

ADVANCED INDUSTRY 4.0

Assignment 2 - Essay

Abstract

Identifying opportunities for industry 4.0 technologies within the Automotive sector from the cradle to the grave whilst evaluating the economic, environmental and societal benefits.

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Introduction

The possibilities and applications of industry 4.0 technologies and techniques are numerous and growing. This essay will identify examples of industry 4.0 (i4.0) being used in the automotive sector as well as proposing avenues these technologies could go down in the near future. This essay will explore areas for i4.0 implementation from cradle to grave in the automotive sector.

This essay will delve into how i4.0 can be adopted and implemented into manufacturing both at the OEM and supplier side. It will also look at how it can improve user experience during the vehicle's lifespan as well as assisting the end of vehicles life, from re-use, recycling and integration into the circular economy. Emerging technologies and trends integral to i4.0 will be investigated and how they can be adapted and utilised into the current process and practices will be explored. The humanistic and environmental impacts and benefits of adopting these changes will be considered.

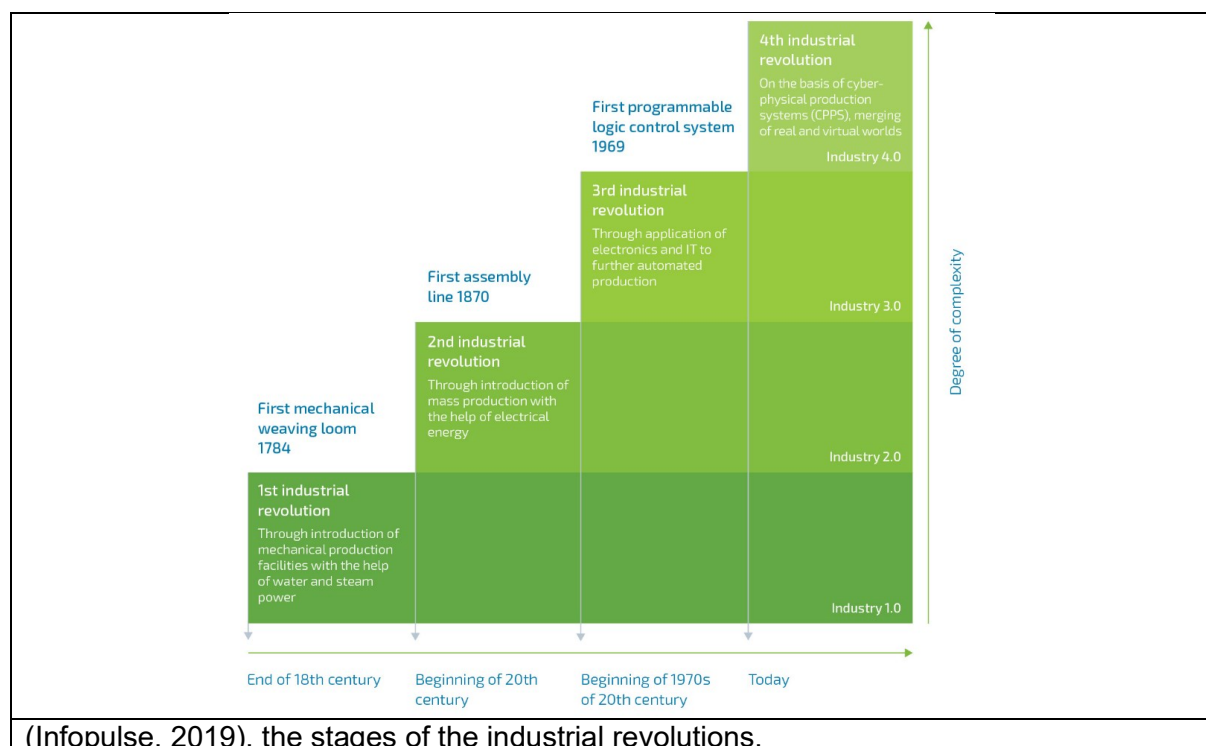
The potential economic, environmental and societal benefits of the proposed i4.0 technologies will also be investigated. The efficiency and productivity gains from i4.0 implementation in the manufacturing sector through to further benefits on the rest of the Product Lifecycle will also be examined.

Examples from within the industry, but also from further afield, will be used to provide case studies and reference points as to how these technologies can be used to transform the sector. They will aid in illustrating how emerging i4.0 technologies can be used in the automotive industry and provide evidence of similar cases from adjoining sectors and services.

What is Industry 4.0?

Industry 4.0 (i4.0) or the Fourth Industrial revolution, is the regarded as the next great leap in manufacturing and one that proposes profound societal changes along with it. The Industrial revolutions are defined by (Schwab, 2018) as follows.

1. First, the mechanisations of production using steam and water power.
2. Second, mass production using electricity as the primary power source.
3. Third, Automation using computing systems.
4. Fourth, Integrating cyber physical systems into production.



According to (Immerman, 2020) Industry 4.0 comprises of the following core elements.

Big Data and Analytics, the collection of data from production lines that is analysed and processed by computers in order to anticipate future trends (Susanto, et al., 2019). Output and maintenance schedules can then be tailored accordingly using big data (Lee, et al., 2017).

Autonomous Robots, work independently from operator input, they can be used for repetitive fast paced tasks and require less frequent downtime or breaks than humans. They can be used for a number of roles such as quality assessment, picking, forming and welding. As (Hansen, 2021) shows autonomous robots can be used for parcel sorting and improve efficiency by up to 45%.

Simulation/Digital Twins, are re-creation of physical objects or processes in a digital space. This can be used to simulate products and processes to refine systems before they are put into production, OEM Ford currently use digital twins for different aspects of their manufacturing process (Palamir, 2022).

Horizontal and Vertical Systems, are designed to integrate multiple production lines or facilities together using data to automatically communicate with one another without the need for manual processing or alerts (Schuldenfrei, 2019).

Industrial Internet of Things (IIoT), integrates sensors with machines, processes and products in order to provide live data, this allows close monitoring of manufacturing output and quality and can help in identifying problem areas for improvement (Taylor, 2022).

Cybersecurity Technology, provides protection for companies as they move towards cyber physical systems. Developments such as blockchain and AI can provide protection from hacking, data theft and ransomware (Hasanova, et al., 2018).

The Cloud, refers to machines and systems that are interconnected through the internet. It allows data and software to be streamed rather than physically stored on a local hard-drive (Agrawal, et al., 2012).

Additive Manufacturing, also known as 3D printing is a process where layers of material are bonded together to form a shape, rather than material being subtracted for a block as used in traditional methods. It is particularly useful in industries that require a quick 'one off' solution such as Formula 1 (van de Werken, et al., 2019).

Artificial Intelligence (AI) and Machine Learning, are computers and machines that use algorithms to process data from which they can then learn from (Immerman, 2020). AI can be used for preventative maintenance by predicting tool wear.

Augmented Reality (AR), manipulates the environment around a user by adding visual overlays and sensory inputs to real process or scenario (The Franklin Institute, 2022). In manufacturing it can be used to simulate processes and procedures for operator training.

This essay will explore ways in which some of these core elements of i4.0 can be applied to the automotive sector both from a manufacturing, usage and circular economy standpoint. It will consider both the cultural and workforce impact of introducing these technologies as well as the social, environmental and economic impact.

Industry 4.0 uses and applications in Manufacturing

Significant gains in both productivity can be made by introducing i4.0 tools and techniques into manufacturing, “automated production 4.0. can boost productivity in technical professions by 45%-55%” (Infopulse, 2019). By introducing additional data harvesting the full lifecycle and traceability of parts can be accurately tracked. The following will explore the potential used for i4.0 within automotive manufacturing and show the potential benefits of doing so.

RFIDs, by introducing Radio Frequency Identification, or similar, into their processes, OEMs can easily keep track of the location and quantity of sub-components, from storage to assembly on the vehicle. RFIDs can be active (using their own power source, or passive (being powered by the reading device) (Amsler, 2022). Utilising RFIDs can reduce manual tracking and counting of components and parts through the manufacturing process. This frees operators and staff from unnecessary and often time-consuming paperwork and manual sorting. As shown by (Donaldson, 2018), RFIDs could be used in a number of applications from shipping and receiving to content verification. Combined with the IoT, ‘next generation’ RFIDS could be used with GPS systems and be applied from the raw material/supplier stage, enabling the full process and carbon footprint of parts to be monitored (Amsler, 2022).

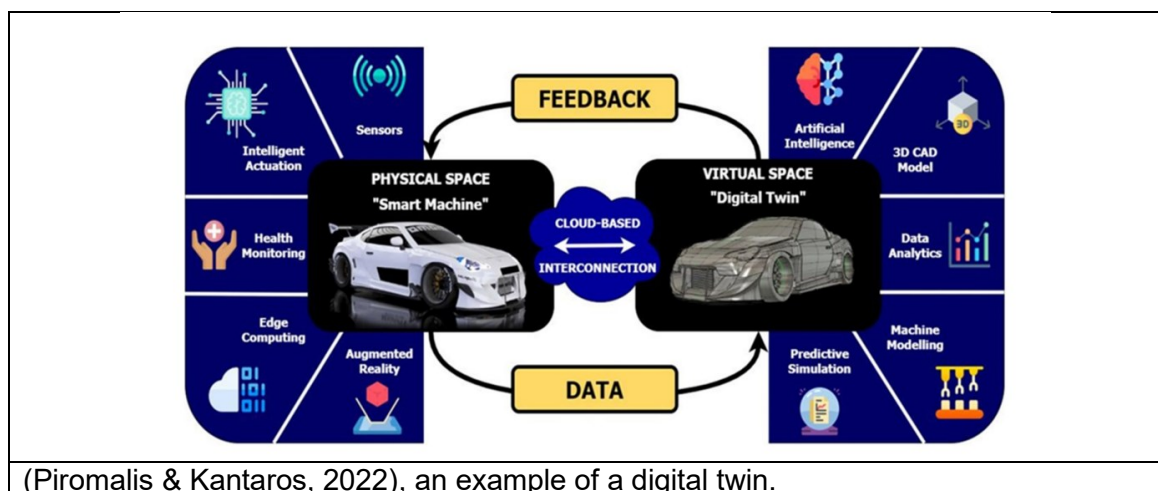
Digital Twins, by digitally twinning the sub-components, a vehicle can be virtually assembled in real time. As (Piromalis & Kantaros, 2022) show, digital twins can be used for replicating, products, process or systems.

Digital twinning of the process can highlight any bottle necks or deviations from the expected assembly time. Using this data OEMs can better plan their assembly lines and processes. Combined with RFIDs and AI the optimal route for parts and vehicles can be established and spare part order suggestions can be placed automatically (pending approval) through integration between horizontal and vertical systems.

As digital twins can also replicate the entire car and its systems, they can also be used to test out software, mechanics, electrics and the physical behaviour of the vehicle in the virtual world before production begins (Piromalis & Kantaros, 2022).

Digital twinning can also have an impact on the workforce, training can be carried out virtually before employees use machinery or processes in the factory (Şimşek, 2022).

Digital representations of vehicles are being used also as NFTs and sold as art (Wright, 2022). OEMs could go one step further, unique codes attributed between the RFIDs and their corresponding vehicle digital twins could be stored through the cloud. The digital twin could also be sold with the vehicle as an NFT to act as a marketing tool, secondary receipt or proof of purchase.



Autonomous Robots, can be used for difficult or repetitive tasks in manufacturing. In the automotive industry they can often be used for jobs such as welding and lifting or as shown by (Park & Jeon, 2018) painting. An operator can monitor the process whilst a robot follows a pre-programmed task.

By talking to one another through integration with The Cloud and the IIoT, autonomous robots could also, with the aid of AI, speed up or slow down production lines depending on the current flow rate and demand within the factory without need for manual input. By freeing workers from repetitive tasks, AR can enable employees to focus on more value-added work. This article by (Čech, et al., 2020) shows how mobile robots can even be used to retrieve parts, allowing operators to stay at their workstation and remove movement waste.

Big Data, The Cloud and IIoT, by collecting more data autonomously through sensors and processing and storing it in the IIoT, OEMs can now have a clearer picture of their processes and how they compare to the theoretical plan. Data can also be shared between facilities and factories seamlessly to trigger internal order or shipments automatically. By evaluating the data received from the production lines OEMs can better understand how their processes work, this level of clarity can highlight 'hidden factories' (Czabak-Górska & Lorenc, 2017) within the industry, efforts can then be made to remove obstacles from the current processes.

By using the Cloud, data collected can be stored automatically online. This allows data to be analysed instantly by anyone within the company or factory, rather than it only being able to be viewed on the local computer or server.

The Cloud, in conjunction with the IIoT will allow factories and their employees to communicate with each other more easily. This can help manufacturing efficiency by highlighting possible delays in supply due to current operating conditions and output elsewhere (Silva, et al., 2021).

Data in areas such as quality can be utilised by using tools such as Pareto Analysis, this can identify the most frequent types of defect and from this conclusion can be drawn as how best to eliminate them in future. Storing this data in the IIoT can allow the OEM to gain a birds-eye view of the factory and compare it to other facilities, lessons learned in one can then be applied to other to improve productivity. Big data can be used to benchmark the environmental impact of automotive manufacturing, factors such as water and energy usage, emissions and waste can be tracked with steps taken to reduce the overall impact to help improve the environment long term (Beier, et al., 2022).

Artificial Intelligence, the uses of AI can be extremely varied. For the purposes of Automotive Manufacturing they can be best focused on the move towards 'smart factories'. By using big data and the IIoT the AI can be used to predict breakdowns of machinery, this can feed into preventative maintenance schedule and prevent unexpected down-time (Meyer, et al., 2022).

Whilst AI can be controversial in some circumstances as it's perceived as replacing people's jobs, in reality it is removing menial tasks from people's schedules. This allows workers to be more productive by engaging in more value-added activities within the factory (Meyer, et al., 2022).

Horizontal and Vertical systems, allow different production lines and factories to communicate with each other. A company will decide if vertical or horizontal integration is required in order to get the best results from their processes. By utilising both systems OEMs can remove 'silo' mentality within businesses and improve clarity and visibility of the overall production picture. Within the Automotive Manufacturing this can be of great benefit due to the lengthy and diverse supply chains (ERP Information, 2022). By working closely with Tier 1 and 2 suppliers the OEM can aim to improve delivery scheduling and better anticipate and resolve any delays or potential supply issues.

Problems can be escalated sooner within the time-plan and resolved with permanent or temporary measures to ensure that manufacturing is not significantly delayed or affected.

The recent global chip shortage (James , 2022) could potentially have been mitigated with better communication between OEMs and suppliers so that chip production was not ramped down during the pandemic to the levels seen. There would then have been sufficient stock available to cover the ramp-up once pandemic restrictions were lifted, reducing the economic impact of short supply and rising costs associated with a sudden increase in demand.

Smart Factories, are a development with many features applicable to improving processes within automotive manufacturing. By adding more sensors into production processes (optical, audio, magnetic, weight, etc) more data can be gathered for analysis. As discussed above the data can then be processed to improve productivity. The cost of creating a smart factory continues to decrease due to Moore's Law (Tardi, 2022), and so the argument for adopting this technology onto existing processes strengthens. The example of the Magna Steyr factory in Austria can be held as an example of an early adopter of i4.0 methodologies to enable 'smart factory' systems within a production environment. As a result, there was a "40% improvement in on time delivery performance" (Wheatley, 2019).

Lean Manufacturing, principles can also be integrated with the above i4.0 techniques. By using existing tools and combining with greater data evidence, engineers can better identify areas for improvement. By using the added data collected through i4.0 tools such as value stream mapping can be applied to make improvements in terms of productivity, cleanliness, quality or waste reduction (Singh & Singh, 2020). Lean can also be applied to supply chain management and integration with the circular economy (Yadav, et al., 2020).

NFT and Blockchain, can also be utilised in automotive manufacturing. As discussed above NFTs could be used in conjunction with digital twins. Blockchain can aid in protecting the data harvested in the processes described so far and stored in the cloud (Arulananth, et al., 2021). Whilst gathering and sharing data online can be of great benefit to a company, there are inherent risks in doing so. Hackers could tap into the data of a company and use it to their own advantage or to blackmail the company. Blockchain can provide secure online data security (Arulananth, et al., 2021). This can enable OEMs to safely embrace i4.0 without risking their data being hacked or leaked.

Industry 4.0 uses and applications during Product Use.

There are currently huge changes happening with regards to how vehicles are used thanks to advances in technology. ADAS systems are enabling cars to become more autonomous (to varying degrees), the IoT, Cloud and mobile applications are enabling new ways of connectivity between cars, users and the internet. This can fundamentally change how the sector will look in the near future, car ownership could become a thing of the past, with autonomous taxi, or subscription hire services becoming the norm, particularly in cities where parking is limited.

The Cloud and IoT

Car companies are now utilising The Cloud and IoT to improve cars once they've left the factory. Vehicles can now download software updates wirelessly that can upgrade the performance of the vehicle, as seen already with Tesla (Tesla, 2022) and their "over-the-air" upgrades. This improved performance can have both environmental and economic benefits by improving fuel efficiency or range.

Companies such as BMW are even exploring subscription services for options like heated seats (Valdes-Dapena, 2022). This can allow users to pay for services when they need them, rather than having the product year-round. The added benefit is that second or third owners of the vehicle can tap into resources that the previous owner may not have wanted or required. This can improve the longevity and sustainability of a vehicles thanks to i4.0 tools such as the cloud.

Big Data,

Big data, used in conjunction with the IoT and The Cloud, could also be utilised by car companies for data collection and diagnostics. From this they could analyse mass vehicle performance and better understand how their vehicle are used and perform in the field (Gough, 2021). This data could inform manufactures of how cars can be set up to better perform in real-world scenarios from engine set up to vehicle dynamics

Big data could also be used for diagnostics, by comparing data from 1000's of vehicles potential failure modes could be anticipated automatically and fed back to the driver. This can allow preventative maintenance to take place with the data source not just being the vehicle but a whole data base of live data and analytics. (Gough, 2021). By adding 2-way interface users could also provide up to date feedback or recommendations direct to the OEM.

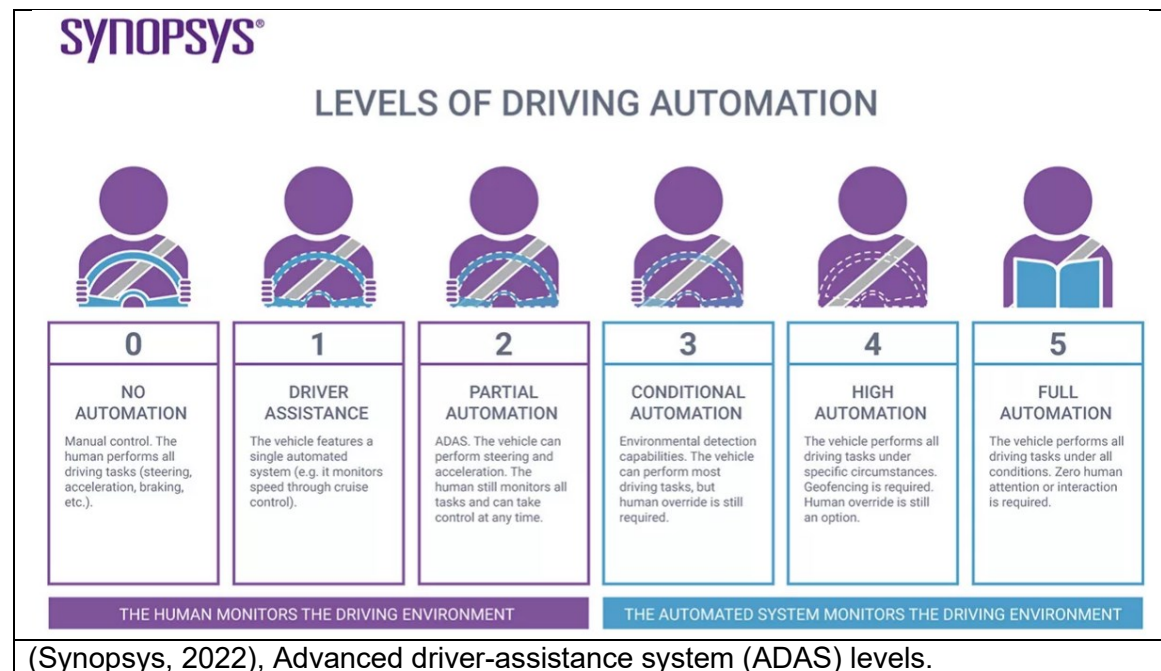
Artificial Intelligence

By using AI within the vehicle OEMs can create vehicles with smart outputs such as autonomous driving (Schroer, 2022). Cars could also suggest settings appropriate to the users driving style, vehicles can also use ADAS systems to aid driving (Schroer, 2022). In future cars could also monitor its own performance and suggest service intervals or even book them on behalf of the owner (pending pre-approved permissions).

Autonomous Vehicles

By adopting I4.0 and its many tools OEMs could also produce fully autonomous vehicles ADAS 4 to 5 (Synopsys, 2022). These vehicles utilise lots of sensors and detection methods that are now much cheaper thanks to Moore's law (Tardi, 2022). An example of this being Tesla that can already use some of these technologies (government approvals pending). Tesla vehicles already display a version of VR on their main screen, a representation of the outer-world as processed by its computers. Data from these

vehicles can be stored, compared and shared to create ever smarter vehicles, live continuous improvement.



Autonomous vehicles could also communicate directly to each other on the road (Henry, 2020), this could enable smoother traffic flow and optimise vehicle performance whilst minimising emissions. Cars could form 'road trains' or 'SARTRE' to safety draft and increase range efficiency (Road Traffic Technology, 2009). Data sharing could also recommend new routes to avoid traffic and delays.

Smart Vehicles don't need to be limited to people who purchase vehicles. Taxi services such as Waymo and Uber are looking into this as an option by adopting level 5 ADAS systems (Synopsisys, 2022). It will allow users to hail taxi's using an app and get into empty vehicles to then be driven to their chosen destination. Some of these technologies could soon feature in buses and trains too.

Subscription services are also being explored by OEMs, vehicles could be automatically delivered and leased to users for a matter of hours per day (McIntosh, 2021). In cities this could be particularly useful as a way of reducing the amount of parking required. It could work in a similar way to the 'Santander cycles' (Visit London, 2022) bike rental scheme already used in London. It also frees people from the need to purchase vehicles when one can be easily rented and used via an app.

Cyber Vehicle Security

By using The Cloud and IIoT vehicles could be monitored by their users via an app. This could be particularly useful in terms of vehicle security. If a car is stolen its location could be live-tracked and the information provided to the police (EVANNEX, 2019). Smart cameras in and around the vehicle could also be used to help identify the thieves. Blockchain could be used in conjunction with this to provide security to the vehicle in terms of blocking hacking threats and proving a unique ID for the vehicle, similar to VIN but in a digital format.

Industry 4.0 uses and applications at the end of Product Lifecycles.

There are considerable benefits to adopting i4.0 technologies early in the products life cycle, greater data sharing and connectivity can help improve the longevity of products or allow easier re-use or recycling of components to improve the overall sustainability of the product. Design with the circular economy in mind can help reduce overall material usage and lower carbon emissions by re-using or recycling energy intensive parts.

Technological aids for The Circular Economy.

By introducing RFIDs, QR codes or similar type device detection into cars from the production stage onwards, parts can be easily identified in terms of age, condition and serial number (Amsler, 2022). Whilst this relies on close collaboration at the initial stages with suppliers, its benefits could be significant at the end of a vehicle's useable life. As vehicles are dismantled and scrapped the age, compatibility and value of its subcomponents can be better identified, and updated during the vehicle's life, to be re-used or recycled accordingly. This will move vehicles away from just being crushed and push them closer towards the circular economy and have numerous environmental benefits that this has (Kalverkamp & Raabe, 2018). Efforts to use more carbon friendly or recyclable raw materials can also help in this process. By using RFIDs with Tier 1 and below suppliers the full process of parts can be better understood, and the overall carbon impact reduced.

Optimised Design for The Circular Economy.

As electric motors begin to overtake internal combustion engines in the automotive sector, the end of life of these vehicles also needs to be carefully considered. Whilst EVs have fewer moving parts and require less maintenance generally speaking, the project useful life of a battery pack is less than an engine due to battery deterioration affecting range (Zheng, et al., 2015). With this in mind careful consideration for battery re-use or recycling needs to be considered. One option is to convert vehicle batteries into home-based energy storage (Martin , 2022). This could be of societal benefit as it could protect households from blackouts or aid in renewable energy storage from solar panels. Whilst others are to either refurbish old battery cells or to recycle and re-process them.

Re-use for The Circular Economy.

As companies such as Toyota have shown (Seto, 2022), EVs could be re-furbished rather than recycled. Whilst big data can be used to track and calculate the residuals second and third 'sales/leases' of vehicles can present an opportunity to reduce waste. Improved understanding of supply chain management can also help in sourcing environmentally friendly materials from the start of the process (Yadav, et al., 2020), meaning greener products from the beginning of production.

Conclusion

The societal and economic advantages of embracing industry 4.0 are clear. From manufacturing through to product use and then end of life recycling or refurbishment. Using the automotive industry as a case study, examples of these innovative practices already being used can be found, with future trends still to come into fruition.

More specifically, in manufacturing the clarity of processes and materials can be greatly improved with i4.0. With more data and more processing, the source of raw materials, their ethics in terms of mining or processing and their subsequent use in manufacturing as well as their full lifecycle can be more closely traced (Amsler, 2022). Additional information can allow businesses and customers to make informed choices in terms of where their products come from. This can have humanistic, societal, work force and environments benefits worldwide whilst economically favouring reputable and ethical businesses and practices. However, the validity of this data will sometimes come into question and need to be verified. The example of Asos shows that some companies have been accused of 'greenwashing' their brands and forced to remove such "misleading eco claims" (Faithfull, 2022). Greater data sharing combined with AI and the IIoT can lead to further optimisation of processes, products or procedures within manufacturing. This can lead to greater output or more efficient usage of the work force, materials and resources. The economic impacts of embracing i4.0 can lead to significant growth for businesses "Nearly, 50% of business with industry 4.0. projects underway expect to see double-digit growth in the next 5 years" (Infopulse, 2019).

In terms of product use industry 4.0 can be used to optimise usage or performance of products as shown by (Tesla, 2022) and their car software updates via the cloud. As shown in the automotive sector, vehicles already in use can download updates to improve software, user interfaces or vehicle performance by improved wireless connectivity. The internet of things can also allow vehicles to communicate with one another to improve traffic flow and emissions. Short duration, car rental schemes similar to the Santander cycles (Visit London, 2022) scheme could reduce the need for people to own a car. Long term this can reduce the quantity of cars required and lower yearly emissions outputs for vehicle production.

At the end of product life the options for recycling, re-use or refurbishment can now be better utilised as understanding of the circular economy. Materials used in a product and their source becomes clearer using a combination the cloud and RFID technology (Amsler, 2022). Reducing waste and using more sustainable material sources can be greatly aided by improved data gathering and sharing using i4.0.

The example of the automotive sector shows where i4.0 methodologies are already being used, and highlights areas where it could go next. It is clear that the transferable benefits of i4.0 can more broadly be transposed to industries and economies from all areas. From its adoption the economic, societal, humanistic, work force and environmental benefits of doing so are profound.

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