed 23rd October 2023].

Bhuiyan, J., 2023. *TheGuardian.* [Online]
Available at: https://www.theguardian.com/us-news/2023/aug/10/san-francisco-self-driving-car-autonomous-regulation-google-gm
[Accessed 20th Decemebr 2023].

Burak, E., Kluckzek, A. & Baginski, J., 2022. The COVID-19 Impact on Supply Chain Operations of Automotive Industry: A Case Study of Sustainability 4.0 Based on Sense–Adapt–Transform Framework. *Sustainability,* 14(10), pp. 1-33.

Burn, J., 2021. *AutoExpress.* [Online]
Available at: https://www.autoexpress.co.uk/honda/e/353911/honda-e-long-term-test-review#:~:text=I've%20also%20found%20that,ve%20driven%20closer%20to%2080.
[Accessed 18th December 2021].

Campbell, M., 2022. *euronews.green.* [Online]
Available at: https://www.euronews.com/green/2022/02/01/south-america-s-lithium-fields-reveal-the-dark-side-of-our-electric-future
[Accessed 5th July 2023].

Campbell, M., 2022. *euronews.green.* [Online]
Available at: https://www.euronews.com/green/2022/02/09/we-re-facing-a-lithium-battery-crisis-what-are-the-alternatives
[Accessed 9th July 2023].

capgemini, 2020. *Capgemini -The Automotive Industry in the Era of Sustainability.* [Online]
Available at: https://www.capgemini.com/wp-content/uploads/2021/02/Infographic-The-Automotive-Industry-in-the-Era-of-Sustainability-1.pdf
[Accessed 12th September 2023].

CascadeCollision, 2020. *CascadeCollision.* [Online]
Available at: https://cascadecollision.com/blog/what-is-the-average-life-of-a-car/#:~:text=What%27s%20the%20Average%20Life%20of,longer%2C%20up%20to%20300%2C000%20miles.
[Accessed 9th July 2023].

Charlton, A., 2023. *Forbes.* [Online]
Available at: https://www.forbes.com/sites/alistaircharlton/2023/09/07/bmw-drops-controversial-heated-seats-subscription-to-refocus-on-software-services/
[Accessed 12th November 2023].

Connett, D., 2015. *Independant.* [Online]
Available at: https://www.independent.co.uk/climate-change/news/volkswagen-emissions-scandal-more-carmakers-implicated-as-tests-reveal-pollution-levels-of-popular-diesels-a6674386.html
[Accessed 4th October 2023].

Cook, P., 2021. Image and reality: 'digital twins' in smart factory automotive process innovation – critical issues. *Regional Studies,* Volume 55, p. 1630–1641.

Cronin, C., Conway, A. & Walsh, J., 2019. Flexible manufacturing systems using IIoT in the automotive sector. *Procedia Manufacturing,* Volume 38, pp. 1652-1659.

Cronin, C., Conway, A. & Walsh, J., 2019. Flexible manufacturing systems using IIoT in the automotive sector. *ScienceDirect,* Volume 38, pp. 1652-1659.

Crosse, J., 2023. *Autocar.* [Online]
Available at: https://www.autocar.co.uk/car-news/technology/how-ai-will-allow-us-talk-our-cars
[Accessed 1st November 2023].

da Silva, T. H. H. & Sehnem, S., 2022. The circular economy and Industry 4.0: synergies and challenges. *Revista de Gestão,* 29(3), pp. 300-313.

DHL, 2023. *DHL.* [Online]
Available at: https://www.dhl.com/discover/en-global/logistics-advice/logistics-insights/5g-and-logistics
[Accessed 20th November 2023].

dubizzle, 2023. *Dubizzle.* [Online]
Available at: https://www.dubizzle.com/blog/cars/cars-become-less-fuel-efficient/
[Accessed 12th September 2023].

Edwards, J., 2023. *Zapmap.* [Online]
Available at: https://www.zap-map.com/ev-stats/ev-market/
[Accessed 12th June 2023].

Ellen MacArthur Foundation , 2023. *Ellen MacArthur Foundation.* [Online]
Available at: https://ellenmacarthurfoundation.org/circular-examples/groupe-renault
[Accessed 16th June 2023].

Estl, H., 2018. *5GTechnologyworld.* [Online]
Available at: https://www.5gtechnologyworld.com/how-adas-is-paving-the-way-for-autonomous-driving/
[Accessed 17th October 2023].

EV Connect, 2022. *EV Connect.* [Online]
Available at: https://www.evconnect.com/blog/how-long-does-an-electric-car-battery-last#:~:text=On%20average%2C%20EV%20batteries%20only,longer%20than%20ICE%20drivetrain%20components.
[Accessed 8th July 2023].

Frankel, T. C., 2016. *Washington Post.* [Online]
Available at: https://www.washingtonpost.com/graphics/business/batteries/congo-cobalt-mining-for-lithium-ion-battery/
[Accessed 23 August 2023].

Freeman, O. J., 2023. *Medium.* [Online]
Available at: https://medium.com/@OjFRSA/5-ways-iot-and-iiot-revolutionise-global-supply-chains-and-supply-chain-management-4345cccе99bb
[Accessed 6 September 2023].

Gastelu, G., 2023. *FoxNews.* [Online]
Available at: https://www.foxnews.com/auto/ai-powered-system-inspect-car-seconds-bomb-detecting-tech
[Accessed 19th October 2023].

Gautam, B. T., 2023. *Times of India.* [Online]
Available at: https://timesofindia.indiatimes.com/blogs/voices/benefits-of-connected-cars-with-iot-and-adas/?source=app&frmapp=yes
[Accessed 7th November 2023].

Gemes, N., 2021. *Green Citizen.* [Online]
Available at: https://greencitizen.com/blog/lithium-ion-battery-recycling/
[Accessed 8th July 2023].

Ghadge , A. et al., 2022. Link between Industry 4.0 and green supply chain management: Evidence from the automotive industry. *Computers & Industrial Engineering ,* Volume 169.

Gibbs, N., 2023. *Autocar.* [Online]
Available at: https://www.autocar.co.uk/car-news/business-environment-and-energy/stellantis-keep-cars-15-years-cut-co2
[Accessed 12th July 2023].

Gill, R., 2014. *TheSun.* [Online]
Available at: https://www.thesun.co.uk/motors/2747264/toyota-aygo-citroen-c1-or-peugeot-108/
[Accessed 30th October 2023].

GlobalData, 2023. *just-auto.* [Online]
Available at: https://www.just-auto.com/data-insights/innovators-iot-predictive-maintenance-systems-automotive/?cf-view&cf-closed
[Accessed 12th December 2023].

Gorzelany, J., 2022. *Forbes.* [Online]
Available at: https://www.forbes.com/sites/jimgorzelany/2022/10/13/by-the-numbers-how-long-should-an-electric-cars-battery-last/?sh=70f127ad2cc3
[Accessed 20th June 2023].

GreenCars.org, 2023. *GreenCars.org.* [Online]
Available at: https://greenercars.org/greenercars-ratings/how-we-determine-ratings
[Accessed 18th June 2023].

Guinness, H., 2023. *zapier.* [Online]
Available at: https://zapier.com/blog/best-ai-image-generator/
[Accessed 20th December 2023].

Hardigree, M., 2023. *theautopian.* [Online]
Available at: https://www.theautopian.com/why-used-electric-vehicle-prices-are-plummeting-and-why-used-evs-will-probably-get-even-cheaper/
[Accessed 18th December 2023].

Holder, J., 2023. *Autocar.* [Online]
Available at: https://www.autocar.co.uk/car-news/new-cars/citroen-oli-concept-car-first-drive
[Accessed 17th September 2023].

Hull, R., 2023. *This is money.* [Online]
Available at: https://www.thisismoney.co.uk/money/cars/article-12716679/Now-Audi-plans-ramp-charging-extra-unlock-features-built-cars-despite-huge-driver-backlash-paywall-tactic-rival-brand-BMW.html
[Accessed 22nd November 2023].

Ingram, A., 2020. *AutoExpress.* [Online]
Available at: https://www.autoexpress.co.uk/tesla/model-3/107600/new-tesla-model-3-standard-range-plus-2020-review
[Accessed 12th September 2023].

Jenkins, L. M., 2021. *Morning Consult.* [Online]
Available at: https://pro.morningconsult.com/articles/energy-efficiency-series-electric-vehicles-

consumers-polling
[Accessed 8th July 2023].

Kalverkamp, M. & Raabe, T., 2017. Automotive Remanufacturing in the Circular Economy in Europe: Marketing System Challenges. *Journal of Macromarketing,* 38(1).

Kanellou, E. et al., 2021. The DigiPrime KPIs' framework for a circular economy transition in the automotive industry. *Procedia Manufacturing,* Volume 54, pp. 302-307.

Kim, Y., Oh, H. & Kang, S., 2017. Proof of Concept of Home IoT Connected Vehicles. *Sensors,* 17(6), pp. 1-13.

Krasmir, M. & Pavel, V., 2020. Logistics 4.0 and supply chain 4.0 in the automotive industry. *IOP Conference Series. Materials Science and Engineering,* 878(1), pp. 1-7.

Lakshmanan, L., 2021. *Medium.* [Online]
Available at: https://medium.com/embitel-technologies/predictive-maintenance-in-the-automotive-industry-an-insiders-perspective-57388d008c9d
[Accessed 17th October 2023].

LAND ROVER ENGLEWOOD, 2023. *LAND ROVER ENGLEWOOD.* [Online]
Available at: https://www.landroverenglewood.com/service/diy-car-care/how-to-check-oil-pressure/#:~:text=When%20your%20Land%20Rover%20oil,a%20yellow%20oil%20lamp%20light.
[Accessed 12th December 2023].

Landrover, 2023. *Landrover.* [Online]
Available at: https://www.landrover.co.uk/ownership/software-update/alexa.html
[Accessed 30th October 2023].

Landrover, 2023. *Landrover.* [Online]
Available at: https://www.landrover.co.uk/offers-and-finance/finance-calculator.html#/quote/l663_k24__4b1ga__a-com_a-d250_a-ht-90_sp0-com
[Accessed 12th December 2023].

Martinez, I., 2021. *The Future of the Automotive Industry, The Disruptive Forces of AI, Data Analytics, and Digitization.* 1st ed. s.l.:Apress.

McKinsey & Company, 2023. *McKinsey & Company.* [Online]
Available at: https://www.mckinsey.com/featured-insights/mckinsey-explainers/what-is-ai
[Accessed 4th September 2023].

McKinsey, 2022. *McKinsey.* [Online]
Available at: https://www.mckinsey.com/industries/semiconductors/our-insights/the-future-of-automotive-computing-cloud-and-edge
[Accessed 29th November 2023].

Meta, 2023. *Facebook.* [Online]
Available at: https://www.facebook.com/business/small-business/personalized-ads
[Accessed 13th December 2023].

Mitchell, R., 2023. *WSIworld.* [Online]
Available at: https://www.wsiworld.com/blog/how-ai-is-changing-manufacturing-revolutionizing-efficiency-growth
[Accessed 14th October 2023].

Mullen, D., 2021. *The Sunday Times, Driving.* [Online]
Available at: https://www.driving.co.uk/news/environment/ev-chargers-switch-off-peak-times-blackouts/
[Accessed 4th November 2023].

National Scrap Car, 2023. *National Scrap Car.* [Online]
Available at: https://nationalscrapcar.co.uk/scrap-car/recycling/#:~:text=How%20much%20of%20a%20car%20can%20be%20recycled%3F,remaining%2035%25%20is%20also%20recyclable.
[Accessed 12th June 2023].

Nelson, R., 2014. *Electronic Design.* [Online]
Available at: https://www.electronicdesign.com/home/article/21204835/automobile-voice-commands-distracting-and-unreliable
[Accessed 30th October 2023].

Nishanth, P., 2023. *toobler.* [Online]
Available at: https://www.toobler.com/blog/digital-twin-use-cases-in-automotive-industry
[Accessed 12th November 2023].

Ocasio, K., 2023. *Small Buisness Trends.* [Online]
Available at: https://smallbiztrends.com/2023/10/car-rental-app.html
[Accessed 6th November 2023].

Oculii, 2021. 4D Automotive Radar Overlays AI on Existing Hardware. 64(8), pp. 96-98.

Pandremenos, J., Paralikas, J., Salonitis, K. & Chryssolouris, G., 2009. Modularity concepts for the automotive industry: A critical review. *CIRP Journal of Manufacturing Science and Technology,* 1(3), pp. 148-152.

Parkers, 2023. *Parkers.* [Online]
Available at: https://www.parkers.co.uk/toyota/verso/review/
[Accessed 12th September 2023].

Parrott, V., 2023. *Big Issue.* [Online]
Available at: https://www.bigissue.com/news/environment/how-citroens-new-concept-car-could-be-the-future-of-electric-vehicles/
[Accessed 15th June 2023].

Progressive , 2022. *Progressive.* [Online]
Available at: https://www.progressive.com/answers/classic-cars-vs-modern-cars/#:~:text=On%20the%20flip%20side%2C%20a,2000s%20than%20in%20the%201990s.
[Accessed 12th July 2023].

Progressive, 2023. *Progressive.* [Online]
Available at: https://www.progressive.com/answers/how-many-miles-does-a-car-last/
[Accessed 15th June 2023].

PTC, 2023. *PTC.* [Online]
Available at: https://www.ptc.com/en/technologies/cad/generative-design#:~:text=Generative%20design%20is%20a%20method,materials%20to%20generate%20optimized%20designs.
[Accessed 18th October 2023].

Rajput, S. & Singh, S. P., 2019. Connecting circular economy and industry 4.0. *International Journal of Information Management ,* Volume 49, pp. 98-113.

Rapier, G., 2023. *Buisness Insider.* [Online]
Available at: https://www.businessinsider.com/tesla-gigafactory?r=US&IR=T#:~:text=How%20expensive%20is%20a%20Gigafactory,%245.5%20billion%2C%20according%20to%20Reuters.
[Accessed 3rd October 2023].

Ritchie, H., 2022. *Our World in Data.* [Online]
Available at: https://ourworldindata.org/leaded-gasoline-phase-out
[Accessed 9th July 2023].

Rodeffer, M., 2023. *ACEEE.org.* [Online]
Available at: https://www.aceee.org/press-release/2023/02/greenercars-2023-efficiency-and-weight-not-just-electric-vs-gas-shape
[Accessed 18th June 2023].

Rosenbaum, M., 2017. *BBC.* [Online]
Available at: https://www.bbc.co.uk/news/uk-politics-41985715
[Accessed 9th June 2023].

Ryan, A., 2023. *FleetNews.* [Online]
Available at: https://www.fleetnews.co.uk/news/ev-manufacturer-nio-opens-30th-battery-swap-station-in-europe
[Accessed 3rd December 2023].

Saracco, R., 2023. *cmte.* [Online]
Available at: https://cmte.ieee.org/futuredirections/2023/07/02/ai-agi-asi-time-to-revise-our-definition/#:~:text=the%20reaching%20of%20a%20human,%E2%80%93%20Artificial%20Super%20Intelligence%20%2DASI.
[Accessed 16 October 2023].

Schulz , M., Niero, M., Rehmann, . L.-M. & Georg, S., 2021. Exploration of decision-contexts for circular economy in automotive industry. *Procedia CIRP,* Volume 98, pp. 19-24.

Shah, V., 2021. *CarExpert.* [Online]
Available at: https://www.carexpert.com.au/car-news/platform-sharing-the-many-faces-of-mqb
[Accessed 27th October 2023].

Sharma, H., Garg, R., Sewani, H. & Kashef, R., 2023. Towards A Sustainable and Ethical Supply Chain Management: The Potential of IoT Solutions. *arxiv,* pp. 1-9.

Sheer, S., 2023. *Linkedin.* [Online]
Available at: https://www.linkedin.com/learning/introduction-to-prompt-engineering-for-generative-ai/few-shot-learning?resume=false&u=82627780
[Accessed 12th December 2023].

Shepardson, D., 2023. *Reuters.* [Online]
Available at: https://www.reuters.com/business/autos-transportation/teamsters-union-asks-nhtsa-deny-gms-bid-exempt-cruise-safety-standards-2023-09-27/
[Accessed 18th October 2023].

Siemens, 2023. *Siemens.* [Online]
Available at: https://www.siemens.com/global/en/industries/automotive-manufacturing/digital-twin-product.html?acz=1&gad_source=1&gclid=Cj0KCQiA6vaqBhCbARIsACF9M6ln0a_Pue9-1Vfyxr4EOMDFl-XQBgHVKW1FT21yO9u2sd2Mp8Ry1RsaApNvEALw_wcB
[Accessed 10th November 2023].

Singh Bhatia, M. & Kumar, S., 2022. Critical Success Factors of Industry 4.0 in Automotive Manufacturing Industry. *IEEE Transactions on Engineering Management,* 69(5), pp. 2439-2453.

Smith, J., 2023. *The Late Brake Show.* [Online]
Available at: https://www.youtube.com/watch?v=pnh1PRBQOPc
[Accessed 13th July 2023].

Smith, S. D., 2022. *Carscoops.* [Online]
Available at: https://www.carscoops.com/2022/01/toyota-to-extend-its-vehicles-life-in-the-uk-by-remanufacturing-them-up-to-three-times/
[Accessed 12th July 2023].

SSi, 2023. *SSi.* [Online]
Available at: https://ssi-master.eu/what-are-smart-systems/
[Accessed 15th October 2023].

Tesla, 2023. *Tesla.* [Online]
Available at: https://www.tesla.com/en_gb/support/software-updates
[Accessed 10th November 2023].

The Manufacturer, 2022. *The Manufacturer.* [Online]
Available at: https://www.themanufacturer.com/articles/how-sustainable-are-electric-cars/
[Accessed 23rd June 2023].

Tihanyi, . V. et al., 2021. Towards Cooperative Perception Services for ITS: Digital Twin in the Automotive Edge Cloud. *Energies,* 14(18), pp. 1-27.

Toyota Forklifts, 2023. *Toyota Forklifts.* [Online]
Available at: https://toyota-forklifts.co.uk/automated-solutions/automated-pallet-carrier/
[Accessed 15th October 2023].

Tracy, D., 2023. *theautopian.* [Online]
Available at: https://www.theautopian.com/i-bought-a-2000-electric-car-with-a-failing-battery-heres-how-bad-it-is/
[Accessed 18th December 2023].

Transport for London, 2017. *Transport for London.* [Online]
Available at: https://tfl.gov.uk/info-for/media/press-releases/2017/april/gla---mayor-plans-to-introduce-ulez-in-april-2019
[Accessed 9th June 2023].

ultimatespecs, 2023. *ultimatespecs.* [Online]
Available at: https://www.ultimatespecs.com/car-specs/Tesla/116266/Tesla-Model-3-Standard-Range-Plus.html
[Accessed 12th September 2023].

ultimatespecs, 2023. *ultimatespecs.* [Online]
Available at: https://www.ultimatespecs.com/car-specs/Volkswagen/127021/Volkswagen-ID3-45kWh-150HP.html
[Accessed 12th September 2023].

ultimatespecs, 2023. *ultimatespecs.* [Online]
Available at: https://www.ultimatespecs.com/car-specs/Polestar/127028/Polestar-2-63kWh-Single-Motor.html
[Accessed 12th September 2023].

ultimatespecs, 2023. *ultimatespecs.* [Online]
Available at: https://www.ultimatespecs.com/car-specs/Tesla/106026/Tesla-Model-3-Standard.html
[Accessed 12th September 2023].

ultimatespecs, 2023. *ultimatespecs.* [Online]
Available at: https://www.ultimatespecs.com/car-specs/Toyota/65302/2014-Toyota-Verso-2013-22-D-CAT-7-seats.html
[Accessed 12th September 2023].

ultimatespecs, 2023. *ultimatespecs.* [Online]
Available at: https://www.ultimatespecs.com/car-specs/Volkswagen/68516/Volkswagen-Golf-Sportsvan-20-TDI-150HP-DSG-6-Speeds.html
[Accessed 12th September 2023].

ultimatespecs, 2023. *ultimatespecs.* [Online]
Available at: https://www.ultimatespecs.com/car-specs/Volvo/9739/Volvo-C30-Summum-20F.html
[Accessed 12th September 2023].

ultimatespecs, 2023. *ultimatespecs.* [Online]
Available at: https://www.ultimatespecs.com/car-specs/Ford/59483/Ford-Fiesta-7-2012-Facelift-5-doors-Urban-125-60HP-.html
[Accessed 12th September 2023].

UN environment programme, 2021. *UN environment programme.* [Online]
Available at: https://www.unep.org/news-and-stories/press-release/era-leaded-petrol-over-eliminating-major-threat-human-and-planetary
[Accessed 9th June 2023].

Vaughn, M., 2023. *autoweek.* [Online]
Available at: https://www.autoweek.com/news/technology/a43937159/b2u-company-reusing-ev-battery-packs-to-store-solar-energy/
[Accessed 13th July 2023].

Vermesan, O. & et al., 2021. *Artificial Intelligence for Digitising Industry : Applications.* 1 ed. s.l.:Taylor Francis.

Vinkhuyzen, M., 2023. *cleantechnica.* [Online]
Available at: https://cleantechnica.com/2023/09/17/why-ev-batteries-keep-getting-cheaper-cleaner/
[Accessed 20th December 2023].

Wang, Y., Hou, J., Zhang, Y. & Fang, X., 2021. Research on Automotive Cloud Technology Platform and Solutions. *Journal of Physics: Conference Series,* 1915(4), pp. 1-7.

Wasner, C. & Traxler , J., 2019. AI and Automotive Safety. *ATZelectronics worldwide,* Volume 14, pp. 50-53.

Weber, A., 2023. *Assemblymag.* [Online]
Available at: https://www.assemblymag.com/articles/97788-tesla-rethinks-the-assembly-line
[Accessed 20th December 2023].

Webster, T., 2023. *Parkers.* [Online]
Available at: https://www.parkers.co.uk/vans-pickups/news/2021/arrival-electric-van/
[Accessed 20th December 2023].

Weetman, K., 2022. *Wikimedia.* [Online]
Available at: https://commons.wikimedia.org/wiki/File:Linia_kontra%C5%AD_Cirkulero.svg
[Accessed 9th June 2023].

Weisbaum, H., 2006. *nbcnews.* [Online]
Available at: https://www.nbcnews.com/id/wbna12040753#.W5FuNOhKiM8
[Accessed 9th July 2023].

Wilkinson, L., 2023. *car.* [Online]
Available at: https://www.carmagazine.co.uk/electric/longest-range-electric-cars-ev/
[Accessed 12th December 2023].

Wizata, 2023. *Wizata.* [Online]
Available at: https://www.wizata.com/knowledge-base/how-to-optimize-production-line-with-artificial-intelligence
[Accessed 13th October 2023].

WWF, 2023. *WWF.* [Online]
Available at: https://www.wwf.org.uk/learn/guide-to-greenwashing
[Accessed 17th June 2023].

Yuldashev, T. & Solovev, A., 2023. *Integra Sources.* [Online]
Available at: https://www.integrasources.com/blog/differences-between-rfid-and-nfc-systems-their-applications-and-alternatives/
[Accessed 28th November 2023].

Yu, Z., Khan, S. A. R. & Umar, M., 2021. Circular economy practices and industry 4.0 technologies: Astrategic move of automobile industry. *Buisness Strategy and the Environment,* 31(3), pp. 796-809.

Zheng, M., 2023. *Earth.Org.* [Online]
Available at: https://earth.org/lithium-and-cobalt-mining/#:~:text=Though%20emissions%20deriving%20from%20mining,and%20potential%20for%20groundwater%20contamination.
[Accessed 29th June 2023].

Appendices

Appendix 1 Workings for lifetime vehicle emissions comparison

Information in below table sourced from (capgemini, 2020)*

**"Assuming a total lifetime distance of 150,000 Kms, EVs powered by the EU-27+UK grid. The chart shows a comparison of average GHG emissions between five EVs and five ICEs. Electric cars are Tesla Model 3 standard range (2020), VW ID.3 standard range, Polestar 2, Tesla Model 3 standard 50kWh (2018). ICE cars in consideration are Toyota Corolla Verso 177 (2013), VW Golf S2W TDI (2016), Volvo C30 2.0 and Ford Fiesta 1.25 (2017)"* (capgemini, 2020).

Overall lifecycle GHG emission analysis (g.CO2 eq/km)	**ICE**	**EV**
Fuel combustion	208	0
Power production/fuel production	50	67
Battery	0	72
Maintenance	9	9
Production of body/components	37	43
Total (g.CO2 eq/km)	**304**	**191**

Calculations

EV range and cost data.

Electric Car	**Avg consumption (KwH)**	**Battery Capacity KwH**	**range (miles)**	**Price (£)**	**Source(s)**
Tesla Model 3 2020	0.26	75	258	£40,490	(ultimatespecs, 2023) & (Ingram, 2020)
VW ID.3	0.24	45	218	£36,375	(ultimatespecs, 2023)
Polestar 2	0.27	63	249	£42,150	(ultimatespecs, 2023)
Tesla Model 3 2018	N/A	N/A	220	£42,990	(ultimatespecs, 2023)
		Average	**236.25**	**£40,501**	

ICE range and cost data.

ICE Cars	**Miles Per Gallon (MPG)**	**Fuel Tank Capacity (gallons)**	**Range (miles)**	**Price (Parkers)**	**Source(s)**
Toyota Corolla Verso 177 (2013)	49	12.1	589	£17,220	(ultimatespecs, 2023) & (Parkers, 2023)
VW Golf S2W TDI (2016)	61	11	675	£17,625	(ultimatespecs, 2023)
Volvo C30 2.0	36	12.1	438	£14,585	(ultimatespecs, 2023)
Ford Fiesta 1.25 (2017)	52	8.8	460	£19,350	(ultimatespecs, 2023)
		Average	**540.5**	**£17,195**	

EV battery degradation data, extrapolated from source (EV Connect, 2022).

Calculation is range in miles * (1-0.023)^10 to simulate compound degradation over 10 years (based on 2.3% annual degradation), then extrapolated over 30 years. (note the average after 7 years = 200.5 miles range).

Electric Car	Range (Miles)	10 years 100,000 miles	20 years 200,000 miles	30 years 300,000 miles
Tesla Model 3 2020	258	204.44	162.00	128.37
VW ID.3	218	172.74	136.88	108.47
Polestar 2	249	197.31	156.35	123.89
Tesla Model 3 2018	220	174.33	138.14	109.46
Average	**236.25**	**170.39**	**135.01**	**106.99**

ICE efficiency loss data, assumptions based on data cited from (dubizzle, 2023). Assumed no losses for first 10 years (100,000 miles) as ICE can become more efficient than new after initial running in. Next 20 years (200,000 miles) assumes a yearly reduction in range of 0.5% due to typical engine and vehicle wear and tear resulting in efficiency losses.

ICE Cars	Range miles	10 years 100,000 miles	20 years 200,000 miles	30 years 300,000 miles
Toyota Corolla Verso 177 (2013)	589	589	560.20	532.82
VW Golf S2W TDI (2016)	675	675	642.00	610.61
Volvo C30 2.0	438	438	416.59	396.22
Ford Fiesta 1.25 (2017)	460	460	437.51	416.12
Average	**540.5**	**540.5**	**514.08**	**488.94**

Range comparison ICE vs EV based on the above calculations and assumptions.

Expected Average Range	ICE	EV
Avg Range in miles (full tank/battery) new	540.5	236.25
Avg Range in miles (full tank/battery) 10 years 100,000 miles	540.5	170.39
Avg Range in miles (full tank/battery) 20 years 200,000 miles	514.08	135.01
Avg Range in miles (full tank/battery) 30 years 300,000 miles	488.94	106.99

Calculations from (capgemini, 2020) extrapolated over 30 years for ICE (based on maximum useful life of 300,000 miles at 10,000 miles per year) and 28 years from EV (based on assumed useful life of EV determined by minimum range of 200 miles in ideal conditions).

ICE	10 years est	20 years est	30 years est		Total
Fuel combustion	208	208	208		624
Power production/fuel production	50	50	50		150

Battery	0	0	0		0
Maintenance	9	9	9		27
Production of body/components	37	0	0		37
Total (g.CO2 eq/km)	304	267	267		**838**
EV	**7 years est**	**7 years est**	**7 years est**	**7 years est**	**Total**
Fuel combustion	0	0	0	0	0
Power production/fuel production	67	67	67	67	268
Battery	72	72	72	72	288
Maintenance	9	9	9	9	36
Production of body/components	43	43	43	43	172
Total (g.CO2 eq/km)	191	191	191	191	**764**

Calculations extrapolated to approximately 30 years (300,000 miles) of emissions based on the (capgemini, 2020) data. Examples based on (Weisbaum, 2006) with average ICE length duration of 15 years (150,000 miles each using 2 cars in total) or average ICE age of 8 years (80,000 miles max using 4 cars in total) and an EV with 3 years maximum (10 cars total). EV range value determined by estimated average of 10% loss in efficiency due to weather conditions or driving style (Average range determined to be 212 miles from new dropping to 198.3 miles by year 3 or 30,00 miles.

ICE (replaced every 15 years / 150,000 miles)	**15 years**	**15 years**			**Total after 30 years**
Fuel combustion	312	312			624
Power production/fuel production	75	75			150
Battery	0	0			0
Maintenance	13.5	13.5			27
Production of body/components	37	37			74
Total (g.CO2 eq/km)	437.5	437.5			**875**
ICE (replaced every 8 years / 80,000 miles)	**8 years**	**8 years**	**8 years**	**6 years**	**Total after 30 years**
Fuel combustion	166.4	166.4	166.4	124.8	624
Power production/fuel production	40	40	40	30	150
Battery	0	0	0	0	0
Maintenance	7.2	7.2	7.2	5.4	27
Production of body/components	37	37	37	37	148
Total (g.CO2 eq/km)	250.6	250.6	250.6	197.2	**949**
EV (replaced every 3 years / 30,000 miles to retain min range >~200 miles)	**3 years**	**(30 years)**			**Total after 30 years**
Fuel combustion	0	(0)			0
Power production/fuel production	22.11	(221.1)			221.1

Battery	72	(720)			720
Maintenance	2.97	(29.7)			29.7
Production of body/components	43	(430)			430
Total (g.CO2 eq/km)	140.08	(1400.8)			**1400.8**

Appendix 2 Interior Design Generative AI Data

Interior Design Prompts	Bing AI image generator
An expensive and modern car interior for a luxury Range Rover using leather, oak wood and brushed aluminium materials.	

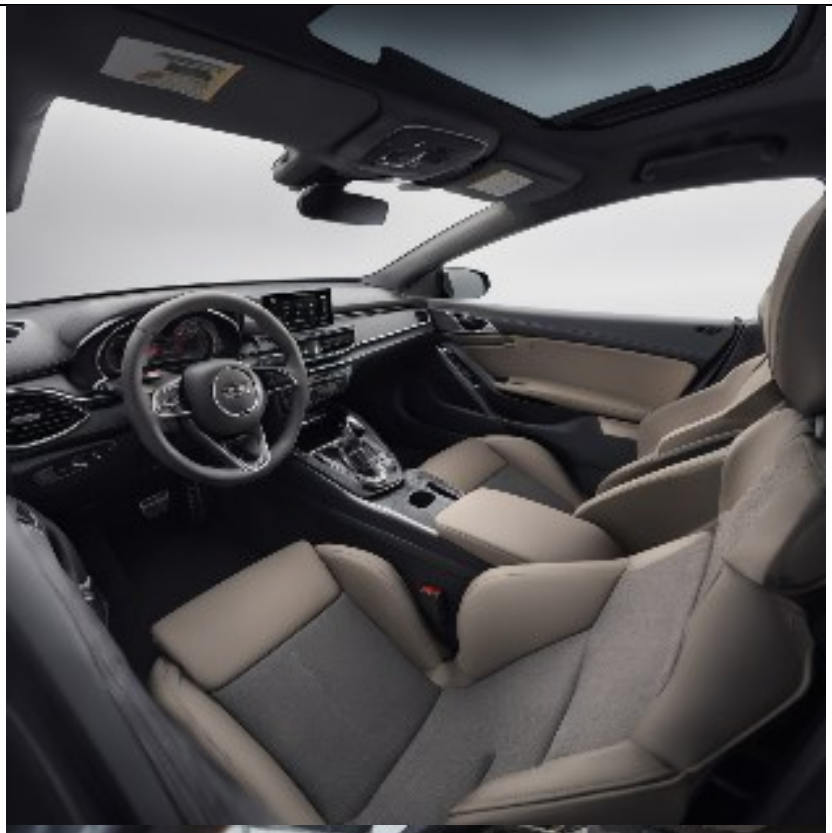
A cheap car interior for a budget brand using grey plastics and a minimalistic layout.	

A car interior inspired with art deco design influences			

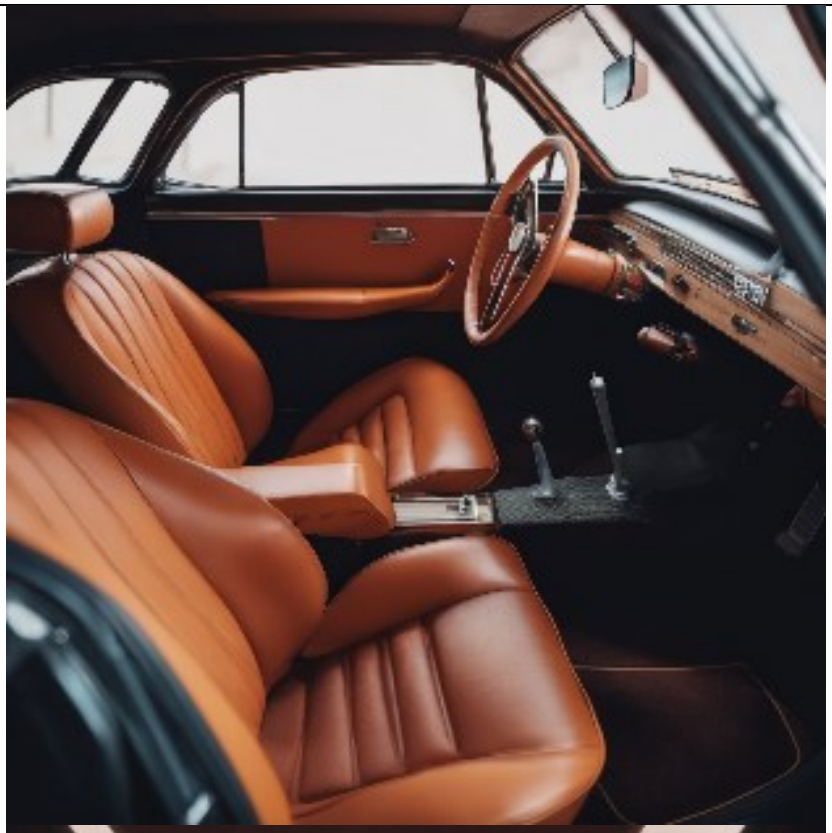
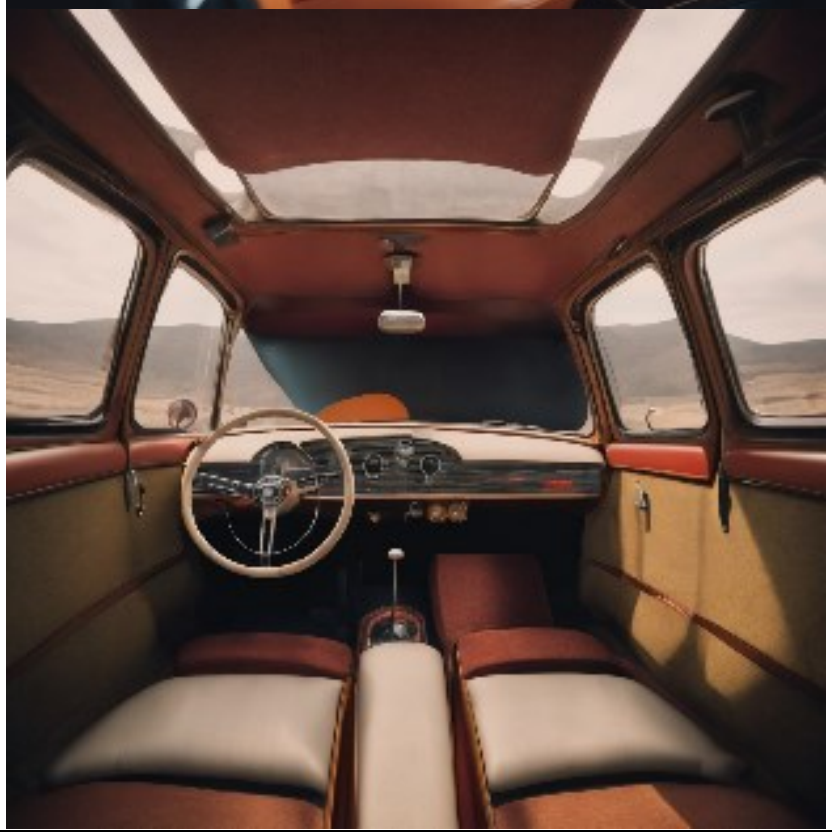
A car interior inspired with Bauhaus design influences			

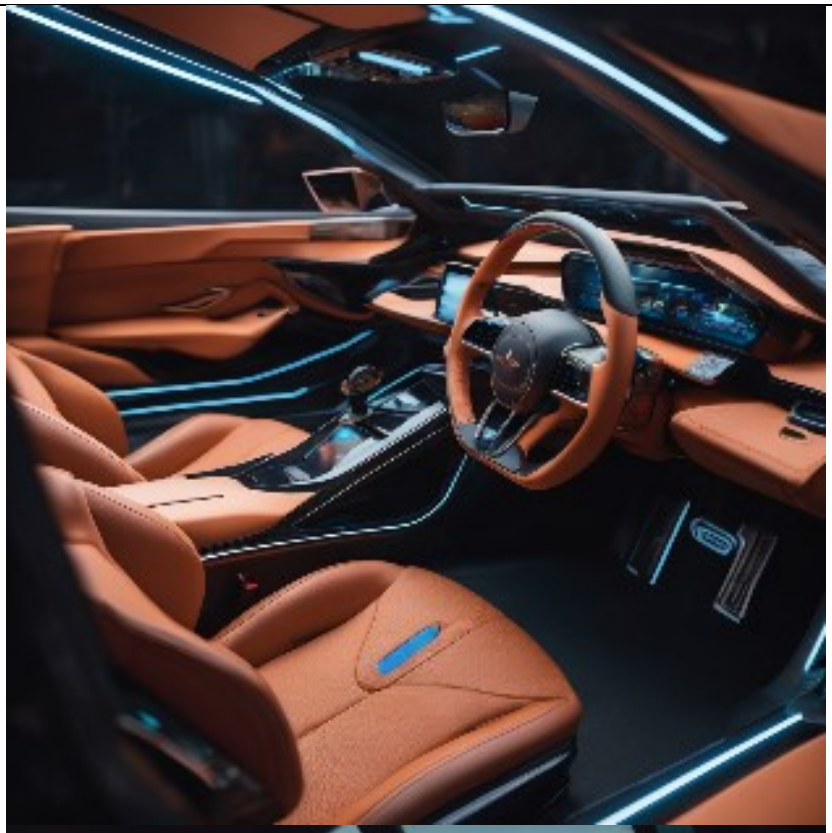
A futuristic car interior inspired with science fiction design influences		

Interior Design Prompts	Gencraft_AI image generator
An expensive and modern car interior for a luxury Range Rover using leather, oak wood and brushed aluminium materials.	

A cheap car interior for a budget brand using grey plastics and a minimalistic layout.	

A car interior inspired with art deco design influences	

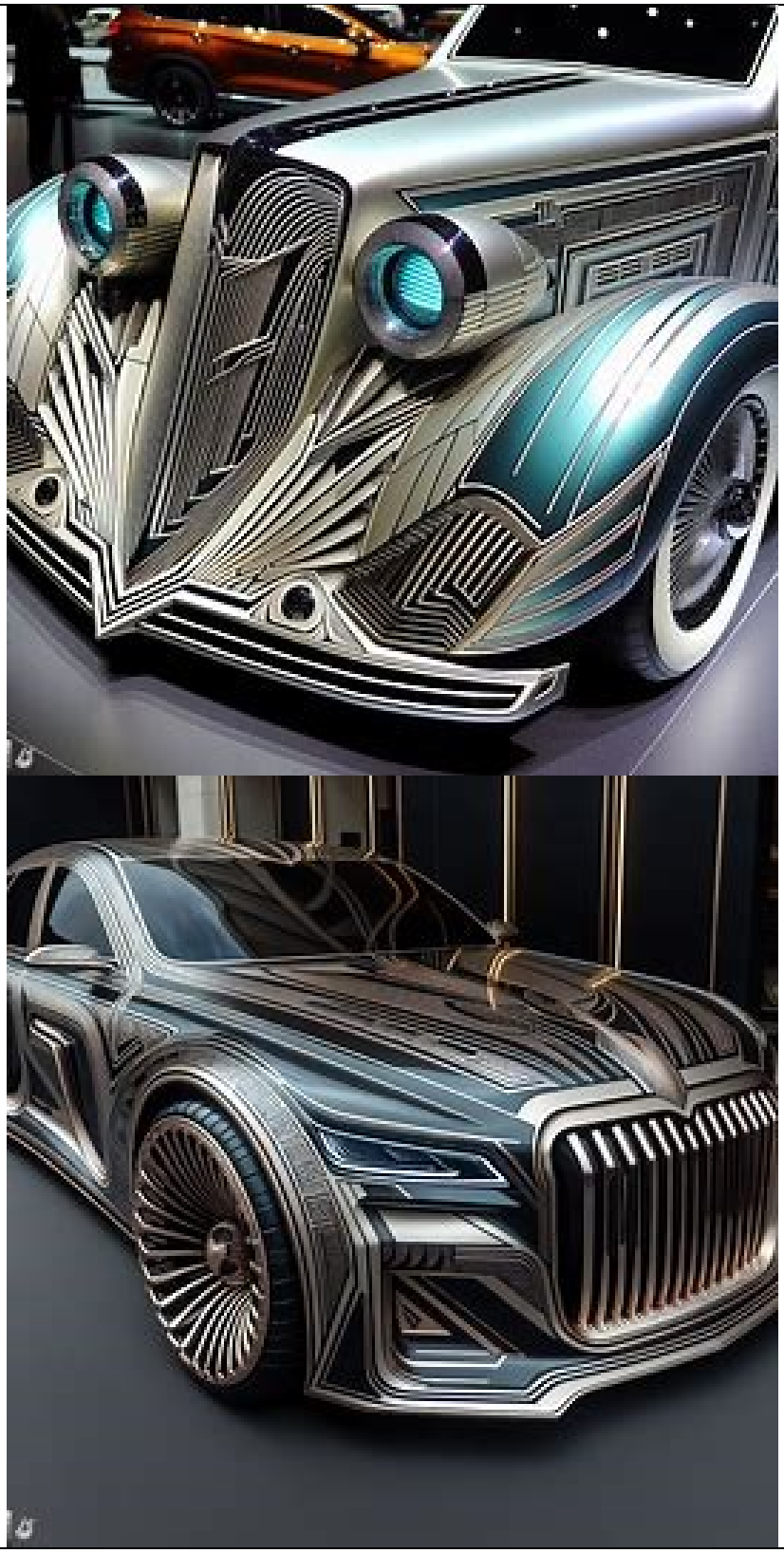
A car interior inspired with Bauhaus design influences		 

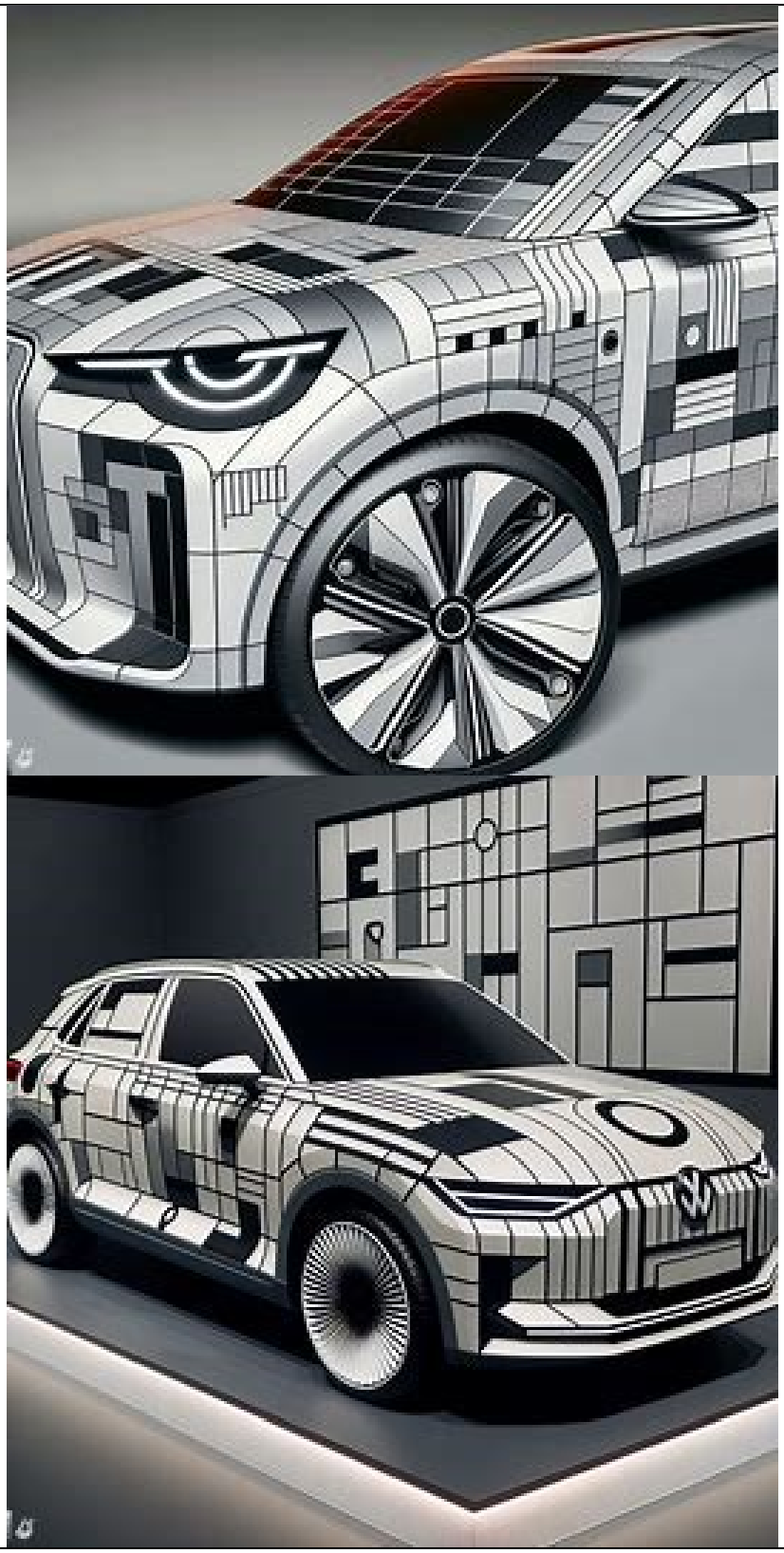
A futuristic car interior inspired with science fiction design influences	

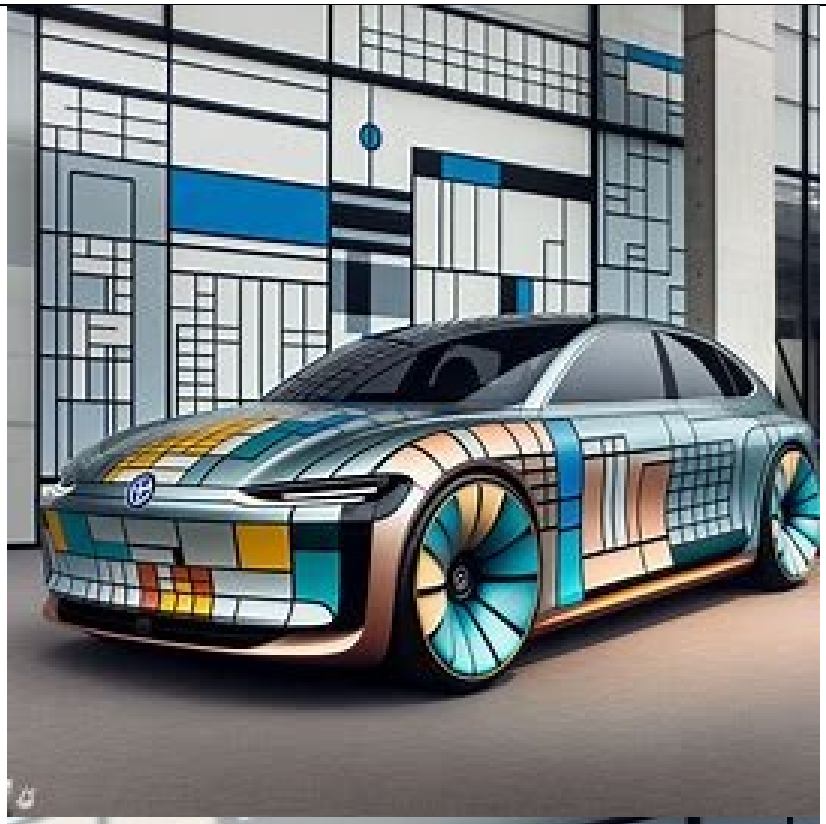
Appendix 3 Exterior Design Generative AI Data

Exterior Design Prompts	Bing AI image generator
A. A modern reimagining of the Jaguar e-type retaining the classic shape.	

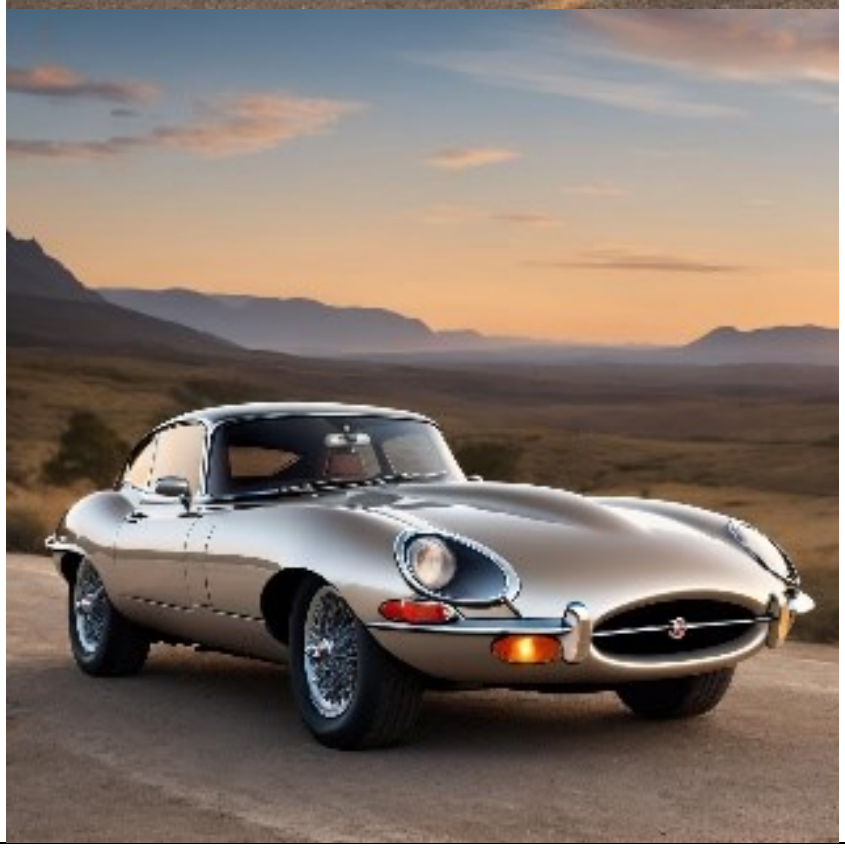
B. A budget brand hatchback car with modern styling similar to a VW Golf and a Renault Clio.		

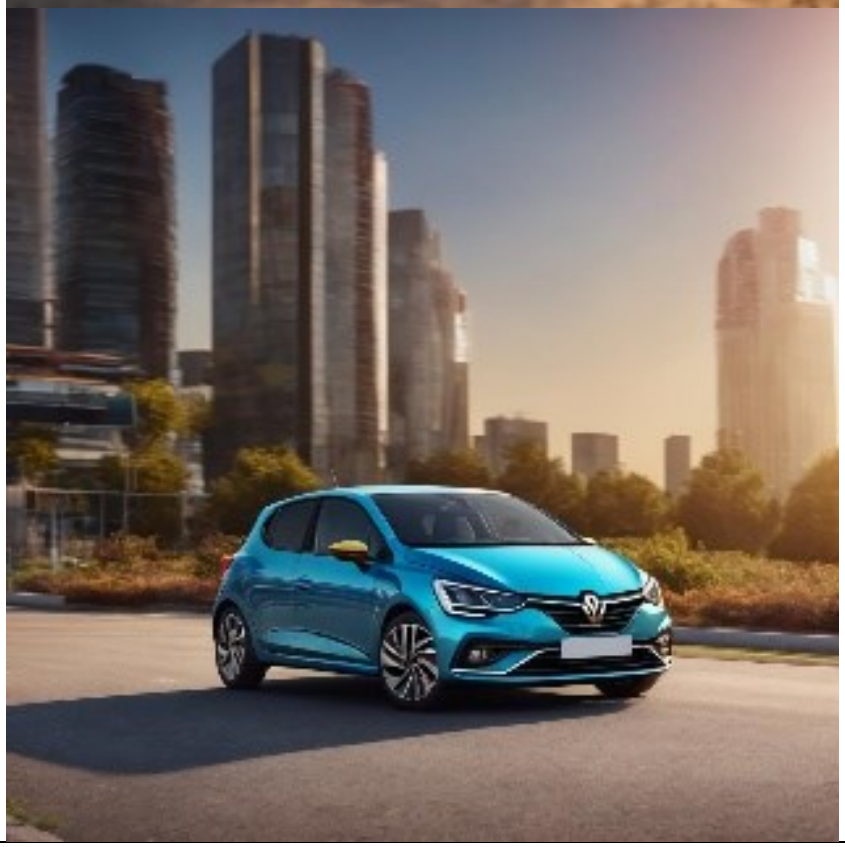
C. A car exterior inspired with art deco design influences	

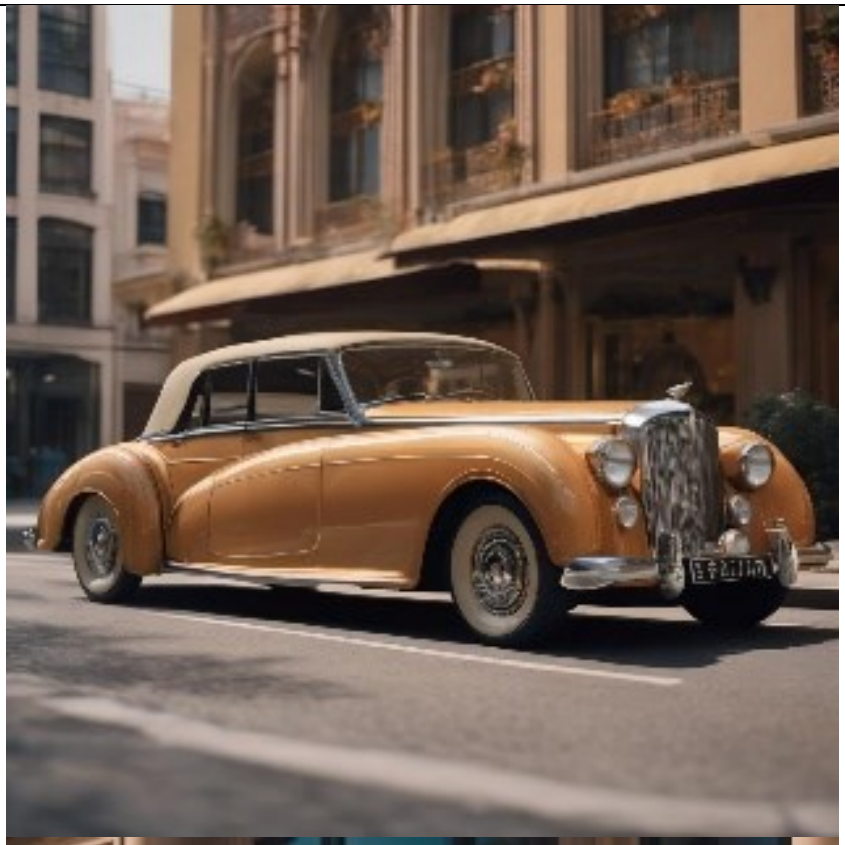
D. A car exterior inspired with Bauhaus design influences	

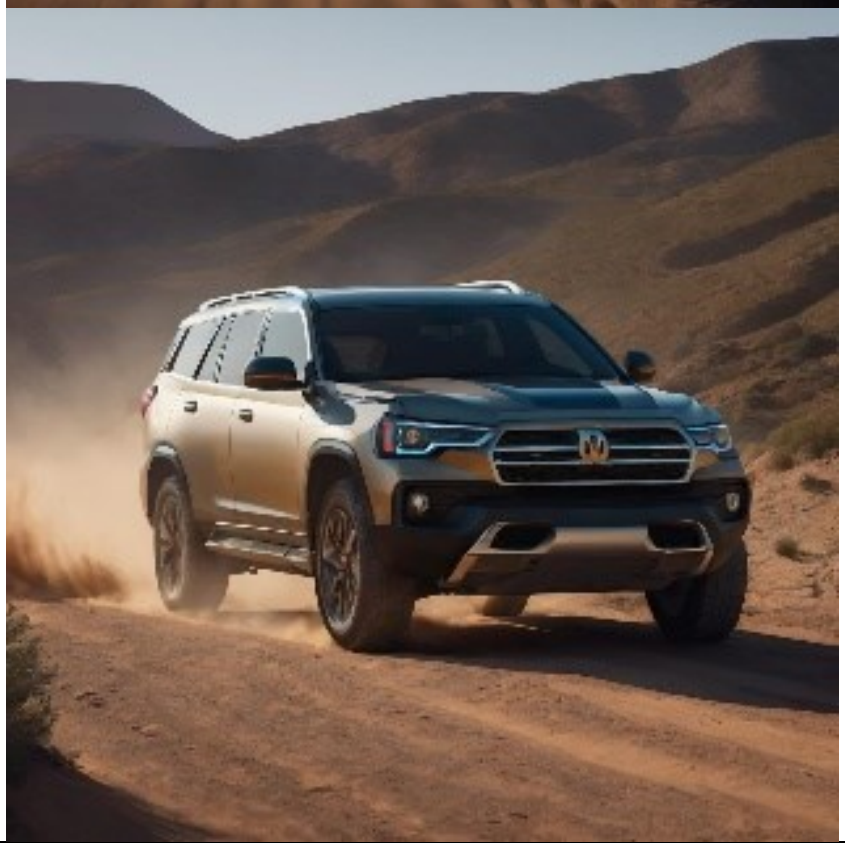
E. An SUV exterior inspired with modern design influences rugged off-roading abilities.		

Exterior Design Prompts	Gencraft AI image generator
A. A modern reimagining of the Jaguar e-type retaining the classic shape.	

B. A budget brand hatchback car with modern styling similar to a VW Golf and a Renault Clio.	

C. A car exterior inspired with art deco design influences	

D. A car exterior inspired with Bauhaus design influences	

E. An SUV exterior inspired with modern design influences rugged off-roading abilities.	

Appendix 4 Technical Documentation Generative AI Data (tabulated and edited)

Data edited and formatted to fit table for ease of comparison. See Appendix 5 Technical Documentation Chat GPT Generative AI Data unedited and Appendix 6 Technical Documentation Bard Generative AI Data unedited.for the unedited data.

Technical documentation Prompts	**Chat GPT**	**Bard AI**
Write a technical document for the process of fitting door onto a vehicle in the manufacturing plant	**Title: Technical Document for Fitting Doors onto Vehicles in the Manufacturing Plant** **Objective:** This document aims to provide a comprehensive guide for the proper fitting of doors onto vehicles within the manufacturing plant. It outlines the step-by-step process, tools required, safety measures, and quality checks involved in the door fitting procedure. **Introduction:** Fitting doors onto vehicles is a crucial stage in the assembly process. Proper fitting ensures structural integrity, safety, and aesthetic appeal of the vehicle. This document details the procedure to be followed by assembly line technicians for precise door installation. **Procedure:** **1. Preparation:** Gather necessary tools and equipment: Door assembly (prepped with necessary components) Torque wrench Fasteners (bolts, screws, etc.) Sealants/adhesives (if applicable) Ensure the work area is clean and free from debris. Use appropriate personal protective equipment (PPE), including gloves and safety glasses. **2. Positioning of the Vehicle:** Place the vehicle in the designated assembly area, ensuring it's securely positioned on the assembly line. **3. Door Alignment:** Inspect the door frame and vehicle body for any irregularities or damages. Position the door carefully onto the vehicle, aligning it with the corresponding hinges and latch points. Use reference markers or templates for precise alignment. **4. Fixation:** Secure the door initially with temporary fasteners to hold it in place. Gradually tighten the fasteners uniformly to ensure even pressure distribution. Use a torque wrench to tighten fasteners to manufacturer-specified torque values. Check for smooth operation of the door (opening, closing, alignment) during the fixation process. **5. Sealing (if applicable):** Apply recommended sealants or adhesives to ensure a proper seal between the door and the vehicle body. Follow manufacturer guidelines for sealant application and curing time. **6. Quality Checks:** Conduct visual inspections to ensure uniform gaps between the door and the vehicle body. Verify that the door operates smoothly without any obstructions or misalignment. Perform functional tests (locking mechanisms, window operation) to ensure proper functionality. Check for any paint damage or scratches that might have occurred during the fitting process. **7. Final Verification:** Once the door is securely fitted, recheck torque values and ensure all fasteners are properly tightened.	**Technical Document: Fitting Vehicle Doors** **Overview** The fitting of vehicle doors is a critical step in the manufacturing process, ensuring the integrity and functionality of the vehicle's structure and occupant safety. This document outlines the standard procedure for fitting doors onto a vehicle in an automotive manufacturing plant. **Equipment** The following equipment is required for fitting vehicle doors: • Door handling equipment: This may include a pneumatic hoist, overhead crane, or specialized door-fitting trolley. • Alignment tools: Accurate alignment tools, such as laser pointers, gauges, and feeler gauges, are essential to ensuring proper door fitment. • Torque wrenches: Proper torque is crucial for securing fasteners and ensuring consistent door alignment. • Measuring tools: To ensure adherence to dimensional tolerances, measuring tools such as calipers and micrometers are needed. **Procedure** 1. Door Acquisition: The door is retrieved from the appropriate storage area or production line. 2. Door Preparation: The door is inspected for any damage, dents, or scratches. If necessary, corrective measures are taken to ensure the door is suitable for installation. 3. Door Handling and Positioning: The door is carefully handled and positioned over the vehicle's opening using the designated door-handling equipment. 4. Pre-Alignment: Using alignment tools, the door is positioned in a preliminary alignment with the vehicle's body structure. This involves aligning the door's edges, hinges, and latch mechanism with their corresponding points on the vehicle. 5. Initial Fastening: Temporary fasteners, such as bolts or clips, are used to secure the door in the pre-aligned position. This allows for further fine-tuning without compromising the door's position. 6. Seatbelt Retraction Mechanism Installation: The seatbelt retraction mechanism is installed into the door panel, ensuring proper routing of the seatbelt beltline through the door opening. 7. Door Seal Installation: The door seal is properly positioned and secured around the door perimeter, ensuring weather sealing and improved noise isolation. 8. Door Check and Adjustment: Using precision measuring tools and alignment gauges, the door is checked for proper alignment, ensuring that it is perpendicular to the vehicle's body and parallel to the adjoining doors. Adjustments are made as necessary to achieve the required tolerances. 9. Final Fastening and Torqueing: The temporary fasteners are replaced with permanent fasteners, such as bolts and nuts, ensuring a secure and

	Conduct a final visual inspection to confirm proper alignment and appearance. **Safety Measures:** Follow all safety protocols and guidelines while handling tools and working around vehicles. Be cautious of sharp edges and moving parts during the door fitting process. Report any safety concerns or potential hazards immediately to the supervisor. **Conclusion:** Proper fitting of doors onto vehicles is critical for ensuring the overall quality and safety of the final product. Adhering to this detailed procedure helps maintain consistency and precision in the assembly process.	durable connection. All fasteners are torqued to the specified values using torque wrenches to maintain consistent and precise tightening. 10. Door Latch Mechanism Installation and Adjustment: The door latch mechanism is installed and adjusted to ensure proper operation and alignment with the vehicle's locking system. 11. Door Sealing and Weatherproofing: The door seals are thoroughly checked for any gaps or irregularities that may compromise weatherproofing. Any discrepancies are corrected to ensure a secure seal against the vehicle's body. 12. Door Functional Testing: The door is opened and closed multiple times to ensure smooth operation, proper latch engagement, and efficient sealing. Any issues are identified and rectified before the vehicle is released for further assembly. **Quality Assurance** Throughout the door-fitting process, strict quality assurance measures are implemented to ensure the door is properly aligned, sealed, and functionally integrated with the vehicle. This includes visual inspections, precision measurements, and thorough functional testing. Any deviations from the specified tolerances or operational parameters are immediately addressed to maintain the vehicle's integrity and safety standards.
Write a technical document for health and safety for factory visitors.	**Title: Health and Safety Guidelines for Factory Visitors** **Objective:** This document aims to inform all visitors to the factory about the health and safety guidelines and procedures they need to follow while on-site to prevent accidents, injuries, and health risks. **Introduction:** [Company Name] is committed to providing a safe environment for all individuals visiting our factory premises. Visitors' safety is of utmost importance, and adherence to these guidelines is mandatory for everyone's well-being. **General Safety Guidelines:** **1. Visitor Registration:** All visitors must register at the main reception upon arrival. Obtain a visitor pass/badge which must be worn prominently at all times while on-site. **2. Personal Protective Equipment (PPE):** Wear appropriate PPE provided by the company, such as safety helmets, vests, goggles, or any other specified equipment based on the designated areas to be visited. Closed-toe shoes are mandatory; avoid wearing loose clothing or accessories that could pose a safety risk. **3. Guided Tour and Supervision:** Visitors must be accompanied by an authorized company representative or guide at all times during their visit. Follow the instructions given by the guide and avoid straying into restricted areas. **4. Emergency Procedures:** Familiarize yourself with the nearest emergency exits, assembly points, and fire evacuation procedures. In the event of an emergency, follow instructions from company staff and evacuate the premises calmly and swiftly. **5. Restricted Areas:** Respect all marked or cordoned-off areas and refrain from entering restricted zones without explicit permission from authorized personnel. **6. Hazardous Materials and Equipment:**	**Technical Document: Health and Safety for Factory Visitors** **Introduction** Factory environments can present unique health and safety hazards for visitors who are not familiar with the working conditions and potential risks. To ensure the safety of all individuals who enter the factory premises, it is imperative to implement comprehensive health and safety guidelines specifically for visitors. This document outlines the key health and safety protocols that visitors must adhere to during their visit to the factory. **Personal Protective Equipment (PPE)** All visitors are required to wear appropriate PPE throughout their entire visit to the factory. This includes: • Hard hat: To protect the head from falling objects, debris, or machinery. • Safety glasses: To protect the eyes from flying particles, sparks, or potential chemical splashes. • Reflective vest or clothing: To enhance visibility in areas with limited lighting or heavy machinery operations. • Steel-toed boots: To protect the feet from falling objects, machinery, or sharp surfaces. **Work Area Restrictions** Visitors are restricted from entering designated areas of the factory unless accompanied by a designated factory personnel. These restricted areas may include: • Production lines: Due to the active machinery and potential hazards, only authorized personnel are allowed in production areas. • Storage areas: Storage areas may contain hazardous materials or heavy equipment that require specialized training and equipment to handle. • High-voltage areas: Visitors must avoid areas with exposed electrical wiring or high-voltage equipment. **Machinery Safety** Visitors must adhere to strict machinery safety protocols: • Keep hands and feet clear of moving machinery.

	Do not touch any machinery, equipment, or materials unless instructed and supervised by authorized personnel. Stay clear of moving machinery, forklifts, or any operational equipment. **7. Hygiene and Health Protocols:** Maintain good personal hygiene and wash hands before and after the visit, especially if handling materials or equipment. Refrain from eating, drinking, or smoking in designated non-smoking areas. **8. Reporting Incidents or Concerns:** Immediately report any accidents, injuries, or safety concerns to the accompanying guide or company staff. Be vigilant and report any unsafe conditions observed during the visit. **Conclusion:** [Company Name] prioritizes the safety of all visitors. Adherence to these guidelines is mandatory to ensure a safe and productive visit to our factory. We appreciate your cooperation in maintaining a secure environment for everyone.	• Do not operate any machinery without proper training and authorization. • Observe all signage and warning labels related to machinery operation. **Hand-washing and Hygiene** Thorough hand-washing is essential to prevent the spread of germs and maintain hygiene standards: • Wash hands with soap and water for at least 20 seconds after using restrooms, handling food, or touching any potentially contaminated surfaces. • Use hand sanitizer if hand washing facilities are unavailable. • Avoid eating or drinking in areas where hand washing is not readily accessible. **Emergency Procedures** Visitors must be familiar with emergency procedures and designated evacuation routes: • Pay attention to emergency signage and alarms. • Follow instructions provided by factory personnel during an emergency. • Evacuate the factory premises promptly and calmly in the event of an emergency. **Reporting Hazards** Visitors are encouraged to report any observed hazards or safety concerns immediately to factory personnel: • Do not attempt to fix or modify machinery or equipment unless authorized. • Contact factory personnel promptly if you observe any safety hazards, spills, or equipment malfunctions. **Compliance and Enforcement** Strict adherence to health and safety guidelines is mandatory for all visitors. Failure to comply with the outlined protocols may result in the visitor's removal from the factory premises. Conclusion The safety of all individuals who enter the factory is of paramount importance. By implementing comprehensive health and safety guidelines for visitors, we can ensure that everyone has a safe and productive visit while minimizing the risk of accidents or injuries. By following the guidelines outlined in this document, visitors can contribute to the overall safety culture of our factory and help maintain a safe working environment for all.
Develop a generalised DFMEA template	**Design Failure Mode and Effects Analysis (DFMEA) Template** **Project/Component Name:** **Date:** **Prepared by:** **Section 1: General Information** 1. **Objective:** Describe the purpose and scope of the DFMEA. 2. **Team Members:** List the names and roles of team members involved in the DFMEA. 3. **Revision History:** • Version Number • Date of Revision • Brief Description of Changes **Section 2: Component/System Description** 1. **Component/System Name:** 2. **Function:** 3. **Functional Requirements:** 4. **Boundary/Interface Description:** **Section 3: DFMEA Table** **Section 4: Severity, Occurrence, and Detection Rating Guidelines**	**Generalized DFMEA Template** **Product: [Product Name]** **Version: [Version Number]** **Date: [Date]** **Team:** • [Name] • [Name] • [Name] 1. **Overview** • Purpose: To identify and evaluate potential design failures that could occur during the product's life cycle. • Scope: The entire product, from concept to manufacturing and service. • Methodology: Failure Mode and Effects Analysis (FMEA) **2. Failure Modes** **3. Control Plans** **4. Traceability** **5. Review and Approval** **6. Appendix**

	1. **Severity (S) Scale:** Define the severity scale (e.g., 1-10) and criteria. 2. **Occurrence (O) Scale:** Define the occurrence scale (e.g., 1-10) and criteria. 3. **Detection (D) Scale:** Define the detection scale (e.g., 1-10) and criteria. **Section 5: Action Plan** 1. **Recommended Actions:** Describe actions to mitigate or eliminate identified failure modes. 2. **Responsibility:** Assign responsible individuals or teams for each action. 3. **Action Status:** Track the progress of each action (e.g., Not Started, In Progress, Completed). **Section 6: Conclusion** Summarize the key findings, actions taken, and any additional notes. Remember, the DFMEA template should be tailored to suit your specific industry, product, or project requirements. Adjust the severity, occurrence, and detection rating scales according to the needs of your organization.	• Additional information, data sheets, or diagrams that support the DFMEA.
Develop a user manual for seat adjustment.	**User Manual: Seat Adjustment** **Introduction:** This manual provides instructions for adjusting the seats in your vehicle to ensure comfort and safety while driving. **Types of Seat Adjustments:** Your vehicle may have several types of seat adjustments, including: 1. **Seat Position:** Moving the seat forward, backward, up, or down. 2. **Seatback Angle:** Tilting the seatback forward or backward. 3. **Lumbar Support:** Adjusting the lumbar area for better back support. 4. **Headrest:** Positioning the headrest for optimal comfort and safety. **Important Safety Information:** • Adjust the seat only when the vehicle is stationary and the engine is off. • Do not adjust the seat while driving to avoid accidents or loss of control. • Ensure the seat adjustments are secure before driving. **Instructions for Seat Adjustment:** 1. **Seat Position Adjustment:** • Locate the seat adjustment lever or buttons on the side of the seat. • To move the seat forward or backward: • Pull the lever up or press the appropriate button to slide the seat forward or backward. • Release the lever or button when the desired position is reached. 2. **Seatback Angle Adjustment:** • Locate the seatback adjustment lever or dial on the side of the seat. • To recline or incline the seatback: • Pull the lever up or turn the dial to adjust	**User Manual: Seat Adjustment** **Introduction** Proper seat adjustment is essential for comfort and safety while driving. This user manual will provide step-by-step instructions on how to adjust your seat to ensure you have a comfortable and safe driving experience. **Equipment** • Seat adjustment lever or knob • Seatback recline handle (optional) • Lumbar support lever (optional) **Adjusting the Seat Height** 1. Locate the seat height adjustment lever or knob. It is typically located on the right side of the seat, near the front of the seat cushion. 2. Pull the lever or knob up to raise the seat or push it down to lower the seat. Adjust the seat height to a comfortable position where your feet can reach the pedals comfortably and your back can be supported by the seatback. **Adjusting the Seat Fore-aft Position** 1. Locate the seat fore-aft adjustment lever or knob. It is typically located on the left side of the seat, near the front of the seat cushion. 2. Pull the lever or knob towards you to slide the seat forward or push it away from you to slide the seat backward. Adjust the seat fore-aft position to a comfortable position where you can reach the pedals, steering wheel, and gearshift comfortably. **Adjusting the Seatback Recline** 1. Locate the seatback recline handle. It is typically located on the left side of the seat, near the top of the seatback. 2. Pull the handle up to recline the seatback or push it down to incline the seatback. Adjust the seatback recline to a comfortable position where you can maintain good posture and visibility. **Adjusting the Lumbar Support** 1. Locate the lumbar support lever (if equipped). It is typically located on the left or right side of the seat, near the top of the seatback. 2. Press the lever to adjust the lumbar support. You can adjust the lumbar support to provide additional support for your lower back. **Adjusting the Headrest**

	the angle of the seatback. • Release the lever or dial when the desired angle is achieved. 3. **Lumbar Support Adjustment:** • Find the lumbar support control, typically a knob or button on the side of the seat. • To adjust the lumbar support: • Rotate the knob or press the button to increase or decrease the support in the lower back area. • Stop when the desired level of support is felt. 4. **Headrest Adjustment:** • Locate the headrest adjustment button or levers on the top of the seat. • To adjust the headrest height or angle: • Press the button or lift the headrest to move it up or down. • Adjust the angle by tilting the headrest forward or backward. • Ensure the headrest is positioned comfortably behind your head. **Conclusion:** Properly adjusted seats not only enhance driving comfort but also contribute to safety. Experiment with the adjustments to find the most comfortable positions for your driving experience. For further assistance or detailed instructions, refer to the vehicle's owner's manual.	1. Locate the headrest adjustment lever. It is typically located on the back of the headrest. 2. Tilt the headrest up or down to adjust the height of the headrest. Adjust the headrest to a comfortable position where it can provide support for your head and neck. **Additional Tips for Comfortable and Safe Driving** • Adjust the mirrors so you can see clearly behind you. • Adjust the steering wheel to a comfortable position where you can reach the pedals and steering wheel comfortably. • Do not wear loose clothing that could get caught in the pedals or steering wheel. • Take breaks from driving every 2 hours to avoid fatigue.
Create the code for adjusting the duration exterior lights stay on when a vehicle is locked.	The code for adjusting the duration exterior lights stay on when a vehicle is locked can vary significantly based on the vehicle's make, model, and the underlying software system controlling these settings. In many modern vehicles, this setting might be accessible through the car's onboard computer system or through a specialized software interface. The exact method to adjust this setting could involve a series of steps or commands within the vehicle's software. For example, in some vehicles, this setting might be accessible through the infotainment system or dashboard controls. A simplified representation of adjusting this setting using Python (which might not directly apply to real vehicle systems but serves as an example) could be: In real vehicles, adjusting such settings typically requires specialized tools or interfaces provided by the manufacturer or authorized service centers. It involves accessing the vehicle's electronic control unit (ECU) or onboard computer system, which isn't directly programmable using general-purpose languages like Python without the appropriate interfaces and protocols. Always refer to the vehicle's manual or consult a certified technician or dealership for instructions on adjusting specific settings in a vehicle. Making changes to vehicle settings without proper knowledge or	The specific code for adjusting the duration exterior lights stay on when a vehicle is locked will vary depending on the vehicle's make, model, and year. However, the general approach is to access the vehicle's electronic control unit (ECU) and modify the settings for the exterior lighting system. Here's a general outline of the process: 1. Connect to the vehicle's ECU: Use a diagnostic tool or software specifically designed to communicate with the vehicle's ECU. This may require a physical connection to the ECU or a wireless connection using a Bluetooth or Wi-Fi adapter. 2. Locate the relevant settings: Access the ECU's programming or configuration menus and locate the settings related to exterior lighting behavior, particularly the duration for which the lights remain on after locking the vehicle. 3. Adjust the settings: Modify the settings to specify the desired duration for which the exterior lights should stay on after locking the vehicle. The duration can be expressed in seconds or a combination of seconds and a delay period, such as "30 seconds after no movement." 4. Save the changes: Save the modified settings to the ECU's memory. This ensures that the changes are persistent and will be

	authorization can lead to unintended consequences or void warranties.	implemented the next time the vehicle is locked. 5. Verify the changes: After saving the changes, test the vehicle to ensure that the exterior lights stay on for the specified duration after locking.
Create the code for adjusting the duration exterior lights stay on when a vehicle is locked using python.	Sure, to simulate adjusting the duration for exterior lights staying on when a vehicle is locked using Python, here's an example: This example demonstrates a basic representation of how you could model adjusting the duration for exterior lights to stay on when the vehicle is locked. This doesn't interface with an actual vehicle but showcases a class (Vehicle) with methods to adjust the duration and simulate locking the vehicle, displaying the set duration. For a real vehicle, the process would involve interfacing with the vehicle's electronic system, which usually requires specialized hardware and protocols provided by the vehicle manufacturer's API or SDK. This script is a simulation and doesn't control an actual vehicle's settings.	Adjusting the duration exterior lights stay on when a vehicle is locked using Python would involve interfacing with the vehicle's ECU, which is typically done through dedicated diagnostic tools or software. Python itself doesn't directly connect to the ECU; it would need to interact with a specific tool or software that provides an API or driver for ECU communication. Here's a simplified example of how you might structure such a Python script: This is a simplified example, and the actual implementation will depend on the specific ECU communication protocol and the diagnostic tool's API or driver. The provided example assumes that the ECU settings can be accessed and modified using SQL queries.

Appendix 5 Technical Documentation Chat GPT Generative AI Data unedited

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You

Hi Chat GPT, you now work from an Automotive OEM and will assist engineers in everyday tasks

ChatGPT

ChatGPT

That sounds exciting! Working in an automotive OEM can involve a wide range of tasks, from designing and testing to optimizing various vehicle components. How can I assist you with your engineering tasks today?

N

You

Write a technical document for the process of fitting door onto a vehicle in the manufacturing plant

ChatGPT

ChatGPT

Certainly! Here's an outline for a technical document on fitting a door onto a vehicle in a manufacturing plant:

Title: Technical Document for Fitting Doors onto Vehicles in the Manufacturing Plant

Objective: This document aims to provide a comprehensive guide for the proper fitting of doors onto vehicles within the manufacturing plant. It outlines the step-by-step process, tools required, safety measures, and quality checks involved in the door fitting procedure.

Introduction: Fitting doors onto vehicles is a crucial stage in the assembly process. Proper fitting ensures structural integrity, safety, and aesthetic appeal of the vehicle. This document details the procedure to be followed by assembly line technicians for precise door installation.

Procedure:

1. **Preparation:**
    - Gather necessary tools and equipment:
        - Door assembly (prepped with necessary components)
        - Torque wrench
        - Fasteners (bolts, screws, etc.)
        - Sealants/adhesives (if applicable)
    - Ensure the work area is clean and free from debris.
    - Use appropriate personal protective equipment (PPE), including gloves and safety glasses.
2. **Positioning of the Vehicle:**
    - Place the vehicle in the designated assembly area, ensuring it's securely positioned on the assembly line.
3. **Door Alignment:**
    - Inspect the door frame and vehicle body for any irregularities or damages.
    - Position the door carefully onto the vehicle, aligning it with the corresponding hinges and latch points.

- Use reference markers or templates for precise alignment.

4. **Fixation:**
   - Secure the door initially with temporary fasteners to hold it in place.
   - Gradually tighten the fasteners uniformly to ensure even pressure distribution.
   - Use a torque wrench to tighten fasteners to manufacturer-specified torque values.
   - Check for smooth operation of the door (opening, closing, alignment) during the fixation process.
5. **Sealing (if applicable):**
   - Apply recommended sealants or adhesives to ensure a proper seal between the door and the vehicle body.
   - Follow manufacturer guidelines for sealant application and curing time.
6. **Quality Checks:**
   - Conduct visual inspections to ensure uniform gaps between the door and the vehicle body.
   - Verify that the door operates smoothly without any obstructions or misalignment.
   - Perform functional tests (locking mechanisms, window operation) to ensure proper functionality.
   - Check for any paint damage or scratches that might have occurred during the fitting process.
7. **Final Verification:**
   - Once the door is securely fitted, recheck torque values and ensure all fasteners are properly tightened.
   - Conduct a final visual inspection to confirm proper alignment and appearance.

Safety Measures:

- Follow all safety protocols and guidelines while handling tools and working around vehicles.
- Be cautious of sharp edges and moving parts during the door fitting process.
- Report any safety concerns or potential hazards immediately to the supervisor.

Conclusion: Proper fitting of doors onto vehicles is critical for ensuring the overall quality and safety of the final product. Adhering to this detailed procedure helps maintain consistency and precision in the assembly process.

Feel free to expand or modify any sections according to the specific processes and requirements of your manufacturing plant!

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You

Write a technical document for health and safety for factory visitors.

ChatGPT

ChatGPT

Absolutely, ensuring the safety of factory visitors is crucial. Here's a template for a health and safety document for factory visitors:

Title: Health and Safety Guidelines for Factory Visitors

Objective: This document aims to inform all visitors to the factory about the health and safety guidelines and procedures they need to follow while on-site to prevent accidents, injuries, and health risks.

Introduction: [Company Name] is committed to providing a safe environment for all individuals visiting our factory premises. Visitors' safety is of utmost importance, and adherence to these guidelines is mandatory for everyone's well-being.

General Safety Guidelines:

1. **Visitor Registration:**
   - All visitors must register at the main reception upon arrival.
   - Obtain a visitor pass/badge which must be worn prominently at all times while on-site.
2. **Personal Protective Equipment (PPE):**
   - Wear appropriate PPE provided by the company, such as safety helmets, vests, goggles, or any other specified equipment based on the designated areas to be visited.
   - Closed-toe shoes are mandatory; avoid wearing loose clothing or accessories that could pose a safety risk.
3. **Guided Tour and Supervision:**
   - Visitors must be accompanied by an authorized company representative or guide at all times during their visit.
   - Follow the instructions given by the guide and avoid straying into restricted areas.
4. **Emergency Procedures:**
   - Familiarize yourself with the nearest emergency exits, assembly points, and fire evacuation procedures.
   - In the event of an emergency, follow instructions from company staff and evacuate the premises calmly and swiftly.
5. **Restricted Areas:**
   - Respect all marked or cordoned-off areas and refrain from entering restricted zones without explicit permission from authorized personnel.
6. **Hazardous Materials and Equipment:**
   - Do not touch any machinery, equipment, or materials unless instructed and supervised by authorized personnel.
   - Stay clear of moving machinery, forklifts, or any operational equipment.
7. **Hygiene and Health Protocols:**
   - Maintain good personal hygiene and wash hands before and after the visit, especially if handling materials or equipment.
   - Refrain from eating, drinking, or smoking in designated non-smoking areas.
8. **Reporting Incidents or Concerns:**
   - Immediately report any accidents, injuries, or safety concerns to the accompanying guide or company staff.
   - Be vigilant and report any unsafe conditions observed during the visit.

Conclusion: [Company Name] prioritizes the safety of all visitors. Adherence to these guidelines is mandatory to ensure a safe and productive visit to our factory. We appreciate your cooperation in maintaining a secure environment for everyone.

Tailor this document to include specific safety protocols and regulations pertinent to your factory's operations and ensure that it aligns with your company's policies and procedures.

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You

Develop a generalised DFMEA template

ChatGPT

ChatGPT

Absolutely, a Design Failure Mode and Effects Analysis (DFMEA) template helps identify and address potential failures in the design process. Here's a generalized template:

Design Failure Mode and Effects Analysis (DFMEA) Template

Project/Component Name:

Date:

Prepared by:

Section 1: General Information

1. **Objective:** Describe the purpose and scope of the DFMEA.
2. **Team Members:** List the names and roles of team members involved in the DFMEA.
3. **Revision History:**
    - Version Number
    - Date of Revision
    - Brief Description of Changes

Section 2: Component/System Description

1. **Component/System Name:**
2. **Function:**
3. **Functional Requirements:**
4. **Boundary/Interface Description:**

Section 3: DFMEA Table

Item/Function	Potential Failure Mode	Potential Effects of Failure	Severity (S)	Potential Causes of Failure	Occurrence (O)	Current Controls	Detection (D)	Risk Priority Number (RPN)	Recommended Actions	Responsibility	Action Status

Repeat rows as necessary for each identified failure mode.

Section 4: Severity, Occurrence, and Detection Rating Guidelines

1. **Severity (S) Scale:** Define the severity scale (e.g., 1-10) and criteria.
2. **Occurrence (O) Scale:** Define the occurrence scale (e.g., 1-10) and criteria.
3. **Detection (D) Scale:** Define the detection scale (e.g., 1-10) and criteria.

Section 5: Action Plan

1. **Recommended Actions:** Describe actions to mitigate or eliminate identified failure modes.
2. **Responsibility:** Assign responsible individuals or teams for each action.
3. **Action Status:** Track the progress of each action (e.g., Not Started, In Progress, Completed).

Section 6: Conclusion

Summarize the key findings, actions taken, and any additional notes.

Remember, the DFMEA template should be tailored to suit your specific industry, product, or project requirements. Adjust the severity, occurrence, and detection rating scales according to the needs of your organization.

N

You
Develop a user manual for seat adjustment.

ChatGPT

ChatGPT
Absolutely, here's a basic user manual for adjusting seats in a vehicle:

User Manual: Seat Adjustment

Introduction: This manual provides instructions for adjusting the seats in your vehicle to ensure comfort and safety while driving.

Types of Seat Adjustments: Your vehicle may have several types of seat adjustments, including:

1. **Seat Position:** Moving the seat forward, backward, up, or down.
2. **Seatback Angle:** Tilting the seatback forward or backward.
3. **Lumbar Support:** Adjusting the lumbar area for better back support.
4. **Headrest:** Positioning the headrest for optimal comfort and safety.

Important Safety Information:

- Adjust the seat only when the vehicle is stationary and the engine is off.
- Do not adjust the seat while driving to avoid accidents or loss of control.
- Ensure the seat adjustments are secure before driving.

Instructions for Seat Adjustment:

1. **Seat Position Adjustment:**
    - Locate the seat adjustment lever or buttons on the side of the seat.

- To move the seat forward or backward:
    - Pull the lever up or press the appropriate button to slide the seat forward or backward.
    - Release the lever or button when the desired position is reached.

2. **Seatback Angle Adjustment:**
    - Locate the seatback adjustment lever or dial on the side of the seat.
    - To recline or incline the seatback:
        - Pull the lever up or turn the dial to adjust the angle of the seatback.
        - Release the lever or dial when the desired angle is achieved.
3. **Lumbar Support Adjustment:**
    - Find the lumbar support control, typically a knob or button on the side of the seat.
    - To adjust the lumbar support:
        - Rotate the knob or press the button to increase or decrease the support in the lower back area.
        - Stop when the desired level of support is felt.
4. **Headrest Adjustment:**
    - Locate the headrest adjustment button or levers on the top of the seat.
    - To adjust the headrest height or angle:
        - Press the button or lift the headrest to move it up or down.
        - Adjust the angle by tilting the headrest forward or backward.
        - Ensure the headrest is positioned comfortably behind your head.

Conclusion: Properly adjusted seats not only enhance driving comfort but also contribute to safety. Experiment with the adjustments to find the most comfortable positions for your driving experience.

For further assistance or detailed instructions, refer to the vehicle's owner's manual.

This manual is a general guide. Specific seat adjustment methods may vary between different vehicle models. Always refer to the vehicle's manual for precise instructions tailored to your vehicle's seat adjustment features.

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You

Create the code for adjusting the duration exterior lights stay on when a vehicle is locked.

ChatGPT

ChatGPT

The code for adjusting the duration exterior lights stay on when a vehicle is locked can vary significantly based on the vehicle's make, model, and the underlying software system controlling these settings.

In many modern vehicles, this setting might be accessible through the car's onboard computer system or through a specialized software interface. The exact method to adjust this setting could involve a series of steps or commands within the vehicle's software.

For example, in some vehicles, this setting might be accessible through the infotainment system or dashboard controls. A simplified representation of adjusting this setting using Python (which might not directly apply to real vehicle systems but serves as an example) could be:

python Copy code

```python
# This is a simplified Python representation and does not control real

def adjust_exterior_lights_duration(duration):
    # Code to interface with vehicle's onboard computer or software sys
    # This might involve sending commands or accessing a settings menu

    # For example, simulating setting the duration for exterior lights
    if duration >= 0 and duration <= 60:
        # Set the duration for exterior lights when locked
        # This could involve sending a signal or updating a configurati
        print(f"Exterior lights duration set to {duration} seconds.")
    else:
        print("Invalid duration. Please enter a value between 0 and 60

# Example usage: Adjusting exterior lights duration to 45 seconds
adjust_exterior_lights_duration(45)
```

```python
# This is a simplified Python representation and does not control real vehicle
systems

def adjust_exterior_lights_duration(duration):
    # Code to interface with vehicle's onboard computer or software system
    # This might involve sending commands or accessing a settings menu

    # For example, simulating setting the duration for exterior lights when locked
    if duration >= 0 and duration <= 60:
        # Set the duration for exterior lights when locked
        # This could involve sending a signal or updating a configuration value
        print(f"Exterior lights duration set to {duration} seconds.")
    else:
        print("Invalid duration. Please enter a value between 0 and 60 seconds.")

# Example usage: Adjusting exterior lights duration to 45 seconds
adjust_exterior_lights_duration(45)
```

In real vehicles, adjusting such settings typically requires specialized tools or interfaces provided by the manufacturer or authorized service centers. It involves accessing the vehicle's electronic control unit (ECU) or onboard computer system, which isn't directly programmable using general-purpose languages like Python without the appropriate interfaces and protocols.

Always refer to the vehicle's manual or consult a certified technician or dealership for instructions on adjusting specific settings in a vehicle. Making changes to vehicle settings without proper knowledge or authorization can lead to unintended consequences or void warranties.

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You

Create the code for adjusting the duration exterior lights stay on when a vehicle is locked using python.

ChatGPT

ChatGPT

Sure, to simulate adjusting the duration for exterior lights staying on when a vehicle is locked using Python, here's an example:

python Copy code

```python
class Vehicle:
    def __init__(self):
        self.exterior_lights_duration = 30  # Default duration in secon

    def adjust_lights_duration(self, new_duration):
        self.exterior_lights_duration = new_duration

    def lock_vehicle(self):
        print(f"Vehicle is locked. Exterior lights will stay on for {se


# Create a vehicle instance
my_vehicle = Vehicle()

# Adjust the exterior lights duration
new_duration = 45  # Change the duration as needed
my_vehicle.adjust_lights_duration(new_duration)

# Lock the vehicle and display the duration
my_vehicle.lock_vehicle()
```


```python
class Vehicle:
    def __init__(self):
        self.exterior_lights_duration = 30  # Default duration in seconds

    def adjust_lights_duration(self, new_duration):
        self.exterior_lights_duration = new_duration

    def lock_vehicle(self):
        print(f"Vehicle is locked. Exterior lights will stay on for
{self.exterior_lights_duration} seconds.")


# Create a vehicle instance
my_vehicle = Vehicle()

# Adjust the exterior lights duration
new_duration = 45  # Change the duration as needed
my_vehicle.adjust_lights_duration(new_duration)

# Lock the vehicle and display the duration
my_vehicle.lock_vehicle()
```


you could model adjusting the duration for exterior lights to stay on when the vehicle is locked. This doesn't interface with an actual vehicle but showcases a class (`Vehicle`) with methods to adjust the duration and simulate locking the vehicle, displaying the set duration.

For a real vehicle, the process would involve interfacing with the vehicle's electronic system, which usually requires specialized hardware and protocols provided by the vehicle manufacturer's API or SDK. This script is a simulation and doesn't control an actual vehicle's settings.

Appendix 6 Technical Documentation Bard Generative AI Data unedited.

N

Hi Bard, you now work from an Automotive OEM and will assist engineers in everyday tasks

PaLM2

Great! I'm happy to assist engineers in their everyday tasks at the Automotive OEM. Here are some of the ways I can help:

- **Research and gather information**: I can access and process information from a variety of sources, including technical documents, engineering reports, and scientific papers. I can also summarize complex information and translate it into easy-to-understand language.
- G**enerate technical documentation**: I can write and format technical documents, such as specifications, requirements, and test plans. I can also create diagrams, tables, and charts to illustrate technical concepts.
- **Solve engineering problems:** I can apply my knowledge of engineering principles and my ability to reason and analyze to solve complex engineering problems. I can also suggest creative solutions to engineering challenges.
- **Develop and test software:** I can write and test software code. I can also debug software problems and optimize software performance.
- **Create training materials:** I can create training materials, such as presentations, tutorials, and exercises. I can also customize training materials to meet specific needs.
- **Provide customer support:** I can answer customer questions about engineering products and services. I can also provide technical support to customers who are using our products.

I'm always learning and improving, and I'm excited to see how I can help engineers at the Automotive OEM achieve their goals.

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Write a technical document for the process of fitting door onto a vehicle in the manufacturing plant

PaLM2

Technical Document: Fitting Vehicle Doors

Overview

The fitting of vehicle doors is a critical step in the manufacturing process, ensuring the integrity and functionality of the vehicle's structure and occupant safety. This document outlines the standard procedure for fitting doors onto a vehicle in an automotive manufacturing plant.

Equipment

The following equipment is required for fitting vehicle doors:

- **Door handling equipment:** This may include a pneumatic hoist, overhead crane, or specialized door-fitting trolley.
- **Alignment tools:** Accurate alignment tools, such as laser pointers, gauges, and feeler gauges, are essential to ensuring proper door fitment.
- **Torque wrenches:** Proper torque is crucial for securing fasteners and ensuring consistent door alignment.
- **Measuring tools:** To ensure adherence to dimensional tolerances, measuring tools such as calipers and micrometers are needed.

Procedure

1. **Door Acquisition:** The door is retrieved from the appropriate storage area or production line.
2. **Door Preparation:** The door is inspected for any damage, dents, or scratches. If necessary, corrective measures are taken to ensure the door is suitable for installation.
3. **Door Handling and Positioning:** The door is carefully handled and positioned over the vehicle's opening using the designated door-handling equipment.
4. **Pre-Alignment:** Using alignment tools, the door is positioned in a preliminary alignment with the vehicle's body structure. This involves aligning the door's edges, hinges, and latch mechanism with their corresponding points on the vehicle.
5. **Initial Fastening:** Temporary fasteners, such as bolts or clips, are used to secure the door in the pre-aligned position. This allows for further fine-tuning without compromising the door's position.
6. **Seatbelt Retraction Mechanism Installation:** The seatbelt retraction mechanism is installed into the door panel, ensuring proper routing of the seatbelt beltline through the door opening.
7. **Door Seal Installation:** The door seal is properly positioned and secured around the door perimeter, ensuring weather sealing and improved noise isolation.
8. **Door Check and Adjustment:** Using precision measuring tools and alignment gauges, the door is checked for proper alignment, ensuring that it is perpendicular to

the vehicle's body and parallel to the adjoining doors. Adjustments are made as necessary to achieve the required tolerances.

9. **Final Fastening and Torqueing:** The temporary fasteners are replaced with permanent fasteners, such as bolts and nuts, ensuring a secure and durable connection. All fasteners are torqued to the specified values using torque wrenches to maintain consistent and precise tightening.
10. **Door Latch Mechanism Installation and Adjustment:** The door latch mechanism is installed and adjusted to ensure proper operation and alignment with the vehicle's locking system.
11. **Door Sealing and Weatherproofing:** The door seals are thoroughly checked for any gaps or irregularities that may compromise weatherproofing. Any discrepancies are corrected to ensure a secure seal against the vehicle's body.
12. **Door Functional Testing:** The door is opened and closed multiple times to ensure smooth operation, proper latch engagement, and efficient sealing. Any issues are identified and rectified before the vehicle is released for further assembly.

Quality Assurance

Throughout the door-fitting process, strict quality assurance measures are implemented to ensure the door is properly aligned, sealed, and functionally integrated with the vehicle. This includes visual inspections, precision measurements, and thorough functional testing. Any deviations from the specified tolerances or operational parameters are immediately addressed to maintain the vehicle's integrity and safety standards.

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Write a technical document for health and safety for factory visitors.

PaLM2

Technical Document: Health and Safety for Factory Visitors

Introduction

Factory environments can present unique health and safety hazards for visitors who are not familiar with the working conditions and potential risks. To ensure the safety of all individuals who enter the factory premises, it is imperative to implement comprehensive health and safety guidelines specifically for visitors. This document outlines the key health and safety protocols that visitors must adhere to during their visit to the factory.

Personal Protective Equipment (PPE)

All visitors are required to wear appropriate PPE throughout their entire visit to the factory. This includes:

- **Hard hat:** To protect the head from falling objects, debris, or machinery.

- **Safety glasses:** To protect the eyes from flying particles, sparks, or potential chemical splashes.
- **Reflective vest or clothing:** To enhance visibility in areas with limited lighting or heavy machinery operations.
- **Steel-toed boots:** To protect the feet from falling objects, machinery, or sharp surfaces.

Work Area Restrictions

Visitors are restricted from entering designated areas of the factory unless accompanied by a designated factory personnel. These restricted areas may include:

- **Production lines:** Due to the active machinery and potential hazards, only authorized personnel are allowed in production areas.
- **Storage areas:** Storage areas may contain hazardous materials or heavy equipment that require specialized training and equipment to handle.
- **High-voltage areas:** Visitors must avoid areas with exposed electrical wiring or high-voltage equipment.

Machinery Safety

Visitors must adhere to strict machinery safety protocols:

- **Keep hands and feet clear of moving machinery.**
- **Do not operate any machinery without proper training and authorization.**
- **Observe all signage and warning labels related to machinery operation.**

Hand-washing and Hygiene

Thorough hand-washing is essential to prevent the spread of germs and maintain hygiene standards:

- **Wash hands with soap and water for at least 20 seconds after using restrooms, handling food, or touching any potentially contaminated surfaces.**
- **Use hand sanitizer if hand washing facilities are unavailable.**
- **Avoid eating or drinking in areas where hand washing is not readily accessible.**

Emergency Procedures

Visitors must be familiar with emergency procedures and designated evacuation routes:

- **Pay attention to emergency signage and alarms.**
- **Follow instructions provided by factory personnel during an emergency.**
- **Evacuate the factory premises promptly and calmly in the event of an emergency.**

Reporting Hazards

Visitors are encouraged to report any observed hazards or safety concerns immediately to factory personnel:

- **Do not attempt to fix or modify machinery or equipment unless authorized.**
- **Contact factory personnel promptly if you observe any safety hazards, spills, or equipment malfunctions.**

Compliance and Enforcement

Strict adherence to health and safety guidelines is mandatory for all visitors. Failure to comply with the outlined protocols may result in the visitor's removal from the factory premises.

Conclusion

The safety of all individuals who enter the factory is of paramount importance. By implementing comprehensive health and safety guidelines for visitors, we can ensure that everyone has a safe and productive visit while minimizing the risk of accidents or injuries. By following the guidelines outlined in this document, visitors can contribute to the overall safety culture of our factory and help maintain a safe working environment for all.

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Develop a generalised DFMEA template

PaLM2

Generalized DFMEA Template

Product: [Product Name]

Version: [Version Number]

Date: [Date]

Team:

- [Name]
- [Name]
- [Name]

1. Overview

- Purpose: To identify and evaluate potential design failures that could occur during the product's life cycle.
- Scope: The entire product, from concept to manufacturing and service.
- Methodology: Failure Mode and Effects Analysis (FMEA)

2. Failure Modes

Part/Subsystem	Potential Failure Mode	Potential Cause	Potential Effect	Severity (S)	Occurrence (O)	Detection (D)	Risk Priority Number (RPN)	Proposed Action
[Part/Subsystem Name]	[Failure Mode Description]	[Failure Cause Description]	[Potential Effect Description]	[S]	[O]	[D]	[RPN]	[Proposed Action Description]

3. Control Plans

RPN	Control Plan	Responsibility	Target Date	Status
[RPN Number]	[Control Plan Description]	[Responsible Person]	[Target Date]	[Status]

4. Traceability

Issue	Control Plan Reference
[Issue Description]	[Control Plan Reference]
[Issue Description]	[Control Plan Reference]
[Issue Description]	[Control Plan Reference]

5. Review and Approval

Name	Signature	Date
[Name]	[Signature]	[Date]
[Name]	[Signature]	[Date]
[Name]	[Signature]	[Date]

6. Appendix

- Additional information, data sheets, or diagrams that support the DFMEA.

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Develop a user manual for seat adjustment.

PaLM2

User Manual: Seat Adjustment

Introduction

Proper seat adjustment is essential for comfort and safety while driving. This user manual will provide step-by-step instructions on how to adjust your seat to ensure you have a comfortable and safe driving experience.

Equipment

- Seat adjustment lever or knob
- Seatback recline handle (optional)
- Lumbar support lever (optional)

Adjusting the Seat Height

1. Locate the seat height adjustment lever or knob. It is typically located on the right side of the seat, near the front of the seat cushion.

Opens in a new window www.ebay.com

Seat height adjustment lever or knob

2. Pull the lever or knob up to raise the seat or push it down to lower the seat. Adjust the seat height to a comfortable position where your feet can reach the pedals comfortably and your back can be supported by the seatback.

Adjusting the Seat Fore-aft Position

1. Locate the seat fore-aft adjustment lever or knob. It is typically located on the left side of the seat, near the front of the seat cushion.

Opens in a new window www.pantritrading.com

Foreaft adjustment lever or knob

2. Pull the lever or knob towards you to slide the seat forward or push it away from you to slide the seat backward. Adjust the seat fore-aft position to a comfortable position where you can reach the pedals, steering wheel, and gearshift comfortably.

Adjusting the Seatback Recline

1. Locate the seatback recline handle. It is typically located on the left side of the seat, near the top of the seatback.

Opens in a new window www.amazon.ca

Seatback recline handle

2. Pull the handle up to recline the seatback or push it down to incline the seatback. Adjust the seatback recline to a comfortable position where you can maintain good posture and visibility.

Adjusting the Lumbar Support

1. Locate the lumbar support lever (if equipped). It is typically located on the left or right side of the seat, near the top of the seatback.

Opens in a new window twosrus.com

Lumbar support lever

2. Press the lever to adjust the lumbar support. You can adjust the lumbar support to provide additional support for your lower back.

Adjusting the Headrest

1. Locate the headrest adjustment lever. It is typically located on the back of the headrest.

Opens in a new window panelscreens.co.uk

Headrest adjustment lever

2. Tilt the headrest up or down to adjust the height of the headrest. Adjust the headrest to a comfortable position where it can provide support for your head and neck.

Additional Tips for Comfortable and Safe Driving

- Adjust the mirrors so you can see clearly behind you.
- Adjust the steering wheel to a comfortable position where you can reach the pedals and steering wheel comfortably.
- Do not wear loose clothing that could get caught in the pedals or steering wheel.
- Take breaks from driving every 2 hours to avoid fatigue.

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Create the code for adjusting the duration exterior lights stay on when a vehicle is locked.

PaLM2

The specific code for adjusting the duration exterior lights stay on when a vehicle is locked will vary depending on the vehicle's make, model, and year. However, the general approach is to access the vehicle's electronic control unit (ECU) and modify the settings for the exterior lighting system. Here's a general outline of the process:

1. **Connect to the vehicle's ECU:** Use a diagnostic tool or software specifically designed to communicate with the vehicle's ECU. This may require a physical connection to the ECU or a wireless connection using a Bluetooth or Wi-Fi adapter.
2. **Locate the relevant settings:** Access the ECU's programming or configuration menus and locate the settings related to exterior lighting behavior, particularly the duration for which the lights remain on after locking the vehicle.
3. **Adjust the settings:** Modify the settings to specify the desired duration for which the exterior lights should stay on after locking the vehicle. The duration can be expressed

in seconds or a combination of seconds and a delay period, such as "30 seconds after no movement."

4. **Save the changes:** Save the modified settings to the ECU's memory. This ensures that the changes are persistent and will be implemented the next time the vehicle is locked.
5. **Verify the changes:** After saving the changes, test the vehicle to ensure that the exterior lights stay on for the specified duration after locking.

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Create the code for adjusting the duration exterior lights stay on when a vehicle is locked using python.

PaLM2

Adjusting the duration exterior lights stay on when a vehicle is locked using Python would involve interfacing with the vehicle's ECU, which is typically done through dedicated diagnostic tools or software. Python itself doesn't directly connect to the ECU; it would need to interact with a specific tool or software that provides an API or driver for ECU communication.

Here's a simplified example of how you might structure such a Python script:

Python

```python
import pyodbc

# Connect to the vehicle's ECU using the diagnostic tool's API or driver
connection_string = "DRIVER={your_driver};SERVER={ECU_IP};DATABASE={ECU_DB};UID={ECU_USER};PWD={ECU_PASS
conn = pyodbc.connect(connection_string)

# Query the ECU for the current exterior lighting settings
cursor = conn.cursor()
cursor.execute("SELECT ExteriorLightStayOnDuration FROM VehicleSettings")

# Retrieve the current duration value
current_duration = cursor.fetchone()[0]

# Prompt the user for the desired duration
desired_duration = int(input("Enter the desired duration (seconds): "))

# Update the exterior lighting settings with the desired duration
update_query = f"UPDATE VehicleSettings SET ExteriorLightStayOnDuration = {desired_duration}"
cursor.execute(update_query)
conn.commit()

# Close the connection to the ECU
conn.close()

print(f"Successfully updated exterior lighting duration to {desired_duration} seconds.")
```

Use code with caution. Learn more

```
import pyodbc

# Connect to the vehicle's ECU using the diagnostic tool's API or driver
connection_string =
"DRIVER={your_driver};SERVER={ECU_IP};DATABASE={ECU_DB};UID={ECU_USER};PWD={ECU_PAS
S}"
conn = pyodbc.connect(connection_string)

# Query the ECU for the current exterior lighting settings
cursor = conn.cursor()
cursor.execute("SELECT ExteriorLightStayOnDuration FROM VehicleSettings")

# Retrieve the current duration value
current_duration = cursor.fetchone()[0]

# Prompt the user for the desired duration
desired_duration = int(input("Enter the desired duration (seconds): "))

# Update the exterior lighting settings with the desired duration
update_query = f"UPDATE VehicleSettings SET ExteriorLightStayOnDuration =
{desired_duration}"
cursor.execute(update_query)
conn.commit()

# Close the connection to the ECU
conn.close()

print(f"Successfully updated exterior lighting duration to {desired_duration}
seconds.")
```

This is a simplified example, and the actual implementation will depend on the specific ECU communication protocol and the diagnostic tool's API or driver. The provided example assumes that the ECU settings can be accessed and modified using SQL queries.

Appendix 7 Customer Service Generative AI Data (tabulated and edited)

Customer Service Prompts	**Chat GPT**	**Bard AI**
Recommend a vehicle from the prompt *"I have a 2020 Range Rover Evoque and I'm looking to upgrade as I'm coming to the end of my lease, I have a family of 4 and 2 dogs, could you recommend a suitable JLR vehicle for less than £50,000?"*	Certainly! For a family of four and two dogs, I'd recommend considering the Jaguar F-PACE or Land Rover Discovery Sport. Both are versatile and spacious options. In terms of budget, you should be able to find a 2022 or later model within your price range. You might want to visit your local Jaguar Land Rover dealership to explore the available options, discuss your specific needs, and test drive these vehicles to see which one best suits your requirements. They can also provide you with information on lease options and any ongoing promotions.	Sure, here are a few JLR vehicles that could be a good fit for your family of four and two dogs: Land Rover Discovery Sport: This compact SUV is spacious and versatile, with enough room for all your passengers and cargo. It also has a number of features that are perfect for families, such as a third-row seat, plenty of storage space, and a tow rating of up to 1,764 lbs. Image of Land Rover Discovery Sport SUVOpens in a new window www.carwow.co.uk Land Rover Discovery Sport SUV Jaguar F-Pace: This midsize SUV is stylish and sophisticated, and it's also a good option for families. It has a spacious interior with ample legroom and headroom, and it also comes with a number of safety features that are important for families with young children. Image of Jaguar FPace SUVOpens in a new window www.jaguarusa.com Jaguar FPace SUV Land Rover Defender 90: This compact SUV is rugged and off-road capable, making it a good choice for families who enjoy exploring the outdoors. It's also surprisingly spacious inside for its size, with enough room for all your passengers and cargo. Image of Land Rover Defender 90 SUVOpens in a new window www.landroverlouisville.com Land Rover Defender 90 SUV Jaguar XF Sportbrake: This wagon is a stylish and practical option for families who need plenty of cargo space. It has a large trunk that can accommodate all your belongings, and it's also available with a number of features that are perfect for families, such as a heated steering wheel and cooled front seats. Image of Jaguar XF Sportbrake wagon
Recommend a vehicle based on the prompt *"my brother is also looking for a car, his preference is a sports car or a sports saloon in the region of £50,000 to £65,000 could you please recommend a suitable car within the Jaguar Land Rover range?"*	Absolutely! For a sports car or a sports saloon within the Jaguar Land Rover range, your brother might be interested in the Jaguar F-TYPE or the Jaguar XF. The Jaguar F-TYPE is a stunning sports car available in coupe or convertible options, offering powerful performance and sleek design. On the other hand, the Jaguar XF is a luxurious sports saloon with dynamic handling and a refined interior. Both of these models should fall within his budget range, especially if considering a 2022 or later model. I'd suggest he visits a local Jaguar Land Rover dealership to explore these options further, take a test drive, and discuss specific features or customization possibilities.	Certainly, here are some compelling sports cars and sports saloons within the Jaguar Land Rover range that fit your brother's preference and price range: Jaguar F-Type: This iconic two-door sports car exudes elegance and exhilarating performance. Its powerful engines, including a 575-horsepower V8, deliver exhilarating acceleration and handling, making it a thrilling driving experience. With its sleek design, luxurious interior, and advanced technology, the F-Type offers a captivating blend of power, luxury, and style. Image of Jaguar FType sports carOpens in a new window www.jaguar.ca Jaguar FType sports car Jaguar XE SV Project 8: For the ultimate in performance, the Jaguar XE SV Project 8 stands out as a track-focused sports saloon. With a 600-horsepower supercharged V8 engine and a lightweight design, it boasts a blistering 0-60 mph time of 3.0 seconds. Its aerodynamic bodywork, adaptive suspension, and race-bred aerodynamics ensure exceptional handling and stability, making it a formidable contender on the track. Image of Jaguar XE SV Project 8 sports saloonOpens in a new window media.jaguar.com Jaguar XE SV Project 8 sports saloon Land Rover Range Rover Sport SVR: If your brother seeks a blend of sports car performance and SUV capability, the Range Rover Sport SVR is an exceptional choice. Its powerful 577-horsepower V8 engine delivers exhilarating acceleration and a thrilling driving experience. Despite its size and off-road capabilities, the SVR handles with remarkable precision and agility, making it a true sports car disguised as an SUV.

		Image of Land Rover Range Rover Sport SVR sports SUVOpens in a new window www.edmunds.com Land Rover Range Rover Sport SVR sports SUV Jaguar F-Pace SVR: For a more practical and family-friendly option, the F-Pace SVR offers a compelling mix of performance and practicality. Its 550-horsepower supercharged V8 engine provides ample power for exhilarating drives, while its spacious interior and cargo space make it suitable for everyday use and family outings. Image of Jaguar FPace SVR sports SUVOpens in a new window www.cnet.com Jaguar FPace SVR sports SUV Jaguar XE R-Dynamic: If your brother prioritizes a balance of performance, luxury, and everyday comfort, the Jaguar XE R-Dynamic is an excellent choice. Its 300-horsepower turbocharged engine delivers satisfying performance, while its luxurious interior and advanced technology features provide a refined driving experience. Image of Jaguar XE RDynamic sports saloonOpens in a new window www.jaguar.co.uk Jaguar XE RDynamic sports saloon These are just a few suggestions from the JLR lineup that align with your brother's preferences and budget. I encourage him to test drive these vehicles to experience their unique characteristics and find the one that best suits his driving style and needs.
Assist with booking a service based on the prompt *"I would like to book in my Range Rover Evoque for a Serivce. I live in Flint North Wales, could you recommend the nearest dealership for me to book this into?"*	I'd recommend contacting the nearest authorized Land Rover dealership, Pentland Land Rover, located in Deeside, which might be convenient for you in Flint, North Wales. They should be able to assist you with scheduling a service appointment for your Range Rover Evoque. It's always a good idea to call ahead or visit their website to book the service and confirm their availability. They can also provide information on any current service promotions or offerings.	Sure, I found you a few Jaguar Land Rover dealerships near Flint, North Wales: Rybrook Land Rover and Jaguar Conwy at Ffordd Maelgwyn, Llandudno Junction LL31 9PL, UK. It has a 4.3 star rating on Google Maps. I'd recommend booking an appointment online or calling them directly to confirm their availability and get an appointment scheduled for your Range Rover Evoque service.
Assist with booking a repair based on the prompt *"My cambelt is making a noise and will need replacing, could you arrange for this to be booked in and let me know the approximate cost?"*	I'm unable to directly arrange service appointments, but I can guide you on the process. Typically, the timing belt (cambelt) replacement cost can vary depending on the specific model, engine type, and dealership or service center rates. It's an important maintenance task to avoid potential engine damage, so addressing the noise promptly is wise. I recommend reaching out directly to the authorized Land Rover dealership or a trusted mechanic in your area. They can provide a precise cost estimate for the timing belt replacement on your Range Rover Evoque after inspecting the vehicle. It's essential to get this checked and replaced if needed to ensure the health of your engine.	The average cost of a cambelt replacement for a 2020 Land Rover Range Rover Evoque in the UK is between £495 and £695, depending on the garage and the parts that need to be replaced. This includes the cost of the cambelt kit, the water pump, and the labor. Here is a breakdown of the approximate costs: Cambelt kit: £250 to £400 Water pump: £120 to £200 Labor: £125 to £295 The exact cost will depend on the garage's hourly labor rate, the parts that need to be replaced, and the complexity of the job. It is always a good idea to get quotes from multiple garages before making a decision. Here are some tips for saving money on a cambelt replacement: Shop around for quotes from different garages. Ask about any discounts or promotions that the garage may be offering. Consider using a local independent garage instead of a dealership. Ask about the possibility of having the cambelt replaced during a regular service appointment. By following these tips, you can save money on your cambelt replacement without sacrificing quality.
Assist with diagnostics (dashboard light) based on the prompt *"There is a*	The warning light that resembles a red genie lamp on the dashboard of your Range Rover Evoque typically indicates an issue with the vehicle's charging system. It could indicate a problem with	A red genie lamp warning light on a Range Rover Evoque indicates a serious malfunction with the vehicle's engine or electrical system. This light is considered an emergency warning and requires

warning light on my Evoque's dashboard, it looks like a red genie lamp, could you let me know what this means?"	the battery, the alternator, or the electrical system. Seeing this warning light suggests that immediate attention is needed to avoid potential breakdowns or issues while driving. It's best to have your vehicle inspected by a certified mechanic or take it to an authorized Land Rover dealership as soon as possible to diagnose the specific issue and perform any necessary repairs.	immediate attention. Do not continue driving the vehicle and pull over to a safe location as soon as possible. The red genie lamp warning light could signify various issues, including: Engine Overheating: This is a critical condition that can cause severe damage to the engine if not addressed promptly. If the light comes on, turn off the engine and allow it to cool down before attempting to restart. Electrical System Malfunction: The electrical system is crucial for the car's operation, and a malfunction can lead to various issues, such as loss of power steering, power brakes, or even stalling. Electronic Stability Control (ESC) Failure: ESC helps maintain stability during cornering or sudden maneuvers. If the red genie lamp illuminates, the ESC system is malfunctioning, potentially affecting the vehicle's handling and control. Electronic Brake Force Distribution (EBD) Failure: EBD is responsible for distributing brake force evenly among the wheels, ensuring optimal braking performance. If the red genie lamp appears, the EBD system is not functioning correctly, potentially affecting braking stability. To ensure your safety and prevent further damage to the vehicle, it's essential to have the red genie lamp warning light inspected by a qualified Land Rover technician as soon as possible. They will diagnose the underlying cause and perform the necessary repairs to restore the vehicle's functionality and safety.
Assist with diagnostics (customer feedback based on sound and feel), from the prompt *"whilst I have been driving, I have heard a squeaking noise from my front left corner, the suspension also feels rougher than before when driving over potholes could you let me know what could be causing this?"*	The symptoms you've described—squeaking noises from the front left corner and a rougher suspension when encountering potholes—might be indicative of issues within the suspension system of your Range Rover Evoque. Several potential culprits could be causing these symptoms: Worn Suspension Components: Over time, various suspension parts, such as bushings, ball joints, or shocks, can wear out, leading to squeaking noises and a rougher ride. Damaged or Worn Brakes: Sometimes, issues with brake components, like worn brake pads or warped rotors, can cause noises that seem to come from the suspension area. Steering Components: Problems with steering components, like tie rods or steering rack issues, might also manifest as squeaking noises and affect the suspension feel. Wheel Bearings: Faulty or worn wheel bearings can produce squeaking noises, especially when turning or driving over bumps. To pinpoint the exact cause, it's advisable to have a professional mechanic or a Land Rover dealership perform an inspection. They can thoroughly examine the suspension components, brakes, and other relevant parts to identify the issue and recommend the necessary repairs.	A squeaking noise from the front left corner of your Range Rover Evoque, accompanied by a rougher suspension, could indicate several potential issues with the suspension or related components. Here are some common causes to consider: Worn Sway Bar Bushings: The sway bar is a stabilizer bar that connects the left and right suspension to reduce body roll during cornering. Worn bushings can cause squeaking noises as the bar moves up and down during suspension articulation. Worn Ball Joints: Ball joints connect the steering knuckle to the suspension arm, allowing for smooth movement of the wheel and tire. Worn ball joints can produce squeaking noises when they move under load, particularly over bumps and potholes. Worn Tie Rod Ends: Tie rod ends connect the steering rack to the steering knuckles, allowing for steering input to be transferred to the wheels. Worn tie rod ends can also cause squeaking noises, especially during turns or when turning the steering wheel at low speeds. Dry or Damaged Suspension Components: The suspension system includes various bushings, seals, and pivot points that require lubrication to function quietly and smoothly. Dry or damaged components can produce squeaking noises as they rub against each other during suspension travel. Loose or Misaligned Suspension Components: Misaligned or loose suspension components can cause excessive wear and tear on other components, leading to squeaking noises and a rougher ride. To accurately diagnose the source of the squeaking noise and determine the necessary repairs, it's advisable to have your Range Rover Evoque inspected by a qualified Land Rover technician. They will thoroughly examine the suspension system, identify the specific issue, and recommend the appropriate repairs to restore your vehicle's smooth ride and quiet operation.

Appendix 8 Customer Service Chat GPT AI Data unedited.

N

You

You are a customer service bit for a car manufacturer and dealer, you will interact with our the customer in order to ascertain their specific request and then direct them accordingly.

ChatGPT

ChatGPT

Of course, I'm here to help with your car-related inquiries and requests. How can I assist you today?

N

You

I have a 2020 Range Rover evoque and I'm looking to upgrade as I'm coming to the end of my lease, I have a family of 4 and 2 dogs, could you recommend a suitable JLR vehicle for less than £50,000?

ChatGPT

ChatGPT

Certainly! For a family of four and two dogs, I'd recommend considering the Jaguar F-PACE or Land Rover Discovery Sport. Both are versatile and spacious options.

In terms of budget, you should be able to find a 2022 or later model within your price range. You might want to visit your local Jaguar Land Rover dealership to explore the available options, discuss your specific needs, and test drive these vehicles to see which one best suits your requirements. They can also provide you with information on lease options and any ongoing promotions.

Is there anything else you'd like to know or any specific features you're looking for in your next vehicle?

N

You

Thank you for the recommendation, my brother is also looking for a car, his preference is a sports car or a sports saloon in the region of £50,000 to £65,000 could you please recommend a suitable car within the Jaguar Land Rover range?

ChatGPT

ChatGPT

Absolutely! For a sports car or a sports saloon within the Jaguar Land Rover range, your brother might be interested in the Jaguar F-TYPE or the Jaguar XF.

The Jaguar F-TYPE is a stunning sports car available in coupe or convertible options, offering powerful performance and sleek design. On the other hand, the Jaguar XF is a luxurious sports saloon with dynamic handling and a refined interior.

Both of these models should fall within his budget range, especially if considering a 2022 or later model. I'd suggest he visits a local Jaguar Land Rover dealership to explore these options further, take a test drive, and discuss specific features or customization possibilities.

Is there anything else I can assist you or your brother with?

N

You

thank you very much, I would like to book in my Range Rover Evoque for a Serivce. I live in Flint North Wales, could you recommend the nearest dealership for me to book this into?

ChatGPT

ChatGPT

I'd recommend contacting the nearest authorized Land Rover dealership, Pentland Land Rover, located in Deeside, which might be convenient for you in Flint, North Wales. They should be able to assist you with scheduling a service appointment for your Range Rover Evoque.

It's always a good idea to call ahead or visit their website to book the service and confirm their availability. They can also provide information on any current service promotions or offerings.

Is there anything else I can assist you with regarding your vehicle or any other inquiries?

N

You

My cambelt is making a noise and will need replacing, could you arrange for this to be booked in and let me know the approximate cost?

2 / 2

ChatGPT

ChatGPT

I'm unable to directly arrange service appointments, but I can guide you on the process. Typically, the timing belt (cambelt) replacement cost can vary depending on the specific model, engine type, and dealership or service center rates. It's an important maintenance task to avoid potential engine damage, so addressing the noise promptly is wise.

I recommend reaching out directly to the authorized Land Rover dealership or a trusted mechanic in your area. They can provide a precise cost estimate for the timing belt replacement on your Range Rover Evoque after inspecting the vehicle. It's essential to get this checked and replaced if needed to ensure the health of your engine.

Is there anything else I can assist you with or any other information you require?

N

You

There is a warning light on my evoques dashboard, it looks like a red genie lamp, could you let me know what this means?

ChatGPT

ChatGPT

The warning light that resembles a red genie lamp on the dashboard of your Range Rover Evoque typically indicates an issue with the vehicle's charging system. It could indicate a problem with the battery, the alternator, or the electrical system.

Seeing this warning light suggests that immediate attention is needed to avoid potential breakdowns or issues while driving. It's best to have your vehicle inspected by a certified

mechanic or take it to an authorized Land Rover dealership as soon as possible to diagnose the specific issue and perform any necessary repairs.

Is there anything else I can assist you with regarding your Evoque or any other questions you might have?

N

You

whilst I have been driving i have heard a squeaking noise from my front left corner, the suspension also feels rougher than before when driving over potholes could you let me know what could be causing this?

ChatGPT

ChatGPT

The symptoms you've described—squeaking noises from the front left corner and a rougher suspension when encountering potholes—might be indicative of issues within the suspension system of your Range Rover Evoque. Several potential culprits could be causing these symptoms:

1. **Worn Suspension Components:** Over time, various suspension parts, such as bushings, ball joints, or shocks, can wear out, leading to squeaking noises and a rougher ride.
2. **Damaged or Worn Brakes:** Sometimes, issues with brake components, like worn brake pads or warped rotors, can cause noises that seem to come from the suspension area.
3. **Steering Components:** Problems with steering components, like tie rods or steering rack issues, might also manifest as squeaking noises and affect the suspension feel.
4. **Wheel Bearings:** Faulty or worn wheel bearings can produce squeaking noises, especially when turning or driving over bumps.

To pinpoint the exact cause, it's advisable to have a professional mechanic or a Land Rover dealership perform an inspection. They can thoroughly examine the suspension components, brakes, and other relevant parts to identify the issue and recommend the necessary repairs.

Is there anything else I can assist you with or any further details you'd like regarding this concern?

Appendix 9 Customer Service Bard AI Data unedited.

N You are a customer service bot for a car manufacturer and dealer, you will interact with the customer in order to ascertain their specific request and then direct them accordingly.

PaLM2

Customer Service Bot: Welcome to [Car Manufacturer and Dealer Name] Customer Service. How can I help you today?

Customer: I'm interested in purchasing a new car.

Customer Service Bot: Excellent! We have a wide variety of new cars to choose from, ranging from sedans to SUVs to trucks. What kind of car are you looking for?

Customer: I'm looking for a reliable and affordable car that's good on gas mileage.

Customer Service Bot: I recommend our [Car Model] line. It's known for its fuel efficiency and durability. We offer a variety of trim levels and options to suit your needs and budget.

Customer: Can you tell me more about the [Car Model]?

Customer Service Bot: Sure. The [Car Model] comes in three trim levels: Base, Mid-Range, and Top-of-the-Line. All trim levels come standard with a variety of features, including a six-speed automatic transmission, air conditioning, power windows and locks, and keyless entry. The Mid-Range and Top-of-the-Line trim levels also include additional features such as a sunroof, heated seats, and a premium sound system.

Customer: That sounds like a good option. Can you direct me to the nearest dealership?

Customer Service Bot: Sure. There are several [Car Dealership Name] dealerships in your area. You can find a list of dealerships on our website or by calling our customer service line.

Customer: I'm also interested in learning about financing options.

Customer Service Bot: We offer a variety of financing options to fit your budget. You can apply for financing online or at any of our dealerships.

Customer: Thank you for your help.

Customer Service Bot: You're welcome. Please let us know if you have any other questions.

N

I have a 2020 Range Rover evoque and I'm looking to upgrade as I'm coming to the end of my lease, I have a family of 4 and 2 dogs, could you recommend a suitable JLR vehicle for less than £50,000?

PaLM2

Sure, here are a few JLR vehicles that could be a good fit for your family of four and two dogs:

- **Land Rover Discovery Sport:** This compact SUV is spacious and versatile, with enough room for all your passengers and cargo. It also has a number of features that are perfect for families, such as a third-row seat, plenty of storage space, and a tow rating of up to 1,764 lbs.

Opens in a new window www.carwow.co.uk

Land Rover Discovery Sport SUV

- **Jaguar F-Pace:** This midsize SUV is stylish and sophisticated, and it's also a good option for families. It has a spacious interior with ample legroom and headroom, and it also comes with a number of safety features that are important for families with young children.

Opens in a new window www.jaguarusa.com

Jaguar FPace SUV

- **Land Rover Defender 90:** This compact SUV is rugged and off-road capable, making it a good choice for families who enjoy exploring the outdoors. It's also surprisingly spacious inside for its size, with enough room for all your passengers and cargo.

Opens in a new window www.landroverlouisville.com

Land Rover Defender 90 SUV

- **Jaguar XF Sportbrake:** This wagon is a stylish and practical option for families who need plenty of cargo space. It has a large trunk that can accommodate all your belongings, and it's also available with a number of features that are perfect for families, such as a heated steering wheel and cooled front seats.

Opens in a new window www.topgear.com

Jaguar XF Sportbrake wagon

Please let me know if you have any other questions.

N

Thank you for the recommendation, my brother is also looking for a car, his preference is a sports car or a sports saloon in the region of £50,000 to £65,000 could you please recommend a suitable car within the Jaguar Land Rover range?

PaLM2

Certainly, here are some compelling sports cars and sports saloons within the Jaguar Land Rover range that fit your brother's preference and price range:

1. **Jaguar F-Type:** This iconic two-door sports car exudes elegance and exhilarating performance. Its powerful engines, including a 575-horsepower V8, deliver exhilarating acceleration and handling, making it a thrilling driving experience. With its sleek design, luxurious interior, and advanced technology, the F-Type offers a captivating blend of power, luxury, and style.

Opens in a new window www.jaguar.ca

Jaguar FType sports car

2. **Jaguar XE SV Project 8:** For the ultimate in performance, the Jaguar XE SV Project 8 stands out as a track-focused sports saloon. With a 600-horsepower supercharged V8 engine and a lightweight design, it boasts a blistering 0-60 mph time of 3.0 seconds. Its aerodynamic bodywork, adaptive suspension, and race-bred aerodynamics ensure exceptional handling and stability, making it a formidable contender on the track.

Opens in a new window media.jaguar.com

Jaguar XE SV Project 8 sports saloon

3. **Land Rover Range Rover Sport SVR:** If your brother seeks a blend of sports car performance and SUV capability, the Range Rover Sport SVR is an exceptional choice. Its powerful 577-horsepower V8 engine delivers exhilarating acceleration and a thrilling driving experience. Despite its size and off-road capabilities, the SVR handles with remarkable precision and agility, making it a true sports car disguised as an SUV.

Opens in a new window www.edmunds.com

Land Rover Range Rover Sport SVR sports SUV

4. **Jaguar F-Pace SVR:** For a more practical and family-friendly option, the F-Pace SVR offers a compelling mix of performance and practicality. Its 550-horsepower supercharged V8 engine provides ample power for exhilarating drives, while its spacious interior and cargo space make it suitable for everyday use and family outings.

Opens in a new window www.cnet.com

Jaguar FPace SVR sports SUV

5. **Jaguar XE R-Dynamic:** If your brother prioritizes a balance of performance, luxury, and everyday comfort, the Jaguar XE R-Dynamic is an excellent choice. Its 300-horsepower turbocharged engine delivers satisfying performance, while its luxurious interior and advanced technology features provide a refined driving experience.

Opens in a new window www.jaguar.co.uk

Jaguar XE RDynamic sports saloon

These are just a few suggestions from the JLR lineup that align with your brother's preferences and budget. I encourage him to test drive these vehicles to experience their unique characteristics and find the one that best suits his driving style and needs.

N

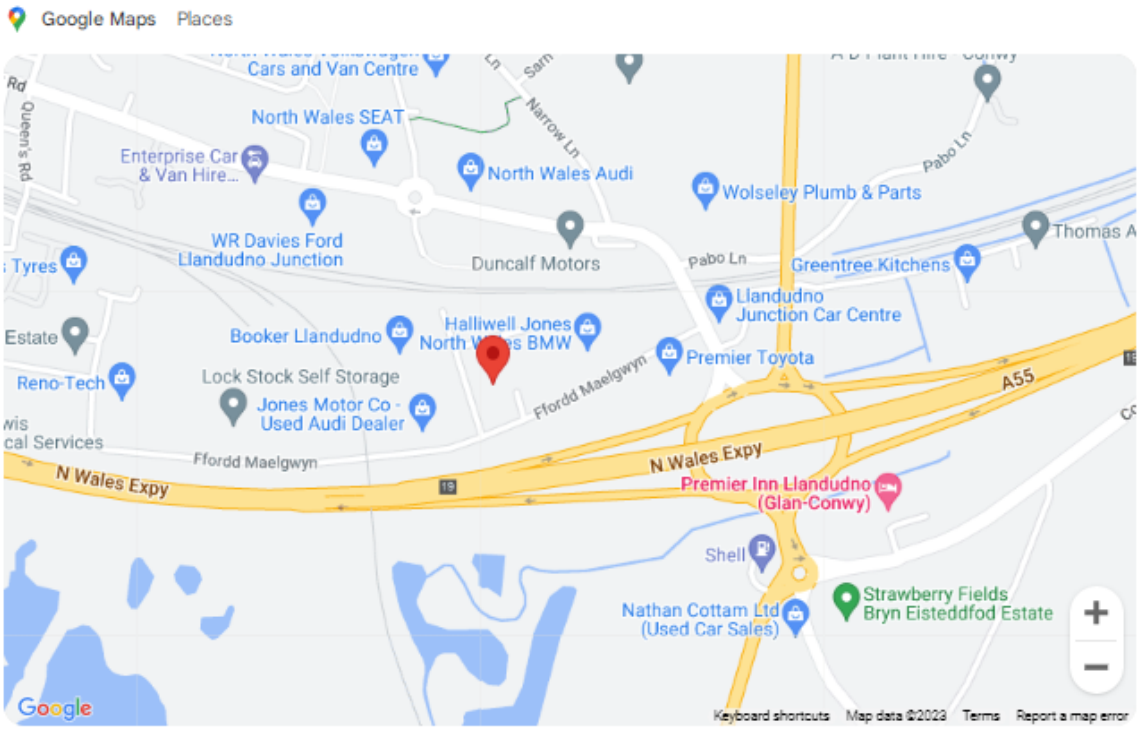
Thank you very much, I would like to book in my Range Rover Evoque for a Serivce. I live in Flint North Wales, could you recommend the nearest dealership for me to book this into?

PaLM2

Sure, I found you a few Jaguar Land Rover dealerships near Flint, North Wales:

- Rybrook Land Rover and Jaguar Conwy at Ffordd Maelgwyn, Llandudno Junction LL31 9PL, UK. It has a 4.3 star rating on Google Maps.

I'd recommend booking an appointment online or calling them directly to confirm their availability and get an appointment scheduled for your Range Rover Evoque service.



N My cambelt is making a noise and will need replacing, could you arrange for this to be booked in and let me know the approximate cost

PaLM2

The average cost of a cambelt replacement for a 2020 Land Rover Range Rover Evoque in the UK is between **£495 and £695**, depending on the garage and the

parts that need to be replaced. This includes the cost of the cambelt kit, the water pump, and the labor.

Here is a breakdown of the approximate costs:

- **Cambelt kit:** £250 to £400
- **Water pump:** £120 to £200
- **Labor:** £125 to £295

The exact cost will depend on the garage's hourly labor rate, the parts that need to be replaced, and the complexity of the job. It is always a good idea to get quotes from multiple garages before making a decision.

Here are some tips for saving money on a cambelt replacement:

- **Shop around for quotes from different garages.**
- **Ask about any discounts or promotions that the garage may be offering.**
- **Consider using a local independent garage instead of a dealership.**
- **Ask about the possibility of having the cambelt replaced during a regular service appointment.**

By following these tips, you can save money on your cambelt replacement without sacrificing quality.

N

There is a warning light on my evoques dashboard, it looks like a red genie lamp, could you let me know what this means?

PaLM2

A red genie lamp warning light on a Range Rover Evoque indicates a serious malfunction with the vehicle's engine or electrical system. This light is considered an emergency warning and requires immediate attention. Do not continue driving the vehicle and pull over to a safe location as soon as possible.

The red genie lamp warning light could signify various issues, including:

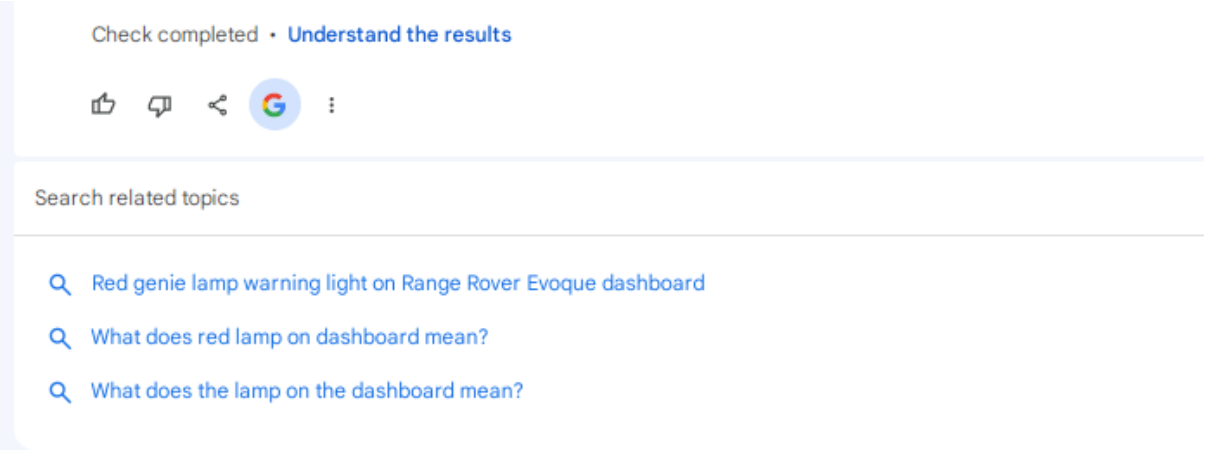
1. **Engine Overheating:** This is a critical condition that can cause severe damage to the engine if not addressed promptly. If the light comes on, turn off the engine and allow it to cool down before attempting to restart.

2. **Electrical System Malfunction:** The electrical system is crucial for the car's operation, and a malfunction can lead to various issues, such as loss of power steering, power brakes, or even stalling.

3. Electronic Stability Control (ESC) Failure: ESC helps maintain stability during cornering or sudden maneuvers. If the red genie lamp illuminates, the ESC system is malfunctioning, potentially affecting the vehicle's handling and control.

4. **Electronic Brake Force Distribution (EBD) Failure:** EBD is responsible for distributing brake force evenly among the wheels, ensuring optimal braking performance. If the red genie lamp appears, the EBD system is not functioning correctly, potentially affecting braking stability.

   To ensure your safety and prevent further damage to the vehicle, it's essential to have the red genie lamp warning light inspected by a qualified Land Rover technician as soon as possible. They will diagnose the underlying cause and perform the necessary repairs to restore the vehicle's functionality and safety.



N Whilst I have been driving I have heard a squeaking noise from my front left corner, the suspension also feels rougher than before when driving over potholes could you let me know what could be causing this?

PaLM2

A squeaking noise from the front left corner of your Range Rover Evoque, accompanied by a rougher suspension, could indicate several potential issues with the suspension or related components. Here are some common causes to consider:

1. **Worn Sway Bar Bushings:** The sway bar is a stabilizer bar that connects the left and right suspension to reduce body roll during cornering. Worn bushings can cause squeaking noises as the bar moves up and down during suspension articulation.

2. **Worn Ball Joints:** Ball joints connect the steering knuckle to the suspension arm, allowing for smooth movement of the wheel and tire. Worn ball joints can produce squeaking noises when they move under load, particularly over bumps and potholes.

3. **Worn Tie Rod Ends:** Tie rod ends connect the steering rack to the steering knuckles, allowing for steering input to be transferred to the wheels. Worn tie rod ends can also cause squeaking noises, especially during turns or when turning the steering wheel at low speeds.

4. **Dry or Damaged Suspension Components:** The suspension system includes various bushings, seals, and pivot points that require lubrication to function quietly and smoothly. Dry or damaged components can produce squeaking noises as they rub against each other during suspension travel.

5. **Loose or Misaligned Suspension Components:** Misaligned or loose suspension components can cause excessive wear and tear on other components, leading to squeaking noises and a rougher ride.

To accurately diagnose the source of the squeaking noise and determine the necessary repairs, it's advisable to have your Range Rover Evoque inspected by a qualified Land Rover technician. They will thoroughly examine the suspension system, identify the specific issue, and recommend the appropriate repairs to restore your vehicle's smooth ride and quiet operation.

Appendix 10 Personalised Advertising Generative AI Data

Aim	Prompts	Bing AI image generator
An image for a car advert aimed at young families.	A mother picking up her young children from school in her Volvo XC90	

An image for a sports car advert.	A convertible sports car driving in the English countryside at sunset	

An image for a premium coupe car advert.	An Audi A5 in a neon lit city at night in the rain.	

For AI to generate a 4x4 or pickup truck Advert targeted for agriculture.	A 4x4 or pickup truck advert targeted at a farmer.	

For AI to generate a budget car Advert including a slogan.	Create an advert for a modern budget hatchback such as the Dacia Sandero with the strap line “affordable for all”	

		AFFORDABLE BUDGET HATCHAR AFFORDABLE FOR ALL £5500 35

Aim	**Prompts**	Gencraft AI image generator
An image for a car advert aimed at young families.	A mother picking up her young children from school in her Volvo XC90	

An image for a sports car advert.	A convertible sports car driving in the English countryside at sunset	

An image for a premium coupe car advert.	An Audi A5 in a neon lit city at night in the rain.	

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