Development of Electric Vehicle Competency Models: A Literature Review

January 2023

TABLE OF CONTENTS

List of Figures

List of Tables

1.0 Introduction

An electric vehicle (EV) is an innovation that leverages an electric motor as a substitute for the internal-combustion engine (ICE). This vehicular concept is devised as a replacement for current-generation automobiles to tackle the issue of global warming, increasing pollution, and depleting natural resources, amongst others. The idea of electric vehicles has been around for a long time. In recent decades it has drawn a significant amount of interest amongst growing concerns around the carbon footprint and other environmental impacts of fuel-based vehicles. The electric vehicle, therefore, was developed as a proxy for the internal-combustion engine, which generates power by burning a mixture of fuel and gases.

2.0 Electric Vehicle Development Trends

2.1 Worldwide Electric Vehicle Development Trends

An electric vehicle is a vehicle that draws power from an electric source that is onboard the vehicle (Sarode and Eadke, 2020). Faraz et al., (2021) describe an electric vehicle as a vehicle propelled by an electric motor that draws power from a battery and can be charged externally. There are three primary categories of EVs (Matthews et al., 2017):

- Hybrid electric vehicles (HEV) and Plug-in hybrid electric vehicles (PHEV) have batteries (to power the motor) and liquid fuel storage refuelling systems (to power the ICE) (Sarode and Eadke, 2020).
- Battery electric vehicles (BEV) use only batteries for energy storage and need to be plugged in to be recharged
- Fuel cell electric vehicles (FCEVs) employ a fuel cell instead of or in conjunction with batteries or supercapacitors to power the electric motor (Matthews et al., 2017; Mersky et al., 2016; Sun et al., 2019).

Electric vehicles (EVs) can contribute to carbon reduction in the transportation sector and the development of low-carbon communities due to their operational energy-efficient technology and minimal emissions. According to the Transport and Environment (2020) report, electric vehicles in the European Union emit 80% and 81% fewer carbon emissions than diesel and petrol, respectively, in their best-case scenarios. Furthermore, the report posits that the European Union car will emit 22% and 28% less CO_2 in a worst-case scenario than diesel and petrol, respectively. Thus the electric vehicle has become one of the automobile industry's core development trends, receiving widespread attention (Amini et al., 2017; Zhao et al., 2015). Energy and environmental problems have been exacerbated by the rise in automobiles powered by internal combustion engines, which rely on non-renewable, conventional fuels (Qiao et al., 2019). Consequently, several nations have turned to new energy vehicles (NEVs), such as electric vehicles, as an alternative to conventional automobiles. These nations are motivated by the desire to lessen their reliance on oil and the air pollution created by conventional automobiles (Hu and Yuan, 2018; C. Li et al., 2019; W. Li et al., 2016).

The electric vehicle is a major disruptor of the automotive value chain. Several drivers of this value chain disruption are described by the acronym STEEP representing Society, Technology, Economics, Environment and Politics (Deloitte, 2017).

The societal drivers include safety awareness, competition for talent, ride-sharing, pay-per-use models, increasing urbanisation, etc. Technological drivers include artificial intelligence, modern telecommunication grids, autonomous driving, energy storage, lightweight technology, 3D printing and stringent cyber security standards. The drivers in the economic space include infrastructure spending, data monetisation, market control by new players, novel sales channels, etc. Environmental drivers include the desire for advanced recycling technology, alternative powertrains, ecological concerns and the demand for pollutant-free production. Finally, the political drivers are the thrust for freedom of trade, the state of public transport infrastructure, etc.

EVs have several benefits (Sarode and Eadke, 2020). The development of electric vehicles creates numerous employment opportunities, including for technicians in the battery manufacturing and charging industries. It also provides a chance for investors to invest in the battery production and charging infrastructure that is driving the revolution of electric vehicles (Berckmans et al., 2017). Ahmadi et al., (2014) asserted that the lithium-ion battery of an electric vehicle could be reused as a device for power storage to assist the utility grid during peak hours. When the electric vehicle battery is leveraged to store electricity during off-peak hours to augment peak demand, it is possible to minimise carbon emissions by up to 56% compared to conventional gas fuels.

EVs also provide opportunities in the component manufacturing side of the value chain. According to the Platform for Electro Mobility (2020), the European Union Electromobility sector is poised to generate 1.1 million jobs by 2030. This includes 31000 jobs in the charging equipment manufacturing subsector, 65 500 jobs in the charging installation and connection subsector, 141 500 jobs in the charging infrastructure operation subsector, 94 000 jobs in the charging infrastructure maintenance subsector, 35 000 jobs in the electricity generation subsector, 27 500 jobs in the grid reinforcement subsector, 72 000 jobs in the battery manufacturing subsector, 6500 jobs in the battery end-of-life sector, 48 500 jobs in the electric powertrain manufacturing subsector and 552 000 jobs in the rail expansion subsector. Battery manufacturing plants generate as many as 3200 jobs per year for a plant capacity of between 30 - 40 GWh/year (Campagnol, Pfeiffer & Tryggested, 2022).

In addition to being emission-free and silent, EVs provide other environmental advantages over conventional vehicles (Sarode and Eadke, 2020). Electric vehicles lack exhaust pipes and hence do not contribute to noise pollution. Conversion of automobiles with internal combustion engines to electric vehicles could significantly decrease the incidence of cardiovascular diseases caused by air pollution. This would result in fewer employee absences due to illness and substantial enhancements to quality and duration of life (Choma et al., 2020; Perera, 2018). EVs also require less maintenance than combustion engines, with quiet operation and low-speed torque (Sarode and Eadke, 2020).

The history of electric vehicles can be divided into six distinct periods: the early pioneers of electric mobility from 1830–1880, the shift to motorised transport from 1880–1914, the growth of the internal combustion engine from 1914–1970, the comeback of electric vehicles from 1970–2003, the electric revolution from 2003–2020, and the tipping point from 2021 onwards (Chan, 2013; Wilson, 2022). After the invention of electrical machinery in the early 19th century, several people were involved in developing the first electric cars (Vscan and Szabo, 2022). Nyos Jedlik, a Hungarian, built a tiny Electric model-powered car in 1828. Vermont's Thomas Davenport invented the first American DC electric motor in 1834. Rechargeable batteries were not invented until 1840; therefore, vehicles couldn't store energy until then (Høyer, 2008). Gaston Plante and Camille Faure's efforts in 1881 to improve battery technology in France paved the way for electric cars and the rise of the European electric car sector. France and Britain were the first to fund electric vehicle research (Guarnieri, 2012; Xie et al., 2022).

The First World War increased electric car demand in Britain and Europe. Europe had 3,200 electric automobiles in 1914. Steam-powered vehicles accounted for 40% of American cars in 1900, while electricity powered 38% of vehicles and gasoline 22%. New roads between US cities were opened in the early 20th century (Sarode and Eadke, 2020). These routes required a longer Range vehicles than electric automobiles. Texas, Oklahoma, and California's oil discoveries increased gasoline availability at low prices causing electric vehicles to lose market share after their peak at the turn of the century (Sun et al., 2019; Vascan and Szabo, 2022).

The energy crisis of 2000 and 2001 revived hybrid and electric vehicle sales. Small enterprises developed and sold electric vehicles to the public due to the lack of huge manufacturers. The Bangalore-based REVA Electric Car Company, created in 1994 by Maini Group India and AEV of California (acquired by Mahindra and Mahindra in 2010), sold 4,600 cars by late 2013 in 26 countries (Vascan and Szabo, 2022). Think Global started making the Think City electric car in 2008. The Think City electric car can attain a maximum speed of 110 km/h and a total distance of 160 km. Tesla Motors, based in California, developed the Tesla Roadster in 2004 (Vascan and Szabo, 2022). The Tesla Roadster was the first mass-produced electric car for American freeways. Between 2008 and 2011, 31 countries sold over 2,100 cars. Roadster is the first vehicle with a single-charge range of over 320 km and a top speed of over 200 km/h. Tesla produced the first cars using lithium-ion batteries (Sun et al., 2019; Vascan and Szabo, 2022).

The Mitsubishi i-MiEV debuted in July 2009 for Japanese fleets and other consumers in April 2010, with leasing employed for sales in Hong Kong and Australia. In December 2010, Europe introduced the Peugeot Ion and Citroen C-Zero IMiEV vehicles (Vascan and Szabo, 2022). In December 2010, the Nissan Leaf became the first mass-produced all-electric vehicle with zero exhaust emissions. Nissan claims a 160-kilometre Leaf range. By December 2011, France, Ireland, the Netherlands, Norway, Portugal, Spain, Switzerland, and the UK received the Leaf. Since its December 2010 launch, over 30,000 Nissan Leafs have been sold worldwide by 2012. Thus, Nissan Leaf is the best-selling electric car worldwide (Vascan and Szabo, 2022).

Sales of brand-new electric vehicles increased by 51.8% in 2021 compared to 2020. As a result, EV sales constituted 5% of all passenger car sales globally in 2021 (IEA, 2022a). Over 6.5 million electric vehicle units were sold, and the market earned US$350 billion overall, with an anticipated compound annual growth rate (CAGR) of 28.9% between 2017 and 2027 (IEA, 2022a; Tsakalidis et al., 2020). China and the US together accounted for a staggering 54.2% of global sales in 2021, selling about five times the number of electric vehicles sold in Germany. In 2023, the market for electric vehicles is predicted to generate US$ 457.60 billion in revenue and reach US$858.00 billion by 2027, with revenue projection at a rate of 17.02% per year (CAGR 2023–2027) (IEA, 2022b).

2.2 Electric Vehicle Development Trends in South Africa

The South African transportation industry is responsible for the consumption of 28% of the country's final energy supply and the production of 11% of the country's greenhouse gas emissions (Dane, 2013; Ledwaba et al., 2019; Winkler et al., 2011). By the year 2050, 76% of South Africa's power will be generated by renewable resources, reducing the country's carbon intensity to 139 g KWh-1 (Francisco and Posada, 2017; Go, 2022). This presents a significant opportunity for adopting electric cars, including battery EVs and plug-in hybrid EVs (PHEVs), to reduce the amount of greenhouse gas emissions caused by road transportation (Alexander and Tonachel, 2016). As a result of the knowledge that this possibility exists, several nations, including South Africa, are spending significant resources on the process of electrifying their transportation systems and transitioning away from the use of fossil fuels by formulating programs that include specific timetables (Bokopane et al., 2019; Tongwane and Moeletsi, 2021; Zhang and Fujimori, 2020).

The first reports on electric automobiles in South Africa date back to the 1970s (Calitz and Bansal, 2022; Grant, 2014; Tongwane and Moeletsi, 2021). However, the South African electric vehicle industry had not grown as envisaged till the late 2000s when the sector began generating interest again (Liu et al., 2015; Tongwane and Moeletsi, 2021). In 2008, the Joule, an electric car prototype built and manufactured domestically in South Africa by Optimal Energy, was presented to the public for the first time (Grant, 2014b; Sophie Edwards, 2017). The Industrial Development Corporation and the Technology Innovation Agency of the Department of Science and Technology provided significant funding for the Joule project; however, the project was shelved in the middle of 2012 because Optimal Energy could not secure financial support from private parties (Swart, 2015). In November 2013, Nissan became the first automaker in South Africa to offer a Battery Electric Vehicle (BEV) for sale to the general public (Venter, 2013; Grant, 2014b). Various firms such as BMW and Volkswagen acknowledged a minimum demand for PHEVs and BEVs in South Africa by declaring plans to make automobiles available locally (Grant, 2014b). By the end of 2018, South Africa had more than a thousand electric vehicles and 100 charging outlets (Deonarain, 2019; Stone et al., 2018). This number has increased to 1559 electric vehicles and over 250 charging outlets by late 2022 (Malinga, 2022a; Malinga, 2022b). These electric vehicles run the gamut of private passenger vehicles, light commercial vehicles, medium commercial vehicles, utility vehicles, trucks, mining vehicles, and buses (Ahjum et al., 2018; Tongwane and Moeletsi, 2021; Mi Power Electric Bus, 2023; Melex Electrovehicles, 2023).

The adoption index for electric vehicles in South Africa is low, and the sector's growth is relatively slow compared to that of other nations. This is the case even though electric vehicles offer great benefits (Tongwane and Moeletsi, 2021). According to studies, some of the issues faced by electric vehicles in South Africa include high purchase costs, an undetermined value of electric vehicles, and a shortage of maintenance professionals (Andersen, 2013; Tongwane and Moeletsi, 2021). In response to these concerns, South Africa's government produced several policies and frameworks, such as the South African Automotive Masterplan (SAAM 2035), the DTIC's Auto Green Paper (2021), and the Green Transport Strategy for South Africa (2018-2050), to help the country's automobile industry.

Chege (2021) opined that the electric vehicles manufacturing value chain begins from material assembly to component production, then to component assembly and finally to system assembly. This value chain is depicted in Figure 1. Table 1 provides details of the value chain with its constituent and allied subsystems, including electric vehicles, solar PV, and battery storage.

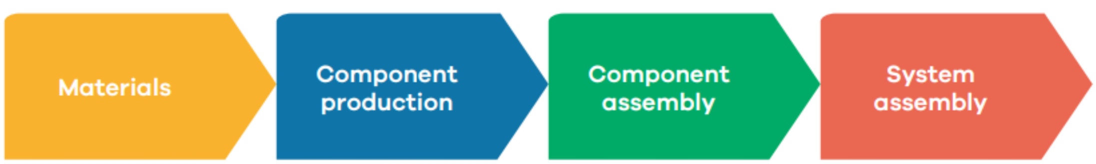

Figure 1: Electric Vehicle Value Chain

Table 1: Details of the Electric Vehicle Value Chain

Materials	**Component Production**	**Component Assembly**	**System Assembly**
• Steel • Aluminum • Copper • Glass	• Catalytic Converters • Shock absorbers • Clutches/ Shaft couplings	• Vehicle chassis • Drive train • Tyres • Propulsion system	Electric Vehicle

• Rubber • Special fibres • Plastics • Lead • Titanium • Magnesium	• Axles & Filters • Auto tooling • Brake pads • Engines • Ignition/ Starters • Gaskets • Gear Boxes • Radiators • Tyres & Glass		
• Silicon & Glass • Cement & Concrete • Iron & Steel • Polymers & Plastics • Aluminum & Alloys • Other metals & Minerals (E.g Cadmium)	• Cells • Aluminium frames • Super-substrate (Glass) • Backing sheet • Ethylene Vinyl Acetate (EVA) • Copper wiring • Junction box • Magnetics • Transformers • Circuit Boards • Electronics • Enclosures • Steel profiles • Aluminium profiles • Clamps • Nuts & Bolts • Conductors • Insulation • Armour	• Modules • Inverter • Mounting structures & trackers. • Cabling.	Solar PV system.
▪ Cobalt ▪ Graphite ▪ Lithium ▪ Manganese ▪ Nickel ▪ Titanium ▪ Phosphate ▪ Aluminum ▪ Copper ▪ Iron ▪ Polymers & Plastics	▪ Cathode ▪ Anode ▪ Electrolyte ▪ Separator ▪ Current location ▪ Cell casings ▪ Electronics	▪ Battery pack ▪ Battery management system ▪ Cooling system (Inverter)	Energy storage system

The Automotive Supply Chain Competitiveness Initiative ASCCI (2022) provided a comprehensive analysis of the electric vehicle value chain in South Africa and identified components in the supply chain that can be localised. This analysis is detailed in Table 2.

Table 2: Localisation framework for the South African EV component supply chain

Components	Mineral Resources	Raw material	Manufacturing Technology
Motor	• Silica • Copper Ore • Coal • Iron Ore • Nickel • Rare earth elements like Bauxite	• Plastic polyamide (PA6/PA66) • Plastic Polypropylene (PP) • Copper • Aluminum • Copper wire • Steel • Electrical steel (imported)	• Plastic injection moulding • Aluminium stamping • Aluminum High-pressure Die – casting • Precision machining and Turning forging sintering
Transmission	▪ Silica ▪ Coal ▪ Chromium ▪ Iron Ore ▪ Nickel ▪ Bauxite (SADC)	▪ Aluminium ▪ Steel ▪ Stainless steel	▪ Aluminium High – pressure Die casting. ▪ Forging ▪ Machining
PCB Assembly (FR4)	▪	▪ Epoxy ▪ Resin ▪ Copper ▪ Thermal Paste ▪ Potting material	A place for the assembly of semiconductors and passive components of the PCB
Housing	Aluminum	Aluminum Die-casting	
High voltage wiring harness	▪	▪ Copper ▪ Plastic (PVC or PA6, PBT) ▪ Aluminium sheets (EMI Shielding)	▪ Plastic injection moulding ▪ Crimping ▪ Copper/aluminium extrusion ▪ Plastic extrusion ▪ Overmoulding
Charge Port	▪	▪ Plastic (PA6/PA66) ▪ Copper	▪ Plastic injection moulding ▪ Over moulding

3.0 Overview of Key Electric Vehicle Policy Documents

3.1 South African Automotive Master Plan (2021 – 2035)

The South African government commissioned the development of a "South African Automotive Masterplan to 2035", a partnership between the government, Original Equipment Manufacturers (OEMs), suppliers in the automotive industry, and labour. The master plan was in response to the challenges bedevilling the automotive sector and sought to develop a sustainability-driven policy framework for the industry's value chain. Justin, Barnes and Anthony Black were the two consultants appointed to head the process on behalf of the national government in early 2016, reporting to the Minister of Trade and Industry and a selected group of industry stakeholders (Barnes and Black, 2017). Their mandate was explicit: "*Using both independent research and extensive industry discussions, produce a clear, strategic plan for the future of the South African automotive industry through 2035*". In addition, the consultants were tasked with designing an automotive policy framework post-2020 that fit with the master plan's vision and objectives, with both the master plan and the policy recommendations undergoing intensive stakeholder examination and participation before finalisation (ANTONIO et al., 2021; Department of Trade, 2021). The project began in April 2016 and finished in May 2017, following five rounds of intense work. The most important phases of the project were Phases 4 and 5, with Phase 4 ending in the development of the South African Automotive Masterplan (SAAM, completed in November 2016) and Phase 5 resulting in policy recommendations to assist in the implementation of the SAAM (The Department of Trade, 2018).

SAAM's vision for 2035 is "a globally competitive and transformed industry that actively contributes to the sustainable growth of South Africa's productive economy, providing prosperity for industry stakeholders and the broader society (Barnes and Black, 2017)." This vision consists of four primary components. The first component refers to the industry's competitive position. By 2035, the South African automobile sector will be globally competitive (compared to the leading International automotive manufacturers) (Barnes and Black, 2017). The second component is the industry's contribution to the transformation of the South African economy. This includes numerous aspects, such as employment equity and the expansion of black-owned enterprises inside the automotive supply chain. The third component refers to the economic development of South Africa in a sustainable manner. The critical factors included in this component pertain to the expansion of the industry, the creation of jobs, the development of skills, and the reduction of the environmental effect of products and industrial processes (Barnes and Black, 2017). The fourth component refers to the shared prosperity created by the industry, with the essential parts being the financial health and well-being of enterprises within the value chain, fair employee compensation, and the value chain's broader contribution to the South African Fiscus (Arbib and Seba, 2017; Barnes and Black, 2017; Department of Trade, 2021).

The four pillars of global competitiveness, sustainable development, industrial transformation, and societal contribution form the aspirational core of the SAAM vision. The SAAM acknowledges that the vision of the South African automotive industry can only be realised by achieving a set of essential development goals. Six factors have been recognised as crucial to the success of the SAAM (Barnes and Black, 2017; Department of Trade, 2021; The Department of Trade, 2018):

1. Increase South African vehicle output to 1% of world output (projected to reach 140 million units annually by 2035).
2. Increase the local content of South African-assembled automobiles to 60% (from the current level of 38.74%).
3. Increase overall employment in the automotive value chain by twofold (from 112,000 to 224,000).
4. Raise the automobile industry's competitiveness to the level of leading international rivals (such as Turkey and Thailand).
5. Achieve transformation of the South African automotive industry by employing Black South Africans, upskilling Black employees, empowering dealerships and authorised repair facilities, and significantly increasing the contribution of Black-owned automotive component manufacturers to the automotive supply chain.
6. Increase value addition within South African automotive value chains (across certain commodities/technologies).

The attainment of these six mutually supporting objectives is anticipated to have a profoundly transformative effect on the position of the South African automotive industry, with the private sector, government, organised labour, and broader society all standing to gain significantly from their accomplishment (Barnes and Black, 2017).

3.2 Green Transport Strategy for South Africa (2018 – 2050)

The Green Transport Strategy (GTS) was drafted in response to the National Climate Change

Response Policy white paper, which argues for a climate-resilient and low-carbon economy by 2050 (Ahjum et al., 2019). The GTS proposes measures that would contribute equitably to achieving the national goal of a low-carbon transport sector (Transport Department: Republic of South Africa, 2020). The GTS aims to decrease greenhouse gas emissions and other environmental consequences from the transportation industry by 5% by 2050. The GTS will support the transport sector's contribution to the country's social and economic development while starting creative green alternative reforms to reduce harmful emissions and negative environmental impacts connected with transport systems (Cheng et al., 2021; Dominković et al., 2018).

The GTS aims to (Transport Department: Republic of South Africa, 2020):

1. Support the efficient operation of a modern economy and meet the transportation requirements of growing human settlements;
2. Ensure a healthy environment and supportive eco-system services while eradicating apartheid's structural exclusion of the poor from economic opportunity;
3. Lower the cost and improve the convenience and safety of transportation, i.e. by offering guidelines for promising cost-effective future green energy technologies.

The Green Transport Strategy has the following key objectives:

1. Enabling the transportation industry to fairly participate in the country's effort to combat climate change while also acknowledging the DoT's and the industry's primary duty of fostering the development of effective integrated transportation systems to support sustainable socioeconomic development;
2. Promote behavioural shifts toward sustainable mobility options through information, education, and awareness-building,
3. Assisting with the alignment and development of policies that encourage energy efficiency and emission control measures in all transport modes by involving the sector in the low carbon transition;
4. Reducing the adverse environmental effects of transportation activities, and
5. Enabling a just transition in the industry to infrastructure and transportation that is climate resilient.

The GTS core elements:

1. To achieve modal shifts in the transport sector that reduce GHG, congestion and improve temporal, spatial, and economic efficiency - in particular, by shifting passenger and freight transport from road to rail and promoting public transport and non-motorised transport
2. To promote the use of electric vehicles and environmentally sustainable low-carbon fuels, including CNG, biogas, biofuels, and renewable energy, to provide electricity for transport.
3. To reduce fossil-fuel-related emissions in the transport sector by promoting norms and standards and putting in place regulations that promote improved efficiency in fossil-fuel-powered vehicles.
4. To promote strategies for delivering transport infrastructure and integrated transit planning that build climate resilience in urban and rural communities and minimise the environmental impact of transport infrastructure.

The GTS Strategic Focus:

1. Green Fuel Economy standards: provide norms, standards and regulations that promote fuel economy in vehicles that improve fuel emission standards in South Africa.
2. Green Transport technologies:
    - reduce the carbon footprints of fossil fuels
    - promote alternative fuels such as Compressed Natural Gas/ Biogas;
    - promote the uptake of electric and hybrid–electric vehicle technologies;
    - explore the option of Fuel Cell/ Hydrogen technology.
3. Green Rail: Extend the Rail network to provide reliable, safe, efficient and affordable high-speed transport.
4. Green Roads:
    - provide infrastructure to promote non-motorised transport;
    - shift freight transport from road to rail;
    - shift passengers from private to public transport, especially rail.

The Green Transport Strategy conceptualised long-term and short-term visions for the South African transportation sector. Both visions are briefly detailed below (Transport Department: Republic of South Africa, 2020):

3.2.1 Long-Term Vision: Using Resources Efficiently and Supporting the Eco-System

1. Instituting "no-car zones," with most central business districts closed to car use. Emphasising eco-mobility modes of transportation like walking and cycling as the preferred mode of transport, allowing significant areas of urban real estate currently used for parking to be used for affordable inner-city housing and businesses.
2. A vast system of bike lanes and walking paths to re-orientate South African in towns and cities to do away with automobiles. By lowering hazardous air pollution and encouraging healthy exercise, investments in non-motorised transportation infrastructure are poised to benefit human health.
3. The National Freight Logistics Strategy has designated long-distance freight as being limited to rail, creating "Green Corridors" in the road network to encourage the adoption of more environmentally friendly technology in our freight sector. This, along with accelerated modal changes in passenger transportation, will significantly lower road traffic and the costs of maintaining urban and national roadways, allowing funds to be re-distributed to ecologically responsible improvements of rural road infrastructure.
4. With the advancement of vehicle technologies with low or no tailpipe emissions, such as electric and fuel cell vehicles, combined with a significantly lower national electricity grid emissions factor due to a large-scale switch to renewable energy improvements, motorised transportation will have a substantially lower carbon intensity.
5. All trash collection trucks and some public transportation buses that have not yet been replaced by electric vehicles will be converted to allow propulsion using a combination of biogas and biofuels made from household, commercial, and agricultural waste.

3.2.2 Short-Term Vision: Using Resources Efficiently and Supporting the Eco-System

The "quick wins" for the approach include the short-term strategic goals that will effectively fall under the implementation plan for the first 5 to 7-year period (Transport Department: Republic of South Africa, 2020). These are detailed thusly:

1. To implement modal shifts in the transportation industry that lower GHG emissions and other harmful pollutants, ease traffic congestion, and enhance the sector's temporal, spatial, and economic efficiency. Furthermore, to advance a 20% shift in passenger travel from private vehicles to public transportation and eco-mobility to achieve a 30% shift in freight transportation from road to rail.

2. To transition 5% of the fleet in the public and national sectors to cleaner alternative fuel and efficient technology vehicles (ideally powered by renewable energy) and environmentally sustainable low-carbon fuels by 2025, including the use of CNG, biogas, and biofuels as well as the use of renewable energy to provide electricity for transportation.
3. To lessen emissions linked to fossil fuels in the transportation sector by promoting norms and standards for fuel economy and putting policies in place that support more efficient fossil fuel-powered cars and better environmental performance from fossil fuels.
4. To encourage policies and guidelines for creating transportation infrastructure, integrated transit planning, and systems that increase climate resilience in urban and rural populations while reducing the environmental effect of transportation infrastructure.
5. To provide best practice standards to ensure land use and spatial planning at the federal, provincial, and local levels embrace integrated climate-friendly transport alternatives.
6. To advance investments in the infrastructure supporting sources of green energy, such as biogas filling stations, electric vehicle charging stations, and GIS-integrated ICT technology platforms for situating stations, governing future pricing and supplying statistics.

3.3 DTIC 2021 Auto Green Paper: On the advancement of New Energy Vehicles in South Africa

The Auto Green paper was put forward by the Department of Trade, Industry and Competition of the South African Government to develop a comprehensive and long-term framework for the automotive industry transformation \ due to the emergence of new energy vehicles. This is due to the disruptive trend of the global automotive industry in the shift from internal combustion engine (ICE) vehicles to New Energy Vehicles (NEVs). The focus of the Green paper includes the following:

1. creation of a high-yielding business environment, including an appropriate fiscal and regulatory framework that makes South Africa a leading and highly competitive location, not only within the African continent but globally, for electric vehicle production;
2. support and investment in the expansion and development of new and existing manufacturing plants to support the production of new energy vehicles and components within South Africa and to grow the level of employment in the sector;
3. development and investment in new energy vehicle component technology and expansion of the fledgling electric supply chain by increasing support and investment in a set of unique NEV components;
4. reinvestment and support towards reskilling and up-skilling of the workforce to ensure the right

skills are available for the design, engineering and manufacturing of electric vehicles and related components and systems;

5. the transition of South Africa towards cleaner fuel technologies available globally.
6. adoption of new and sustainable manufacturing processes to significantly reduce greenhouse gas emissions and improve our environmental wealth; and
7. Ensuring that Research and Development [R&D] investment is strategically targeted at activities that are likely to give South Africa a competitive advantage.

Moreover, the policy marshalled the following policy instruments for the seamless transition to the production and utilisation of Electric Vehicle in South Africa, which is a phased approach to minimise the EV disruption of the automotive industry:

1. Creating and stimulating the production of electric vehicles to generate industrial and job opportunities for local manufacture of vehicles and related components, both for export markets and to satisfy domestic demand. In other words, the country should do everything possible not to have the existing manufacturing capacity confined to ICE vehicles whilst domestic and export consumption shifts to EVs;
2. Consideration should be given to further encouragement of the country's transition to electric vehicles: EVs may need to be incentivised and, based on a careful analysis of cost structures, volumes and the effect of technological innovation, reduce the current price gap compared to ICE vehicles. Any proposed support should have a soft run-out; and
3. Increased foreign investment will benefit the country's growth and recovery ambitions, increase employment, create an upskilled workforce, and sponsor interventions that will progressively promote a healthier environment.

4.0 Technical and Vocational Education and Training (TVET)

TVET (Technical and Vocational Education and Training), also known as Further Education Training (FET), is a high-quality and responsive technical & vocational education training system in South Africa (Sithole et al., 2022). The South African government uses this system to encourage the union of education and training, as well as to improve the mobility of learners and progression, which will ultimately help in achieving the country's human resource demands. TVET systems were developed to meet these human resource demands and strengthen the nation's social, civic, economic, and personal growth (Pareek, 2023; Sebola, 2022). They aim to provide individuals with intermediate to advanced skills that will catalyse further study, simplify the transfer from schooling to the workplace, and nurture independent lifelong learners (Batholmeus and Pop, 2019).

In South Africa, the origins of the institutions formerly known as technical colleges trace back to the 1800s. The vision for young people to have access to technical education was a response to the industrialisation of the late 1800s (Southern African Development Community, 2013). The African National Congress's (1994) policy framework for education and training led to the 1998 publication of White Paper 4: A program for transforming further education and training. This policy statement outlined the essential ideals and vision for constructing the new education and training system (Sebola, 2022); the immediate focus of the TVET policy development process evolved from this document (Sebola, 2022). According to the national curriculum framework for the TVET band, one of the government's primary motivations for implementing these new rules was to address the inadequacies and deficiencies of the TVET college curriculum (Batholmeus and Pop, 2019).

The South African TVET1 college sector was founded in 2002 in accordance with the Further Education and Training (FET) Act of 1998. The merger process in South Africa's nine provinces turned 152 previous technical institutions (state and state-aided) into 50 multi-site TVET colleges (Terblanche and Bitzer, 2018). The TVET college sector has undergone significant policy and governance shifts. These developments have also led to name changes within and for the sector, such as the transition from Further Education and Training to Technical and Vocational Education and Training (TVET) (Batholmeus and Pop, 2019; Field et al., 2014; Terblanche and Bitzer, 2018).

4.1 The Role of TVET in Advancing Human Capital Development in South Africa

TVET represents a significant element of the world's educational system, as most nations have technical and vocational colleges, especially for artisan training. Investment in education and training benefits the individual, society, and the country (Audu et al., 2013). The return on investment will be a competent workforce supporting economic growth and global competitiveness for society and the nation. At the same time, for the individual, it will be a better career path, higher income, and better quality of life (Terblanche and Bitzer, 2018). The successful utilisation and implementation of TVET programs will foster the required competencies and skills to enable the youth to be self-sufficient (Enyekit et al., 2011; Audu et al., 2013). The development of the economy's much-desired human capital would result from this. TVET provides people with the necessary competencies, managerial abilities, and technological know-how to manage people and resources for greater efficiency in an organisational setting (Ngcwangu, 2015).

TVET is a purposeful intervention to promote learning that will increase people's productivity in selected economic sectors. TVET offers the opportunity to improve people's skills and expand their options. It seeks to enable students to satisfy the needs of companies for qualified labour and/or their own production-related needs (Edokpolor and Dumbiri, 2019; Sebola, 2022). TVET strives to develop practical skills, attitudes, and behaviours that make the receiver inventive, resourceful, and creative. TVET is a comprehensive, multidisciplinary, and pragmatic branch of study that improves the relevance and usefulness of its beneficiaries within society (Uwaifo and Uwaifo, 2009). TVET is a crucial yet well-articulated HRD program best suited to fulfil the demands of the new knowledge economy.

4.2 The National Qualification Framework (NQF) Level 4 – 6

The concept of a National Qualifications Framework began before the 1994 democratic elections. This idea was further advanced in the National Training Strategy and the Reconstruction and Development Programme (RDP) (South Africa: Department of Education and Department of Labour., 2002; van Huyssteen, 2002). It was regarded as a significant innovation of the new democratic government as it brought learning across the various tiers of education and industrial training in a single framework of outcomes-based qualifications and standards (African Union, 2022).

The main goals of the framework are to match qualifications with skills, knowledge, and competencies to ensure that qualifications are fit for purpose in the labour market. Furthermore, to ensure that obtained qualifications secure jobs and bring rationality to sub-systems of qualifications, e.g., adult learning, higher education, school awards, and in particular, TVET qualifications, by creating an overarching framework for them, which will support life-long learning (by opening up access to school, targeting investments and recognising non-formal and informal education) (OECD, 2003; Shehi and Gishti, 2021);

The SAQA Act was passed in 1995 with the joint sponsorship of the Ministers of Education and Labour (Gazette and Notice, 1995). The 1997 White Paper on Education in South Africa outlined a set of ingenuities aimed at transforming higher education into a single, coordinated system, including the facilitation of articulation, a program-based approach, and increased facility for the recognition of prior learning. Two bodies primarily responsible for implementing these initiatives are the Council on Higher Education (CHE) and the SAQA (SAQA, 2019). SAQA began work in

1997, and the NQF was established by regulation in 1998. The NQF is a set of principles and guidelines by which records of learner achievement are registered to enable national recognition of acquired knowledge, skills, and competence, thereby ensuring an integrated system that encourages lifelong learning (SAQA, 2019). The NQF consists of 10 levels divided into three bands; Levels 1 to 4 equate to high school grades, 5 to 7 are college diplomas and technical qualifications, and 7 to 10 are university degrees.

Furthermore, the SAQA has a registered qualification titled: Occupational Certificate: Transportation Electrician (Automotive Electrician) under the Manufacturing, Engineering, and Technology field (SAQA Registration qualification, 2020). The NQF Level for this certificate is Level 4. According to the qualification certificate, the learner will be able to perform the following:

- Remove and install a range of original/ aftermarket/ auxiliary auto-electrical equipment and components/systems.
- Test, diagnose, replace and service automotive batteries and related components.
- Test, diagnose and repair automotive starting and charging systems.
- Conduct basic vehicle service operations in an auto-electrical environment.
- Test, diagnose and repair automotive networking and data transfer systems and supplemental restraint systems (SRS); Test, diagnose and repair systems for integrated engine management (fuel injection and ignition), vehicle stability, traction and drive control (VSTDC), transmission, ABS braking, and driver assistance.
- Test, diagnose and repair systems for heating, ventilation and air-conditioning (HVAC), climate control, convenience, security and telematics.

5.0 Relevant Theories for the EV Industry

5.1 Human Capital Theory

Human Capital Theory (HCT) holds that formal education is crucial to a population's productivity. Theorists of human capital say that an educated populace is productive (Wuttaphan, 2017). The human capital theory reveals how education stimulates workers' productivity and efficiency by growing the cognitive stock of economically valuable human capability, which is a product of intrinsic abilities and investment in humans. Formal education is perceived as an investment in human capital, which proponents believe is more valuable than physical capital (Pasban and Nojedeh, 2016). This theory states that investments in human capital will boost economic production. Modern economists agree that education and health care improve human capital and strengthen the nation's economy (Aliu and Aigbavboa, 2019; Emrullah, 2014).

Human development depends on a nation's human capital and economic development. Thus, modern social research focuses on economic production and human behaviour. An individual's asset that boosts economic productivity is called human capital. Education and development policies are also part of human capital. In summary, human capital theorists believe an educated populace is a productive populace (Emrullah, 2014). Human capital theory shows how education promotes worker productivity and efficiency by growing the cognitive stock of economically valuable human capability, which is a product of intrinsic abilities and investment in humans. Formal education is seen as a beneficial investment in human capital, which the theory's proponents value as much as physical capital. Investment in human capital is reasonable for three reasons (Pasban and Nojedeh, 2016):

1. The new generation needs to leverage on the previous generations' wisdom.
2. The new generation should be taught how to apply current knowledge to generate new goods, processes, production methods, and social services.
3. People should be encouraged to develop new ideas, products, processes, and methods using creative approaches.

In the context of electric vehicle (EV) development, this theory can be applied by investing in the education and training of workers in the automotive industry to develop the skills necessary to design, manufacture, and service EV technology. This can include electrical engineering, battery technology, and software development training. Investing in research and development of EV technology can also help increase the industry's productivity and economic growth. This can include funding for EV-specific R&D projects and providing tax incentives for companies that invest in EV-related research and development.

5.2 Resource-Based Theory

The resource-based theory (RBT) implies that firms with valuable, scarce, difficult-to-imitate, and non-substitutable resources would succeed. These strategic resources can build a firm's capabilities for long-term success (Madhani, 2021). RBT illuminates and predicts organisational performance and competitive advantage. RBT focuses on an organisation's internal resources rather than external resources to predict their chances of success or failure (Holdford, 2018; Kozlenkova et al., 2014; Madhani, 2021).

RBT explains how firm-based resources build permanent competitive advantage and why some companies outperform others by becoming more competitive (Madhani, 2021). RBT bases its competitive advantage on a population of firms' resource and competency variability. The Heterogeneity of resources shows that a company with unique resources in a certain setting may perform better and obtain a competitive edge (Kozlenkova et al., 2014; Madhani, 2021).

Holdford (2018) states that internal resources and competencies influence a company's earning potential. Resources in RBT include assets, business processes, capabilities, the firm's attributes, knowledge, information, etc. (Barney et al., 2012). Companies can use these internal and external resources to obtain a competitive advantage. R&D, logistics, brand management, and low-cost procedures are internal resources. External resources include suppliers, customer demand, technology change, and suppliers (Kozlenkova et al., 2014)

Companies have physical, human, and organisational capital. Physical capital include equipment, plant, raw materials, location, and technology. Human capital includes managers' and workers' intelligence, training, judgment, relationships, and insights (Barney et al., 2012). A company's formal structure, informal systems, and planning, managing, and coordinating systems are organisational capital resources. Informal division and business environment relationships are organisational resources.

RBT categorisation of company resources uses physical and intangible assets. Tangible resources include objects and commodities. Intangible resources comprise a company's capabilities, expertise, and organisational, strategic, and societal benefits (Keränen and Jalkala, 2013). Usage of degradation, simultaneous use, and immateriality distinguish tangible and intangible resources. Business process know-how, employee abilities, and other intangible resources don't degrade, can be used by various managers, and are hard to switch. Material goods can be traded and degraded over time (Barney et al., 2011).

This theory can be applied to the development of electric vehicles (EVs) in the following ways:

1. Intellectual Property: A firm that has developed proprietary technology for EV batteries or charging systems can use this as a resource to gain a competitive advantage in the market. This can include patents, trademarks, and copyrights that protect the firm's intellectual property.
2. Human Capital: A firm with a skilled workforce with experience in designing and developing EVs can use this as a resource to create innovative products in high demand. This can include engineers, designers, and managers with expertise in EV technology.
3. Financial Resources: A firm that has access to significant financial resources can use this as a resource to invest in research and development, production, and marketing of EVs. This can include cash reserves, equity, and debt financing.
4. Brand Reputation: A firm with a strong brand reputation for producing high-quality EVs can use this as a resource to attract customers and increase sales. This can include customer loyalty, positive reviews, and industry awards.

By identifying and leveraging these resources and capabilities, a firm can gain a competitive advantage in the EV market and achieve long-term success.

5.3 Organisational Culture Theory

Organisational theory is the sociological study of social organisations like businesses and bureaucracies (Mwangeka, 2020). The organisational theory analyses organisational performance and employee and group behaviour (Robbins and Judge T. A, 2016). Some organisational theories include:

1. Classical theory: Classical theory covers a business's formal organisational structure. This theory examines how to divide professional tasks efficiently and effectively. Classical theorists focus on how professional dynamics and connections affect a company's function and productivity (Kates, 2018). This approach helps companies design the best structures to achieve their aims. Four classical theory principles include division of labour, scalar/functional processes, structure, and span of control (Duque, 2018).
2. Neo-classicism: The neo-classical approach has focused on emotional and psychological aspects of organisational behaviour and how leadership, morale, and cooperation affect professional behaviour. This theory states that professional success depends on a sense of belonging and social approval (Saravanakumar, 2019).

3. The modern organisational theory incorporates several management development methods. This theory covers organisation-environment interactions and intra-organisational interactions. This theory was developed using systems analysis and quantitative and behavioural sciences (Önday, 2016). This approach allows professional executives to use statistical and mathematical data to make commercial decisions while simultaneously considering employee pleasure and happiness. This strategy may require managers to understand employees' behaviours to build productivity and professional development initiatives (Önday, 2016).
4. Open systems or social practice theory holds that an organisation's environment affects it, and managers can improve their leadership by understanding this influence (Penuel et al., 2016). Theorists classify organisational environmental elements as specific or broad. A company's vendors, distributors, competitors, and government bodies that regulate production and regulation may be factors (Penuel et al., 2016).

5.4 Social Practice Theory

This theoretical framework focuses on social practices, or how people interact and engage with the world around them. It also considers how people shape and is shaped by the development of technology. In the context of electric vehicle (EV) development, SPT can be used to understand how societal norms, values, and practices influence the design, production, and adoption of EVs, as well as how the widespread use of EVs may, in turn, change those same social practices.

SPT can be used to examine how cultural beliefs about the environment and sustainability shape the development and marketing of EVs as "green" and "clean" transportation options. Additionally, it can be used to examine how the infrastructure and policies needed to support EV use (such as charging stations and tax incentives) are developed and implemented in different regions and communities.

It can also be used to investigate how integrating electric vehicles into transportation systems shapes people's daily transportation practices, mobility, and energy consumption. Overall, SPT can provide valuable insights into the complex social and cultural factors that influence the development and adoption of EVs and can help to inform strategies for promoting and supporting the widespread use of these vehicles.

5.5 Curriculum Development Theory

Curriculum theory is one of the least-known ideas within the curriculum field, although it essentially entails analysing the learning environment (Coşkun Yaşar and Aslan, 2021). Miller (2010) posits that curriculum theory is a set of concepts that give meaning to a school's curriculum. Akubuilo et al., (2019) define curriculum theory as a collection of analyses, interpretations, and comprehensions of curriculum phenomena. The Encyclopedia of Curriculum Studies defines curriculum theory as an interdisciplinary curriculum study that examines the curriculum in its historical, sexist, political, racial, international, postmodern, autobiographical, and religious components (Behar-Horenstein, 2010). The curriculum is the educational constitution that guides an education system and moulds the individuals to be raised in society. Curriculum decisions provide crucial indicators influencing the entire teaching and learning process.

The four dimensions of curriculum theory are goals or objectives, subject matter or content, methods or processes, and evaluation or assessment. The first dimension speaks to the rationale behind the inclusion of certain subjects and the exclusion of others. The arguments for curricular inclusion can be roughly categorised into four categories: logical delineations between fields of knowledge, different mental or cognitive activities, cross-cultural social distinctions, and deliberation about the ideal society (Coşkun Yaşar and Aslan, 2021). The second dimension is content or subject matter, which refers to the implicit knowledge, skills, or dispositions in selecting things and their arrangement. The degree of integration between distinct pieces of knowledge and advancement within the domain are the two most essential forms of relationships between different types of knowledge (Coşkun Yaşar and Aslan, 2021). Curriculum theorists have also focused on the expression of these goals and objectives. The three paradigms proposed are curriculum as a product, curriculum as a process, and curriculum as content. Methods or processes constitute the third dimension, which refers to pedagogy and is governed by the choices made regarding the first two dimensions. Pedagogy is defined as the mode of curriculum delivery. It includes imitation, Didacticism, inter-subjective dialogue, and apprenticeship (Coşkun Yaşar and Aslan, 2021). The fourth dimension, assessment or evaluation, relates to determining whether the curriculum has been successfully applied (Coşkun Yaşar and Aslan, 2021).

Curriculum development for electric vehicle (EV) development can utilise a variety of theories depending on the program's specific focus. Some examples include:

1. Constructivism theory emphasises the learner's active role in constructing knowledge

through experiences and interactions with the environment, which could be applied to hands-on EV design and development projects.

2. Systems thinking theory, which focuses on the interrelationships and interdependencies of components within a system, could teach students about the various systems within an EV and how they work together.
3. Adult learning theory, which recognises that adults have a wealth of life experiences and knowledge to bring to the learning process, could be used to create an EV curriculum that is relevant and applicable to working professionals in the industry.
4. Active learning theory, which emphasises the importance of student engagement and participation in the learning process, could be applied through group projects, case studies, and other interactive learning activities related to EV development.
5. Problem-based learning theory, which centres on real-world problems and challenges, could be used to design an EV curriculum that addresses current issues in the industry and prepares students to problem-solve in the field.

6.0 Competency and Skill Development

6.1 Overview of Competency

Spencer and Spencer (1993) defined competency as "*an underlying characteristic of an individual that is casually related to criterion–referenced effective and/ or superior performance in a job or a situation"*. In the views of Wong (2020), competencies are a predictor of job performance superiority in business organisations. The term competency gained popularity in the work of McClelland (1973) when he suggested that it is more beneficial for organisations to test for competency than intelligence. This is due to the encompassing trait and characteristics of the former, which includes not just cognitive skill and knowledge but personality variables such as interpersonal skills, leadership, communication skills, and goal–setting ability, among others. This was further bolstered by the Job Competence Assessment (JCA) technique of Boyatiz (1982), where he opined that competencies differentiate top performers from average performers. To Devos et al., (2015), competency is the gap between theory and practice.

Furthermore, the acceptance of the uniqueness of competency/ competence has led to several scholarly definitions. Page and Wilson (1994) defined competencies as the abilities, skills, and personal characteristics that are needed as a superior or successful manager, encompassing both implicit competencies (personal attributes) and explicit competencies (knowledge and skills). Parry (1996) viewed competencies as a "*set of interrelated knowledge, skills, and attributes that represent a key component of a person's job role and responsibility that associates with performance in a job, that can be measured against well–established standards, and that can be reinforced through training and development*". Athey and Orth (1999) opined that competencies are "*a set of observable performance dimensions, including individual knowledge, skills, attitudes and behaviours, as well as collective team process and organisational capabilities, which are linked to high performance, and provide the organisation with sustainable competitive advantage*". Draganidis and Mentzas (2006) averred that competencies are direct and indirect behaviours and skills that invigorate an individual to perform given tasks and achieve goals. Chung and Lo (2007) posit that competencies are knowledge, skills and capabilities that should be embedded in individuals in completing tasks, roles and goals assigned to them. Wong (2020) further espoused the concept of competency as a set of measurable and observable success factors and attributes that a person needs to complete a task, which includes skills, knowledge, personal traits, concept and values, and motives. Competencies measure one's capability to perform a task in line with worldwide standards. It is the ability to deliver specific tasks irrespective of geographical location or organisational setting. In the context of electric vehicle development, Competence is a functional combination of transferable skill set, value-driven personality traits, knowledge base, social attributes, and technological attributes in the performance of tasks irrespective of the resources for production, organisational culture, and managerial style.

Competency is not something anyone or any setting can take away from an individual. The individual capability to deliver is not subject to this environmental nature ceteris paribus; resources for production or performance are available.

Consequently, there are different perspectives on 'competence' and 'competency', as opined in the research of Wong (2020), Moore, Cheng and Dainty (2002), and Moghabghab, et al., (2018). According to Moghabghab, et al., (2018), competency and competence are used interchangeably in describing the capacity to do something effectively. The authors opined that competency is "*an important skill that is needed to do a job*", while competence is "*the ability to do something well*". The authors further did a concept analysis of different definitions, whereby competency is "*a component of knowledge, skill, and/or judgment, demonstrated by an individual, for safe, ethical and effective practice*". *At the same time,* competence is "*an individual capability for consistently integrating the required knowledge, skill, and judgment for safe, ethical and effective practice*".

Also, Armstrong (1998) stated that competence describes what an individual needs to possess for optimal job performance, while competency refers to the behavioural dimensions behind the competent performance. Moore et al., (2002) describe the distinction as follows: competence – an area of work; competency – the behaviours supporting an area of work; and competencies – the attributes underpinning a behaviour. In the research of Wong (2020), competency and competence are two distinctive approaches. Competency is a person-oriented behavioural approach, while Competence is a task-oriented functional approach. Burgoyne (1988), utilising both synonymous words, stated that "*being competent"* is achieving the demands of a job or a role while "*having competencies"*. Yuvaraj (2011) gave a set of distinctive differences between Competency and Competence, as shown in Table 3, which justified the earlier reviewed definitions.

Table 3: Difference between Competence and Competency

S/N	Competence	Competency
1.	Focus on the results	Focus on a person's behaviour
2.	Describe the features of the area of work tasks or job output.	Describe the attributes of the person.
3.	Constitutes the various skills and knowledge needed for performing the job.	Constitute the underlying attributes of a person for superior work performance.
4.	Assessed by performance on the job	Assessed in terms of behaviours and attitude
5.	Tasks oriented	People-oriented
6.	Not transferable skill and knowledge; it is more specific to performing the job.	Transferable from one person to another.

6.2 Dimensions of Competence

The concept of competencies operates in various forms, dimensions and magnitudes. Kuijpers (2003) and De Vos et al., (2011) postulated that three important types of competencies are used in executing and performing a task. The first is functional competencies, which entail the knowledge and skills necessary for a job's successful performance based on the roles and tasks assigned to the employee. The second is learning competencies based on the knowledge economy, which is the characteristics of an individual to develop new functional competencies. The third one is the career competencies, which are the traits of an employee in plotting a career path whilst leveraging their learning and functional competency. This report focuses on building these competencies for TVET students to possess the electric vehicle industry competencies.

Different types, components, and dimensions of competencies are detailed in the literature (Wong, 2020). According to Katz and Kahn (1966), they include functional and technical competencies, human competencies, managerial competencies, and conceptual competencies. To Boyatzis (2008), dimensions of competencies include emotional, cognitive, and social intelligence competencies. According to Carroll and Mc Cracking (1997), types of competencies are functional, core, and leadership/ managerial competencies. Ellstrom (1997) proposes cognitive factors, perceptual motor skills, affective factors, social skills, and personality traits. Prahalad and Hamel (1990) posit that competencies dimensions include individual–based competencies, organisation–based competencies, behavioural competencies, and technical competencies. According to Le Deist and Winterton (2005), the dimensions of competencies include social, Meta, functional, and personal. Also, Cheetam and Chivers (1998) posit that cognitive competencies, functional competencies, ethical/ values competencies, personal competencies and Meta competencies are dimensions of competencies.

6.3 Development of Competency

In developing competency, irrespective of their types or dimensions, a pathway has to be followed whereby an individual can understand the process, skills, and steps needed to acquire competencies. Competency development is "*an important feature of competency management which encompasses all activities carried out by the organisation and the employee to maintain or enhance the employee's functional, learning and career competencies"* (Forrier, Sels and Styren, 2009), De vos, et al., 2011). However, Heinsman, et al., (2006) describe Competency management as "*an important human resource tool that is often used within an organisation to guide human resource practices such as selection, assessment, career management, employee development, and performance appraisal"*. Furthermore, De vos et al., (2011) opined that competency development emanates from the human resource practices of training, on–the–job learning, and career management. Thus, competency development stems from a conscious effort to create opportunities for engaging and exploiting knowledge in practice and theory conceptualised in various human resource practices. It is also a deliberate effort to invest in the absorptive capacity of an individual. Moreover, Ellstrom and Kock (2008) posit that competency development can be achieved through the education and training of talents.

De vos et al., (2015) developed an integrative competency development model, shown in Figure 2. According to the model, competency development entails training, on–the–job learning and career management, which is subjected to self-directed employee behaviour, then competency assessment, which enables an individual's eligibility for employability. Also, Parry (1996) proposed twelve (12) guideline for competency development, which includes:

- Focus on broad and generic competencies.
- Group similar competencies under broad headings.
- Avoid focusing on entry-level competencies.
- Indicate the observable and measurable behaviours.
- Provide behavioural examples.
- Use simple language.
- Keep it short.
- Carefully define each competency to avoid confusion.
- Focus on future needs.
- Identify the desired outcome first.
- Define and describe levels of excellent performance.
- Exclude personal traits.

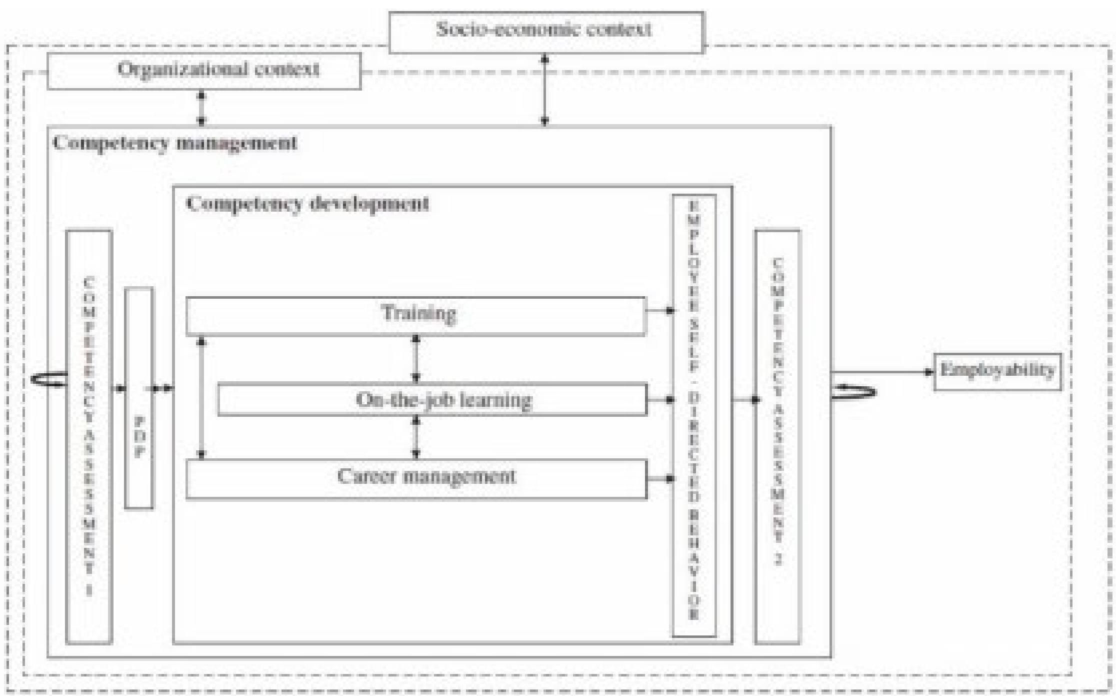

Figure 2: Competency Development Steps (De vos et al., 2011)

Moreover, Boyatiz (1982) proposed the Job Competence Assessment Technique (JCA) to develop a set of competencies needed by an employee in the performance of their jobs. The technique is outlined in Table 4. The technique begins by measuring job performance requirements, conducting a job analysis, conducting a behavioural interview, amalgamating the preceding steps, and then developing the model. JCA builds on the Behavioural Interview Technique developed by McClean (1998), which analyses an individual's characteristics that enable them to perform effectively in a specific job position and role.

Table 4: Job Competency Assessment (JCA) Technique

1.	Identify criterion measures.	• Select a suitable measure of work performance. • Collect data on managers.	• Job performance data on managers.
2.	Analyse Job elements.	• Create a list of attributes perceived to contribute to effective work performance. • Obtain item rating by managers. • Compute a weighted list of attributes. • Analyse categories of attributes.	• A weighted list of attributes perceived by managers that relate to effective work performance. • A list of the categories in which these attributes can be grouped.
3.	Conduct BEI	• Conduct BEIs • Code Interviews for attributes or develop the code and then code the interviews. • Associate the coding with data obtained from work performance.	• A list of attributes hypothesised to differentiate from effective to less effective work performance. • A list of validated attributes or competencies.
4.	Select tests and measures	• Assess competencies identified in the prior two steps relevant to work performance using suitable tests and measures. • Perform tests and measures and cure them. • Relate scores to job performance data.	• A list of validated attributes, or competencies, as assessed by these tests and measures.
5.	Develop and validate the competency model.	• Integrate result from prior three steps. • Determine and document causal relationships among the competencies and job performance from statistical and theoretical perspectives.	• A final validated competency model.

Table 2 is similar to Spencer and Spencer's classic competency study approach (1993), which includes six (6) steps. They are: define performance effectiveness criteria (hand outcome measures, supervisor nominations, peer rating, and customer ratings); identify a criterion sample (top performers, poor performers); collect data (observations, BEIs, panels, and surveys); Analyse data and develop a competency model (job tasks and competency requirements); validate the competency model (Identify second criterion sample, BEIs, tests, and ratings); Prepare applications of the competency model (selection, training, professional development, performance appraisal, and evaluation).

Campion et al., (2011) posit the need for job analysis as a mechanism for competency development. They refer to job analysis as the technique that differentiates average and top performers. The authors posited that job analysis entails – "*the use of multiple data collection methods such as observations, SME (subject matter expert) interviews, and structured brainstorming methods in focus groups to identify potential competency information, the use of clear construct definitions in the competencies, and linkage to theory and literature; the use of survey methodology to empirically identify the critical competencies and to differentiate the job grades where specific competencies, emerge as most important, the use of sampling techniques; the use of appropriate statistical analysis; the assessment of reliability and other psychometric quality checks; the validation of models across sources of information of job groups".* This report integrated these various procedures for competency development, classifying them into qualitative and quantitative methods.

6.4 Skills Development

The various definitions, descriptions, and perspectives on competency have a common denominator and factor: skill. Competency is the advanced utilisation and mastery of a particular skill or combination of skills. This is needed more than ever due to the enormous changes expected across industries and organisations, often stemming from significant technological advances (the automotive industry inclusive). According to Abdel – Wahab et al., (2007) and Payne (1999), skills encompass writing, reading, communication, reliability, reasoning, motivation to assertiveness, problem-solving, leadership, judgment, customer orientation, teamwork, continuous learning, and self–management. Furthermore, Knapp (1963) and Zhang (2019) defined skills as "*the learning ability to bring about pre–determined results with maximum certainty often with the minimum outlay of time or energy or both".* Breivik (2016) posits that skill entails the level of expertise possessed by an individual as a result of experience and training. According to OECD (2019), skills are the ability and capacity to utilise one's knowledge for optimal performance, as it is a holistic concept of competency.

Consequently, skills vary according to individuals, organisations, and industries giving occasion to different types and categories of skills. OECD (2018) categorises skills into three types. The first type of skill is the cognitive and metacognitive skill, which includes creative thinking, critical thinking, self-regulation, and learning–to–learn skill. The second category includes social and emotional skill, which includes self–efficacy, empathy, collaboration, and responsibility. The third category is practical and physical skills, which entails the utilisation of communication technology devices and using new information.

Sida (2018) also divided different skills into four layers of skills, which are basic and foundational skills, transferable skills, technical and vocational skills; and professional and personal skills. Basic and foundational skills include oral expression, active learning, ICT literacy, reading comprehension, and active listening, all acquired through formal and informal learning processes. Transferable skills ensure easy adaptation to different work environments, including adapting and learning, effectively communicating ideas, and self-management of critical thinking. Technical and vocational skills are specialised knowledge and know–how in performing specific tasks and duties. Profession and personal skills ensure an individual carries out a job effectively, including integrity, honesty, work ethic, reliability, and judgment.

Furthermore, the world is currently experiencing the fourth industrial revolution, thus necessitating the development of relevant skills to thrive. According to the World Economic Forum (2016) and Gray (2016), the top ten (10) skills needed to thrive in the fourth industrial revolution by 2025 includes analytical thinking and innovation, complex problem solving, active learning and learning strategies, creativity, originality and initiative, critical thinking and analysis, technology design and programming, reasoning and problem solving, technology use, monitoring and control; and resilience, stress tolerance and flexibility. Li (2022) opined that new kinds of expertise are required with the advent of the fourth industrial revolution and the birthing of seven (7) key disruptive technologies. These technologies include Artificial intelligence and machine learning, 5G and 6G, Quantum computing, the Internet of things (IoT) and Industrial Internet of things (IIoT), Data Science and Business intelligence, Green energy and Cyber security. These technologies will displace 85 million jobs and create 97 million new jobs by 2025 (Schwab and Zahidi, 2020).

In light of these advances, skills development is an integral part of ensuring competence, especially for the electric vehicle industry, which is an interdisciplinary industry. According to Sida (2018), skill development " refers *to the productive capabilities acquired through all levels of learning and training, occurring in formal, non–formal, informal and on–the–job settings. It enables individuals to become fully and productively engaged in livelihoods, and to have the opportunity to adapt these capabilities to meet the changing demands and opportunities of economy and labour market".* Wahab, Rejendran and Yeap (2021), CEDEFOP (2020), and Muchiri (2022) opined that skill development involves skilling, upskilling, and reskilling. Wahab et al., (2021) utilize the Cambridge dictionary definition, where reskilling is defined as the procedure where an individual learns a new skill to do a different job, whilst upskilling is the procedure whereby an individual learns a new skill to perform a job better. Wahab et al., (2021) further opined that upskilling and reskilling will: enhance optimal industry performance, ensure customer satisfaction, increase flexibility and agility during changes in the industry, maintain sustainability in an organization, minimize the cost of hiring, enhance the experience of employees, encourage loyalty among staff, ensures a gateway for more opportunities, increases the competitiveness of employees and ensure long term cost-effectiveness. Muchiri (2022) posits that skilling is the continuous acquisition of new skills; reskilling entails learning new skills for a new position; upskilling is learning current skills more deeply. Li (2022) averred that upskilling is the mechanism by which employees add new skills to help with the responsibility of their current job, while reskilling focuses on how employees need skill and knowledge to perform a new job entirely. Li avers that upskilling and reskilling are achieved via college education, degree programs, online programs, non–degree programs, employer-sponsored on–the–job training, conference, seminars and webinars, self–study, and certificates offered by a professional organization.

There are other skills development mechanisms, excluding upskilling and reskilling. A veritable skill development mechanism is analysing skill gaps, skill shortages, and skill mismatches (World Bank, 2015). McGuinness and Ortiz (2015) opined that a skill gap is a phenomenon that identifies the insufficiency of skills between what an employee currently possesses and what is required in the performance of their jobs. CEDEFOP (2012) defined skill mismatch as the deficit or excess of skills or qualifications obtained by individuals in relation to their current jobs. Cappelli (2015) viewed a skills gap as a situation where there is a shortfall of expected skills in employees for future jobs, while a skill shortage entails the shortfall of a particular skill in the industry. Skills mismatch is when skill supply and demand are out of synchronization. Donovan et al., (2022) of the US Congressional Research Service defined skill gap, skill mismatch and skill shortages thusly: Skill match is "*an imbalance – an oversupply or undersupply, between the types or level of skills available and labour market*". Skill gap, according to the authors, "*is a shortfall in the aggregate supply of a certain skill or set of skills broadly sought by employers*". Skill shortage "*is the shortfall in the supply of specific skills associated with particular occupations*". Therefore, in developing a competence framework for the Electric vehicle industry in South Africa, the skill gap was analyzed for TVET students to ascertain the level of skills and knowledge required by the industry.

7.0 Bibliometric Analysis of Competency in the Electric Vehicle Industry

Developing a competency framework for electric vehicle production and maintenance is a unique endeavour of interest to industry, government, students and academics. Therefore, there is a need to identify relevant research patterns, research threads, research focus, countries, and documents around competence development for the electric vehicle industry. According to David et al., (2022), these objectives can be achieved by conducting a Bibliometric analysis of relevant databases. In this instance, Vosviewer software is utilized for the bibliometric analysis. The Vosviewer software is a literature review technology that offers extensive functionality to visualize bibliometric networks (David et al., 2022). Scopus database was used for the analysis due to its significance as the most frequently used database by most researchers, with comprehensive coverage compared to other databases (Aighimien et al., 2019). The document type extracted from the Scopus database included published journal articles, books and book chapters, and conference proceedings.

The keywords were "Electric Vehicle" and "Competence" at the Scopus search stage**.** Therefore, publications with these search words in their title, abstracts and keywords were extracted. The search data for this extraction cut across all times, since the Scopus database began or since the first publication of the search words. The Scopus database's initial search includes eighty–five (85) documents across all fields. Thereafter, the search was refined, and the results were limited to the English Language; Medicine and pharmacology, toxicology and pharmaceutical publication are excluded. The remaining publication fields are engineering, energy, computer science, social science, environmental science, business management and accounting, chemical engineering, decision science, economics, econometrics and finance, mathematics, physics and astronomy, material science, biochemistry, genetics and molecular biology, agricultural and biological science, chemistry, and earth and planetary. This reduced the documents to eighty (80) documents extracted from the Scopus database.

7.1 Documents publication date and Authors' details

According to the Scopus analysis of the eighty (80) documents on Competence in electric vehicle production, the first publication was in 2002, with 2022 recording the highest number of publications with seventeen (17) publications. This is shown in Figure 3. Furthermore, using the Vosviewer software, we determine that of the 198 authors who have publications related to "competence" and "electric vehicles", only nine (9) authors have published at least two (2) papers. This is shown in Table 5, along with the authors' citations and total strengths. Figure 4 further shows the research period by the strongest authorship link. These Figures and Tables show a need for more publications on competency for the production of electric vehicles. It also justifies this report's objective to develop a competency framework for electric vehicles.

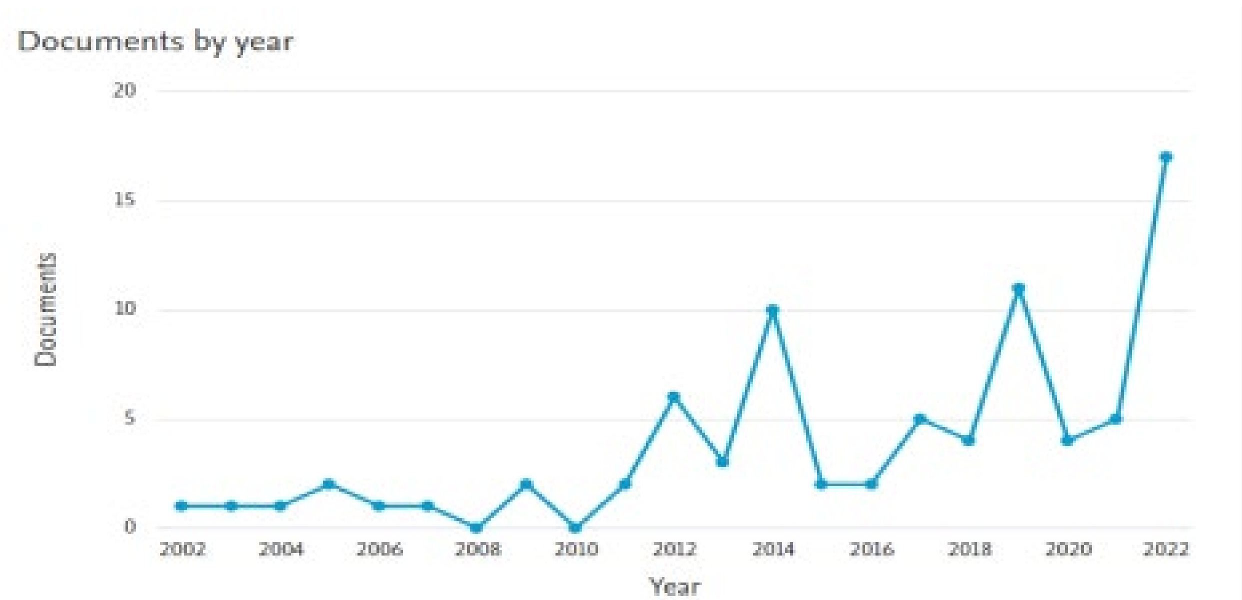

Figure 3: EV and Competence document publications date

Table 5: Authors' Publication details

Authors	No. of Documents	No. of Citations	Total Link strength
Kampker, A.,	7	20	13
Nee, C.,	6	20	12

Burggraf. P.,	5	4	9
Burggraf, P.,	2	16	4
Wang, L.,	2	10	2
Wells, P.,	2	10	2
Frohlich, D.,	2	0	0
Panda, S.,	2	5	0
Wang, Z.,	2	5	0

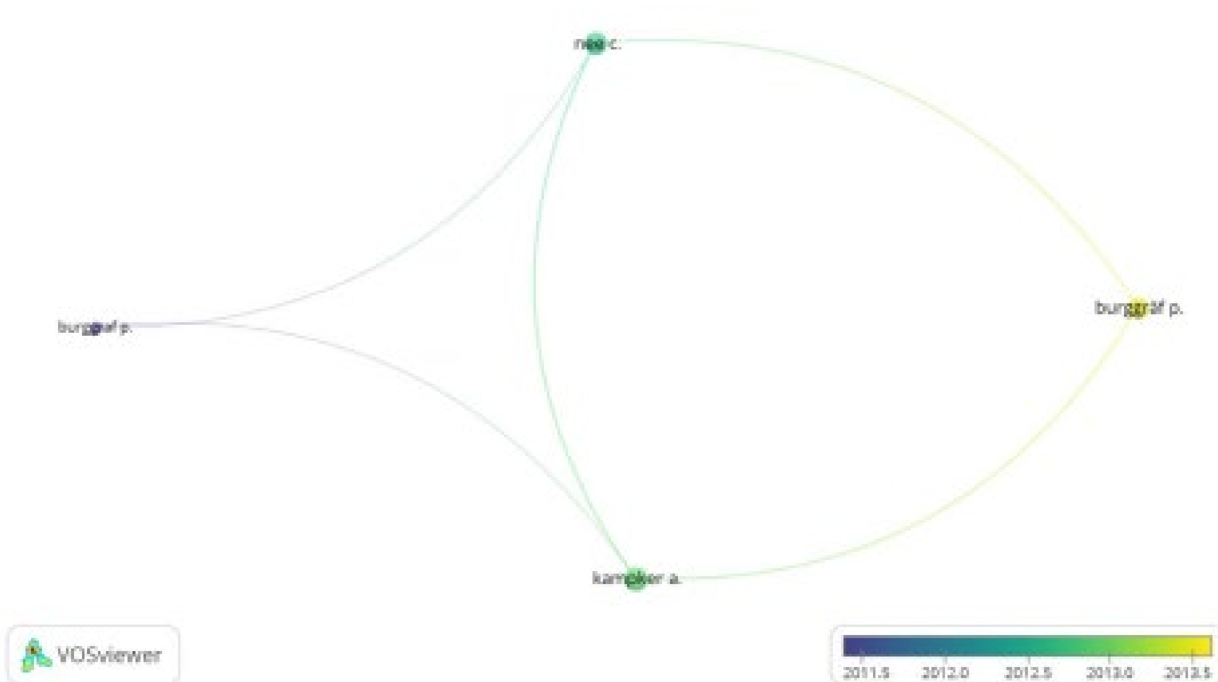

Figure 4: Authors' publication period

7.2 Geographical analysis of publications

Figure 5 shows the publication on Competence in the electric vehicle per country. It shows that the top ten (10) countries publishing on the subject matter are: the United States (15 documents), Germany (14 documents), India (8 documents), the United Kingdom (7 documents), Canada (5 documents), Brazil (3 documents), China (3 documents), Austria (2 documents), Italy (2 documents), and Netherland (2 documents). Others are Pakistan (2 documents), Russian Federation (2 documents), Belgium (1 document), Colombia (1 document), Denmark (1), Ethiopia (1 document), France (1 document), Iran (1 document), Iraq (1 document), Japan (1 document), Malaysia (1 document), Mexico (1 document), New Zealand (1 document), Norway (1 document), Portugal (1 document), Saudi Arabia (1 document), Singapore (1 document), South Korea (1 document), Turkey (1 document) and undefined countries (17 documents). These publications per country show no publication in Southern Africa, just one (1) publication in Ethiopia on competency and electric vehicles. This gap gives huge credibility to the competency framework developed for South Africa, which can provide a skeletal framework for other countries in the Southern Africa region and the whole of Africa. Moreover, using the Vosviewer software, there are thirty–one (31) countries with at least one (1) document on competency for the production of an electric vehicle, with only one document for the whole of Africa (shown in Figure 6). Table 6 shows twelve (12) countries with at least two documents in our domain of interest.

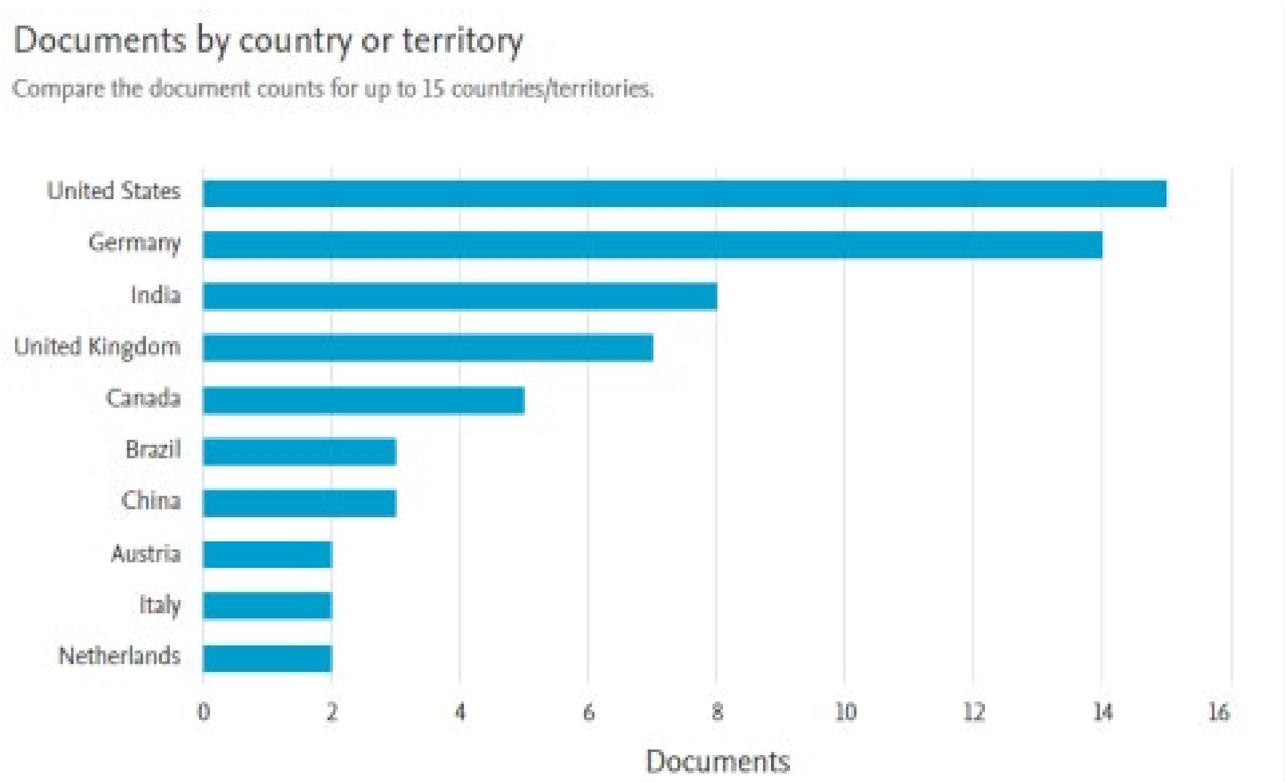

Figure 5: Top ten countries with publications on Competence and electric vehicles

Figure 6: Countries that have publications on competence and the electric vehicle

Table 6: Publication details of countries with at least two publication

Country	No. of Documents	No. of Citations
China	3	64
Pakistan	2	55
Austria	2	0
Brazil	3	10
Canada	5	12
Germany	14	27
India	8	31
Italy	2	6
Netherland	2	0

Russian Federation	2	0
United Kingdom	7	58
United States	15	56

7.3 Research Clusters Analysis

To identify the research clusters in the competence development and electric vehicle nexus, the Vosviewer was utilized to map out the keywords co-occurrence. The co–occurrence visualization map is shown in Figure 7, depicting four (4) clusters with “electric vehicle” as the most linked keyword. A review of the keywords in Figure 7 shows that the concept of competence has not been entrenched in the electric vehicle industry. It further depicts the need for a competency framework in the electric vehicle industry. This report will be the first on the Competence framework for electric vehicle production. Also, Figure 7 shows that for the electric vehicle industry, competency development should focus on the industry's technological, technical and system engineering aspects, which this report has considered.

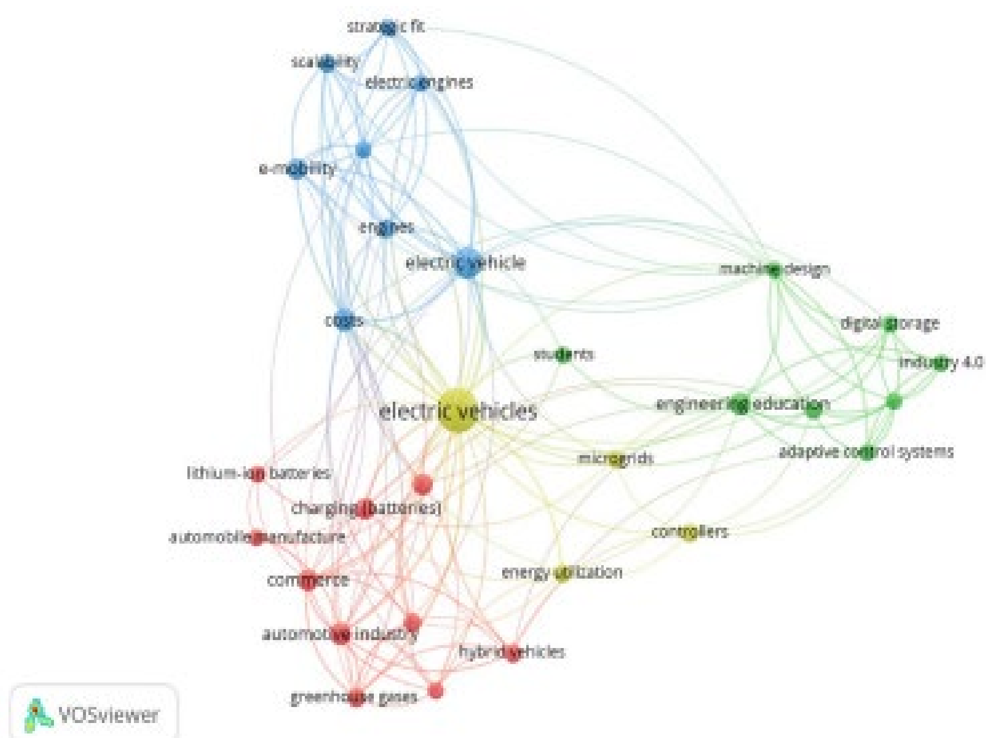

Figure 7: Keywords co-occurrence

The identified research clusters based on the keyword co-occurrence analysis is detailed below:

Cluster 1: Battery Technology

The first cluster in Figure 7 are the keywords with red colour, which are ten (10) in number. They include automobile manufacturing, the automotive industry, charging batteries, commerce, gas emissions, greenhouse gases, hybrid vehicles, life cycle, lithium–ion batteries, and vehicles. These keyword shows that battery technology is the common thing related to them, depicting that in building competence in the electric vehicle industry, competence must be centred on battery technology for the car.

This cluster is important, and the papers in this cluster highlight that, over the years, efforts have been concentrated on developing newer and optimal battery energy technologies. Arnoldi (2022) opined that South Africa could leverage the Lithium deposits in other Southern African countries for the production of Lithium–ion batteries and other batteries for electric vehicles. Therefore, building competence around this technology will be a goldmine for the Republic of South Africa and the Southern region.

Cluster 2: System Engineering Education

The second cluster has eight (8) items, as shown in the green colour of Figure 7, which includes these keywords: adaptive control systems, digital storage, electric power system control, embedded systems, engineering education, industry 4.0, machine design, and students. These keywords are centralized around system engineering education, which focuses on understanding the internal mechanism of an electric vehicle. Hence, the competency framework for the electric vehicle should have an aspect that deals with system engineering. This conforms to the research of Swart (2016) on the essence of system engineering for electric vehicle production in South Africa. Also, one of the keywords in this cluster is industry 4.0, which depicts the inevitability of the technologies of the fourth industrial revolution on electric vehicle production.

Cluster 3: Digital Mobility

This cluster in colour blue encompasses eight (8) items: costs, e – mobilities, e – mobility, electric engines, electric vehicle, engines, scalability, and strategic fit. All these keywords depict digital mobility, which is concerned with optimizing the managerial aspect of electric vehicle production in terms of its ecosystem with digital technology. According to Cubic Transportation system (2021), Digital mobility is "*the digitalization and integration of mobility management and operation systems to achieve policy goals and an optimized network for smoother, faster and more sustainable transport*".

Cluster 4: Energy system for Electric Vehicles

The fourth cluster contains four (4) keywords: controllers, electric vehicles, energy utilization, and microgrids, which depict the energy system for electric vehicles. Thus, a competency framework in the electric vehicle industry should focus on combining the complexities and nature of energy systems in the production, operations, and maintenance of electric vehicles. This shows the need to understand the charging infrastructure to ensure the electric vehicle's smooth adoption and operation.

7.4 Research Cluster Time Variation Analysis

Figure 8 shows the overlay visualization of the publication thread for the subject matter, beginning from 2014 to 2022. This enables us to see how the keywords (and the research clusters) have varied over the years. In 2014 the keywords were hybrid vehicles, automotive industry, commerce, automobile manufacturing, engines, e – mobility, scalability, electric engines, and strategic fit. However, recent publications as of 2022 have the following keywords: digital storage, industry 4.0, embedded systems, adaptive control systems, controllers, Lithium–ion batteries, charging batteries, and microgrids.

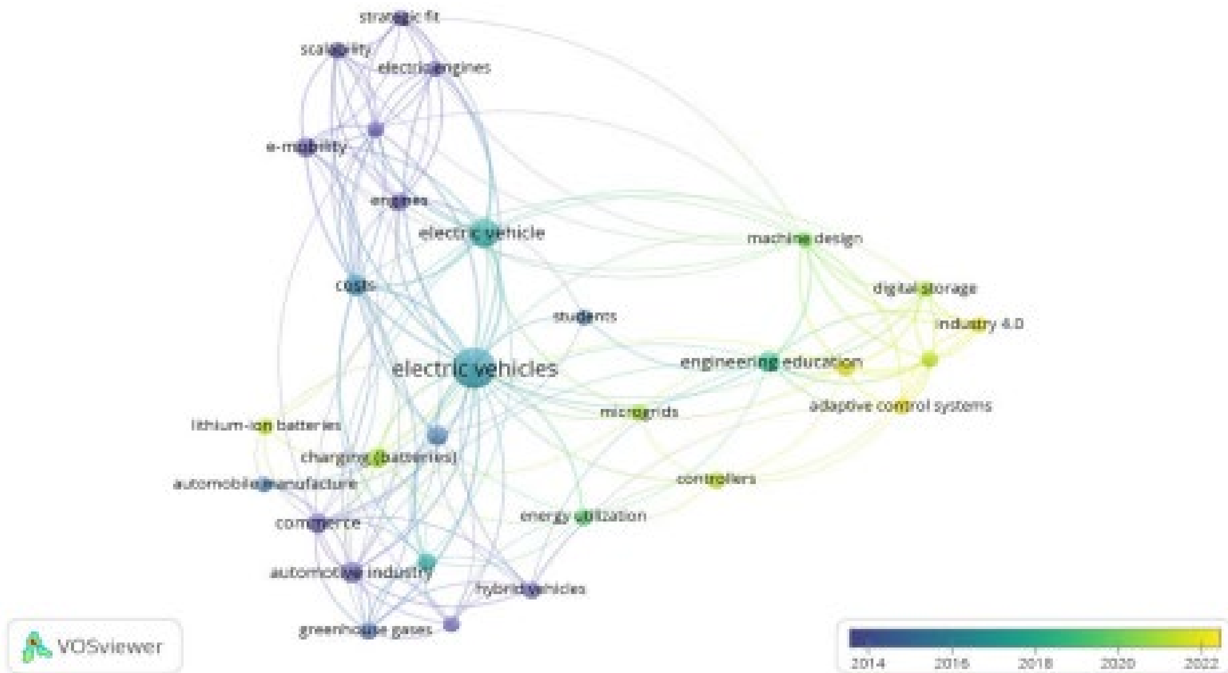

Figure 8: Time Variation of the Research Clusters

8.0 Related Competency Frameworks for Electric Vehicles

In developing a competency framework for producing and operating an electric vehicle, there is a need for an overview of existing related frameworks. Ten related frameworks are chosen and analyzed in detail in this subsection. Table 7 details the related frameworks with a brief description after that.

Table 7: Related Competency Frameworks

S/N	Frameworks/ Models	Constructs	Organisation/ Country	Authors
1.	National Electrification Skills Framework	✚ Supply chain & Logistics ✚ Circular Economy & Sustainability ✚ Technology Development & Deployment ✚ Battery Management ✚ Power Electronics, Motor & Drive ✚ Electrification	✓ Catapult ✓ University of Warwick ✓ The Faraday Institution (United Kingdom)	Howard, et al., (2021)

2.	In – demand Automotive Manufacturing Competence	▪ Personal Effectiveness Competencies ▪ Academic Competences ▪ Workplace competencies ▪ Industry-wide Technical Competencies ▪ Industry – section Technical Competencies	✓ High Gear (South Africa)	High Gear (2020)
3.	Conceptual Key Competency Model for Smart Factories	✚ Openness to Learning ✚ Flexibility/ Adaptation to change ✚ Technical Literacy ✚ ICT Literacy ✚ Innovation & Creativity ✚ Soft skills	Journal Publication	Jerman, et al., (2020)
4.	Holistic Competence Model	▪ Cognitive Competence ▪ Meta Competence ▪ Functional Competence ▪ Social Competence	Journal Publication	Le Deist & Winterton (2005)
5.	Competence–in–use Framework	✓ Formal Competence ✓ Actual Competence ✓ Officially demanded Competence ✓ Competence required by Job	Journal Publication	Ellstrom (1998)
6.	Competence Framework for Bridging Skill gap in the European Li-ion Battery Industry	✚ Cognitive Competence ✚ Functional Competence ✚ Method and Process Competence ✚ Meta Competence ✚ Social Competence	KTH Royal Institute of Technology	Zahiraldinni (2000)
7.	APICS Supply Chain Manager Competency Model	▪ Personal Effectiveness competence	The Association for Operation	APICS (2009)

		▪ Academic Competences ▪ Workplace & Leadership Competencies ▪ Operation Management Knowledge areas and technical competences ▪ Supply chain manager knowledge areas and technical competencies. ▪ Association membership & certification	Management (USA)	
8.	Behavioural Competency Framework for supply chain team leaders	✓ Positivity ✓ Concern for standards ✓ Custom service focus ✓ Collaboration & Teamwork ✓ Motivating & Inspiring team ✓ Holding team to account ✓ Developing the team ✓ Reasoning	Co-Op Logistics	Co-op Logistics (2009)
9.	System Engineering Competency Frameworks	▪ System thinking ▪ Holistic lifecycle view ▪ System Engineering Management	UK International Council on System Engineering (INCOSE)	INCOSE (2015)
10.	Regional Model Competency Standards for Manufacturing Industry	✦ Basic Manufacturing process ✦ Casting & Moulding ✦ Machine Operation & Component Assembly ✦ Fabrication & Finishing ✦ Equipment Services & Maintenance	International Labour Organization	International Labour Organization (2007)

8.1 National Electrification Skills Framework

The objective of this framework was to prepare UK workers for the green industrial revolution in energy and transportation. It is a systematic framework that is in stages. The first stage of competencies and skills entails supply chain and logistics, circular economy and sustainability, and technology development and deployment. This is metamorphosed into the second stage, which includes: battery management, power electronics, motors and drive, and electrification. These two stages lead to curriculum development in terms of curating new skills via education and training and catalyzing upskilling and reskilling via industry/ employers. This is shown in Figure 9.

Figure 9: National Electrification Skills Framework (Howard et al., 2021)

8.2 In-Demand Automotive Manufacturing Competencies

This is a framework developed by the collaboration of the National Association of Automotive Component and Allied Manufacturers (NAACAM), the Department of Higher Education and Training and High to identify competencies that are demanded from TVET graduates to make sure students are consuming what the industry needs. The report was done using surveys, virtual workshops and interviews across thirty-six (36) firms. The report generated five prioritized industry competencies for TVET graduates: sector-specific technical, industry-wide technical, effective work habits, and academic and personal effectiveness. The personal effectiveness competencies entails: interpersonal skills (which is the ability to work effectively with others and a team in terms of acting professionally, empathy and sensitivity, listening and maintaining open relationship); professional conduct and ethics (this is displaying and accepting work behaviour and social norms); emotional intelligence (application of the concept of emotional intelligence to oneself and team in terms of self-awareness, self - management, trustworthiness, conscientiousness, adaptability, achievement orientation and Initiative); Lifelong learning (ability to learn and apply new skills and knowledge); and Leadership (ability to display leadership within a team). The second category of competencies is the academic competencies, which comprises of: communication (both visual and verbal communication), reading, locating and using information, writing, science, technology, engineering, and math (STEM), critical and analytical thinking, information technology fundamentals (general computer knowledge, hardware, software, common IT application use, and Cybersafety). The third tier of competencies is the workplace competencies, which comprises of: business fundamentals (situation awareness, business ethics, and market knowledge), teamwork (team roles, productive relationships, team objectives, resolving conflicts); customer focus (understanding customer needs, personalized service, acting professionally, and keeping customers informed); Scheduling and coordinating (ability to plan and prioritize work to manage time effectively to accomplish tasks); creative thinking and problem solving skills; Checking, examining, and recording (this entails entering, transcribing, storing, recording and maintaining information in written or digital format); working with tools and Technology; Health, safety and environment (for a safe and healthy workplace); and change management and Coaching. The fourth competencies is the industry - wide technical competencies, which include manufacturing process design/ development (critical work functions, technical drawings and schematics, engineering concepts, technological applications, design lifecycle and concepts, development lifecycle - commissioning, testing/ troubleshooting, research and development, workflow assessment); operation management (production materials, manufacturing process applications and operations, industrial process, industrial productions, manufacturing types, production/ process monitoring, industry - wide standards, project management and execution, organizational design and management); maintenance, installation and repair (general asset management skills, machining skills, and engineering maintenance with respect to their fields); and Production in supply chain/ Supply chain logistics (automated material handling, awareness of global impacts, detailed scheduling and planning, executing operations, managing inventory, packaging and distributing product, production systems, resources planning, and supply - chain management); Quality assurance and continuous improvement (quality assurance, quality improvement, problem solving tools, quality inspection, principles of lean manufacturing, quality assurance audits, continuous improvement, corrective and preventive actions, benchmarking and best practice, statistical process control methods, and data analysis and presentation); process and equipment health, safety and environment; and financial accounting (critical work functions, cash versus accrual accounting, basic financial statements, budget preparation, variance analysis, financial analysis of capital investments and strategic initiatives, return on investment). The fifth and last competency is the industry technical workplace competencies, which includes: supply chain dynamics for automotive components (automotive supply chain management, tiers of suppliers, consumer segments and sales channels, supply chain factors, competition, changing consumer demands, regulations, quality standards, and technology); automotive components manufacturing processes (engine/motors and axle parts manufactured by electrical and mechanical equipment's, gearbox transmission systems, suspension and brakes, electrical parts, chassis and steering, wheel assembly and tires, air conditioning and heating systems, lubrication, fuel and battery systems, and interior/ exterior trim and seats). These competencies are shown in Figure 10.

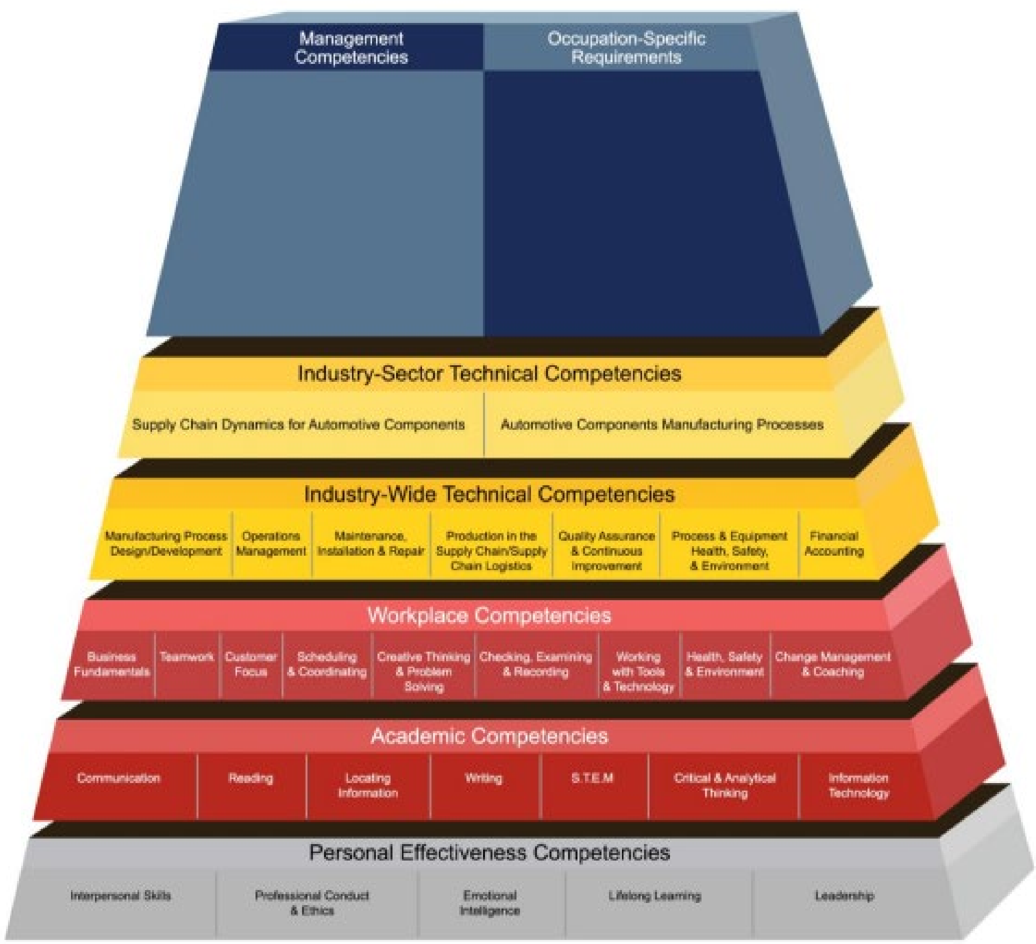

Figure 10: In-Demand Automotive Manufacturing Competencies (High Gear, 2020)

8.3 Conceptual Key Competency Model for Smart Factories

The model was developed in response to the continuous development and innovation in the automotive industry. The model was developed from data sourced from a semi-structured interview. The model consists of two groups: operational knowledge and personality characteristics. The operational knowledge competencies entail technical literacy, ICT literacy, innovation and creativity. The personal characteristics relevant in the fourth industrial revolution include soft skills, openness to learning, flexibility, and adaptation to change. According to the Authors, these groups' perspectives differ from those of government, education sector experts, and private sector experts. Government experts proposed innovation and creativity, technical literacy, and ICT literacy. Education sector experts proposed openness to learning,

Innovation and creativity, while the private sector expert proposed soft skills, flexibility and adaptation to change. These different competencies are shown in Figure 11.

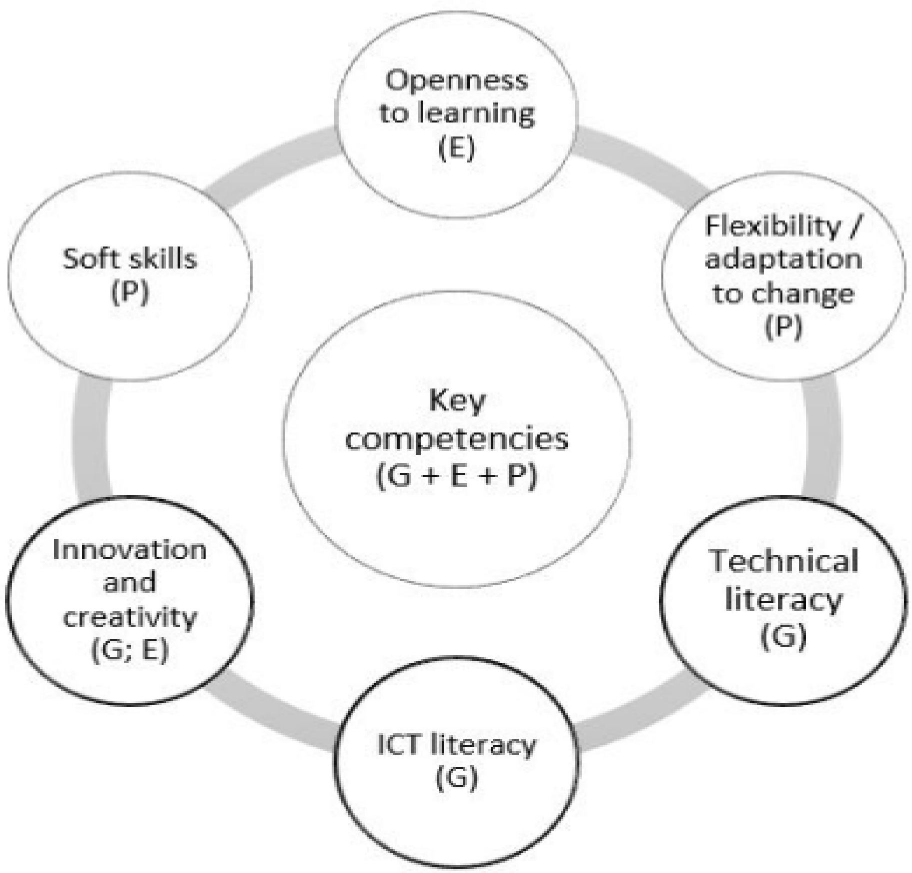

Figure 11: Conceptual Key Competency Model for Smart Factories (Jerman et al., 2020)

8.4 Holistic Competence Model

Their framework was an answer to the inadequacies of a one - dimensional framework of Competence after comparing different competency frameworks in the USA, Austria, and the United Kingdom (Le Deist and Winterton, 2005). The authors argue that the competencies required for an occupation include conceptual (in terms of cognitive, knowledge, and understanding) and operational (in terms of psycho-motor, functional, and applied skills). Also, the competencies for individual effectiveness are conceptual or Meta - Competence and operational or social. After that, the authors regrouped them into four types of competence: cognitive competence, Meta competence, functional competence, and social competence. This is represented in Figure 12.

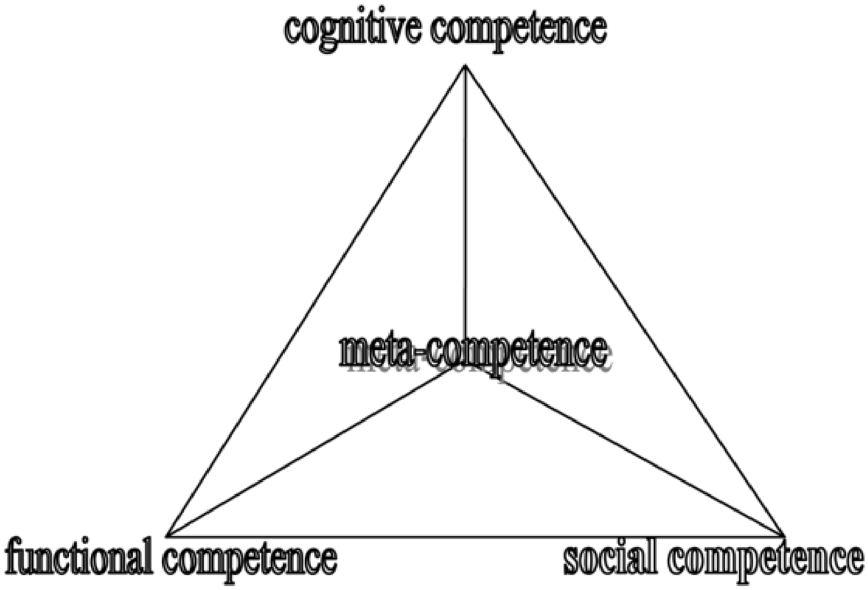

Figure 12: Holistic Competence Model (Le Deist and Winterton, 2005)

8.5 Competence in Use Framework

The framework was based on workplace dynamics, which often affects production and process technologies, and changing production cycles and strategies (Ellstrom, 1998). The competence in Use Framework can be said to cover occupational competence basically. According to the author, there are three views on developing competence. The first view is seeing competence as an attribute of an individual. This is divided into formal competence (measured by an individual's credentials and educational background); and actual competence (the capability of an individual to handle a job or finish a task). The second view is competence as a job requirement. This is elaborated in two ways: the official demand for competence (that is, the criteria for recruitment, selection and determination of wages); and the competence required by the job. The third view, which the author called the interactive view, is the competence-in-use, which is based on the notion that competence is neither an attribute of an individual nor the job. Still, it's the interaction between the individual and the job, which is the worker's competence and the job's characteristics. This Competence - in - use framework, as acclaimed by many authors, is shown in Figure 13

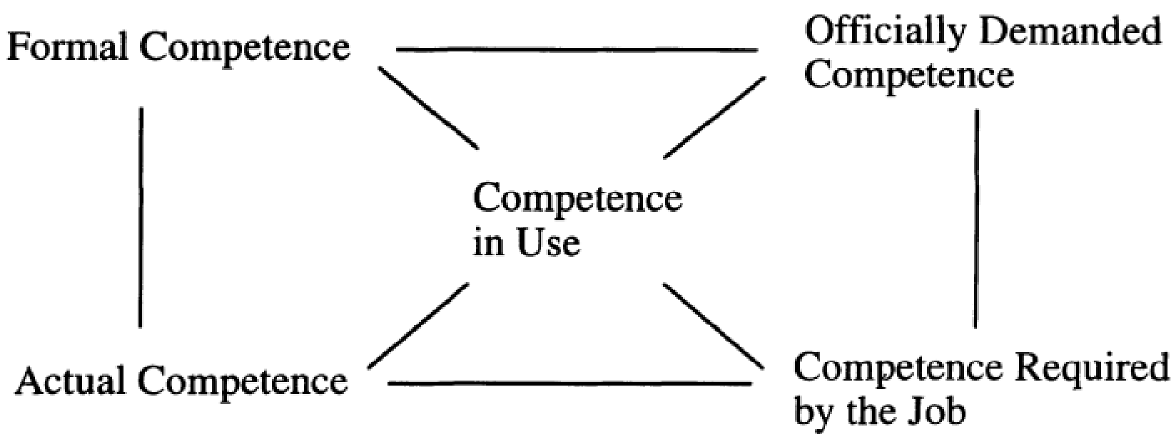

Figure 13: Competence–in–use Framework (Ellstrom, 1998)

8.6 Competence Framework for Bridging Skill gap in the European Li-Ion Battery Industry

This framework centres on the need to reskill engineering talents to grow the electric vehicle and battery industry, which will bridge its skill gap and remove the bottleneck on growth (Zahiraldini, 2022). Using a qualitative analysis of the interview survey, the author proposed two categories of Competence: Occupational Competence and Personal Competence. Occupational Competence includes cognitive Competence, which entails electrochemistry and Lithium-ion battery knowledge, data analytics and automation, educational background, and battery manufacturing process and serial manufacturing. Another aspect of occupational Competence is functional Competence, which entails commissioning (especially for process engineers), machine and equipment knowledge, and shop floor experience. Occupational Competence also includes methods-and-process competence, which encompasses quality standards of ISO9001, VDA 6.3, structured problem solving, and continuous improvement. Hence, occupational competencies include cognitive, functional, and methods-and-process competencies, which all focus on the need for technical skills in producing an Electric vehicle battery. The second competence construct proposed by the author is personal Competence. The first Competence under personal Competence is meta competence, which entails understanding the task context, the ability to prioritize and balance requirements and tasks, and autonomous and self-directed learning. Another competence on personal Competence is social Competence, which entails communication, networking skills, and attitude and personality. Personal Competence comprises Meta competence, and social Competence focuses on the output of individual personal skills in relating with other people, understanding concepts and managing oneself. This is conceptualized in Figure 14.

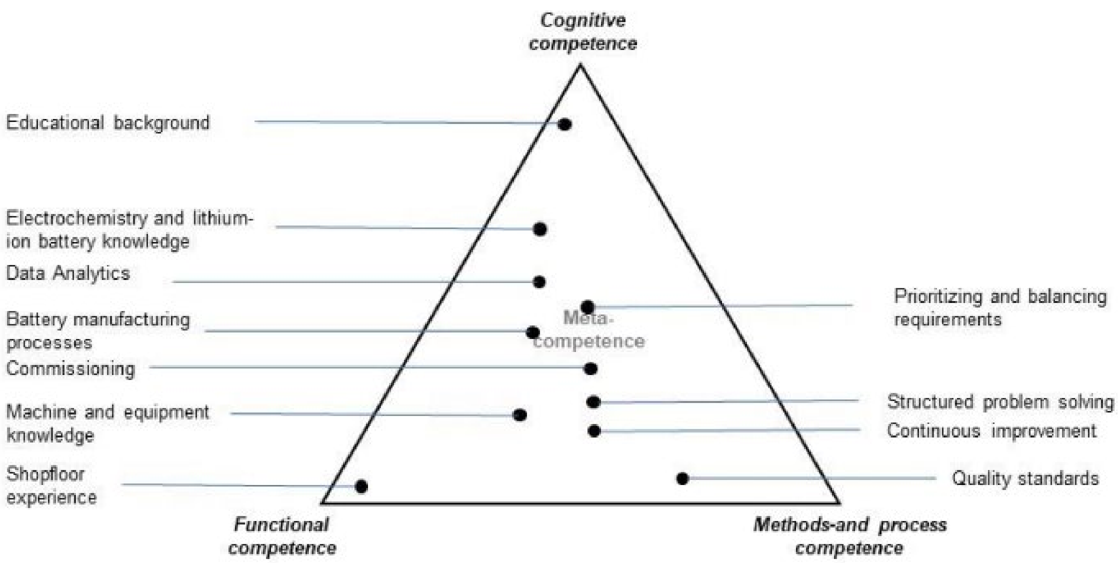

Figure 14: Competence Framework for Bridging the Skills gap in the European Li-ion Battery Industry (Zahiraldinni, 2022)

8.7 APICS Supply Chain Manager Competency Model

The model was developed with the guidelines of the Employment and Training Administration of the US Department of Labor. The model is grouped into three aspects of competencies: Foundational, Professional, and Occupation competencies. The foundational competencies are grouped into three kinds of competencies, which are: workplace and leadership competencies (this entails problem-solving and decision-making, teamwork and collaboration, accountability and responsibility, conflict management, planning and organizing, enabling technology, and customer focus), Academic competencies (this comprises of analytical thinking, reading and writing, applied science and technology, supply chain fundamentals, business management, and operation and enterprise economics); and Personal effectiveness competencies (this entails self - management styles and interpersonal, in terms of awareness of the needs of others, integrity, continuous learning, effective communication, interpersonal skill, and creativity). The Profession related competencies are divided into two, which are: Supply Chain manager knowledge areas and technical competencies (this Competence comprises knowledge and ability in performance tradeoffs, warehouse management, transportation management, supply chain synchronization, risks, sustainability, location facilities, distribution, warehousing, logistics, international regulations, strategic sourcing and supplier relationship, customer relationship management, and applying lean and six sigma tools). The second aspect of the profession related is operation management knowledge areas and technical competencies, which are skills and knowledge on strategy development and application, supply chain management, process improvement and six sigma, project management, lean management, enabling technology application, and execution, planning and scheduling control. The third one is Occupation - related competencies, which entail certification, licensure, specialized educational degrees, post-secondary education, and association membership in the supply chain field. The association membership, according to the framework, includes the Association for operations management (APICS), the Institute of Supply Management (ISM), the Supply Chain Council (SCC), the Council of supply chain management professionals (CSCMP), the American Society for Transportation and Logistics (ASTL), and Warehousing Education and Research Council (WERC). All these can be domesticated in South Africa.

8.8 Behavioural Competency Framework for Supply Chain Team Leaders

The competency framework was developed to aid managers' and team leaders' development and career progression. It consists of nine (9) competencies, shown in Figure 15. The first is positivity, which entails the ability and willingness to maintain a positive approach to a task or work irrespective of changes or challenges. The second competency concerns standards, which is the pride in achieving and surpassing standards and commitment to excellence while implementing procedures and processes. The third is customer service focus, which is understanding a customer's internal and external wants to meet and exceed their service expectations. The fourth is collaboration and teamwork, which is working cooperatively with team members to attain a goal. The fifth area of competence is motivating and inspiring the team, while the sixth competence is holding the team to account, which is the ability and willingness to ensure a standardized way of doing things for optimal performance. The seventh competence is developing the team, which encompasses a periodic mechanism of ensuring team members are learning and giving themselves to development. The eight one is cooperative commitment, which is the ability and awareness to understand how working with others affects business goals and values. The ninth is reasoning, which is the ability to think through activities and situations to make an informed decision.

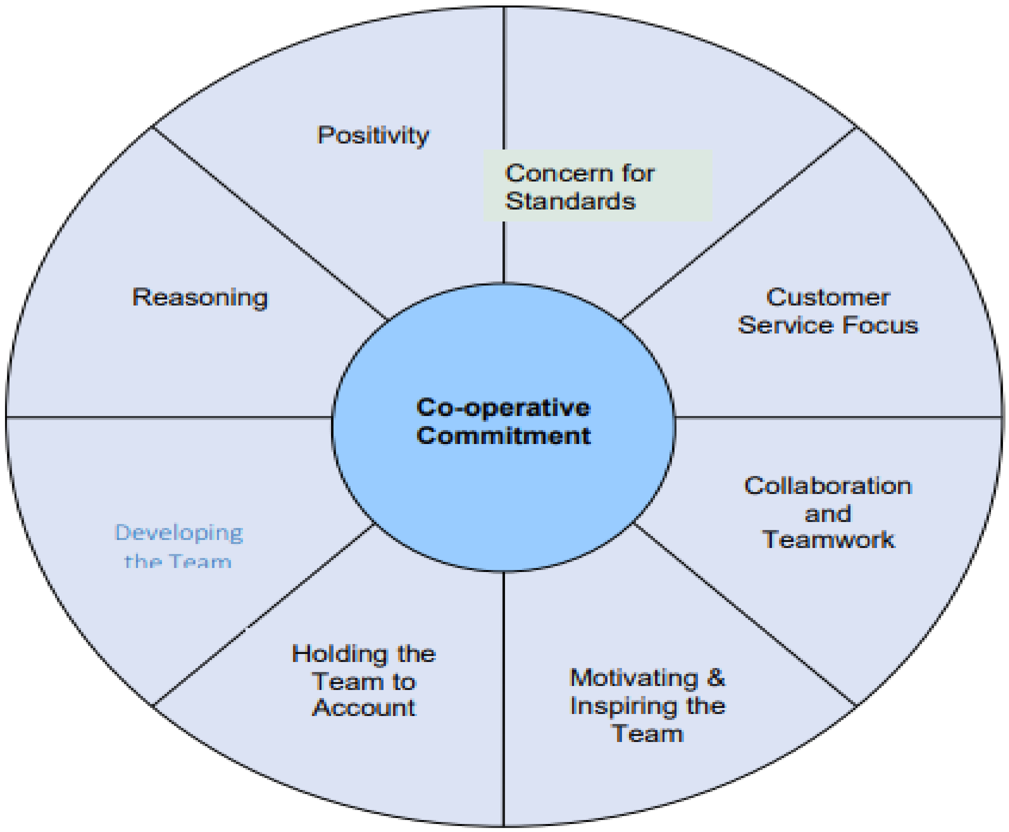

Figure 15: Behavioural Competency Framework for supply chain team leaders (Co-op Logistics, 2009)

8.9 System Engineering Competency Frameworks

The framework was developed to describe the competencies for system engineering, which must be tailored to a specific application or industry (INCOSE, 2015). The competency framework is grouped into three themes: Systems Thinking, Holistic Lifecycle View, and Systems Engineering Management. System thinking entails concepts and skills encompassing enterprise and technology environments. The Holistic lifecycle view comprises all the skills within a system lifecycle, from need assessment to operation and disposal. System engineering management entails skills for planning, managing, and controlling the system engineering process. The system thinking theme includes understanding system concepts, super-system capability issues, and enterprise and technology environments. The Holistic lifecycle view comprises architectural design, concept generation, functional analysis, interface management, maintaining design integrity, modelling and simulation, selection of preferred solutions, system robustness, integration and verification, validation, and transition to operation. The systems engineering management competencies entail enterprise integration, concurrent engineering, lifecycle process definition, integration specialism, and planning, monitoring and controlling.

8.10 Regional Model Competency Standards for the Manufacturing Industry

According to the International Labour Organisation (2007), "*The fundamental concept of competency in the Manufacturing RMCS is that it focuses on what is expected of an employee in the workplace rather than on a learning process or time spent in training or education*". The competency framework entails five (5) categories: basic manufacturing processes, casting and moulding, machining operation and component assembly, fabrication and finishing, and equipment servicing and maintenance. The basic manufacturing process entails routine tasks, handling fluids/ gases, operating mobile load-shifting equipment, warehouse tasks, packaging materials, purchasing materials, basic process planning and production scheduling, and preparing basic engineering drawings. The second area of competence is casting and moulding, which entails: the capability to operate a melting furnace, perform a gravity die casting machine, mix sand for metal moulding, fettling and trim metal castings/ forgings, an assemblage of plated patterns, and capability for heat operation. The third area of competence is machining operation and component assembly, which entails: understanding the operational maintenance of machines/equipment, performance of machine setting, general machining, lathe operations, grinding operations, milling operation, cutter grinding operations, and operating computer-controlled machines and processes. The fourth one is fabrication and finishing, which encompasses: manual production assembly, performing sheet and plate assembly, electronic/ electrical assembly, capability for setting assembly stations, performing soft soldering and routine oxy acetylene welding, carrying out mechanical cutting, the performance of automated thermal cutting, welding practices, thermal cutting, gouging and shaping, automated thermal cutting, monitoring of the quality of production, assembling of fabricated components, finishing and polishing of materials, and application of protective coatings and electroplate protective finishes. The fifth area for competency development is equipment servicing and maintenance, which includes: inspection of pre-packed articles, the performance of verification/ certification, maintaining and overhauling mechanical equipment, the performance of equipment condition monitoring and recording, isolating machines/equipment and maintenance of pneumatic systems, and hydraulic systems.

9.0 Conclusion

This comprehensive literature review covers the development of the electric vehicle, the state of the industry in South Africa, the TVET educational system and the need for human capital, as well as the transportation policy of South Africa. Moreover, the review covers theories underpinning the development of competency, which includes the human capital theory, resource-based theory, organizational culture theory, social practice theory, and curriculum development theories. The bibliometric analysis of competency development in the Electric vehicle industry was conducted, and it showed that papers on competency development are few, indicating that research on this topic is still developing. The bibliometric analysis also shows that the competency study focused more on the technical aspects, neglecting other important ones.

Furthermore, from the Bibliometric review analysis and the exploratory review of different frameworks, there is no competency framework for electric vehicle production and maintenance in South Africa. The competency framework currently being developed will be unique to South Africa but will draw insights from several other competence frameworks. This EV Competency framework will guide TVET College students to become electric vehicle production and maintenance experts. The competency framework is not just technical but also focuses on managerial aspects. This will aid TVET college students in understanding the dynamics of the market and the changing pattern of consumers in the design, production and marketing of electric vehicles, as they would have imbibed the needed managerial and soft skills. Moreover, the competency framework will increase their employability skills in the electric vehicle industry, as they would become innovators in the industry and aid South Africa in realizing its potential in the Electric vehicle industry.

10.0 References

Abdel - Wahab, M.S., Dainty, A.R.J., Ison, S.G., Bryer, L., and Hazlehurst, G., (2005). Productivity, skills, and Training: A Problem of Definition. Retrieved from: https://research portal.uws.ac.uk/en/publications/productivity-skills-and-training-a-problem-of-definition

Adepoju, O.O., David, L.O., Nwulu, N.I. (2022). Analyzing the Impact of Human Capital on Renewable Energy Penetration: A Bibliometric Reviews. Sustainability 2022, 14, 8852. https://doi.org/10.3390/su14148852

African Union Working Document (2022). National Qualifications Frameworks Twelve cases-a new mapping of types and governance models in Africa.

Aghimien, D.O., Aigbavaboa, C.O., Oke, A.E., Thwala, W.D., 2019. Mapping out research focus for robotics and automation research in construction-related studies. J. Eng. Des. Technol. https://doi.org/10.1108/JEDT-09-2019-0237

Ahjum, F., Hartley, F., and Merven, B. (n.d.). The Green Transport Strategy of South Africa: GHG mitigation potential of road transport interventions and their economy-wide impact. Retrieved from: www.ClimateCompatibleGrowth.com

Ahjum, F., Merven, B., Stone, A., and Caetano, T. (2018). Road transport vehicles in South Africa towards 2050: Factors influencing technology choice and implications for fuel supply. *Journal of Energy in Southern Africa*, *29*(3), 33–50. https://doi.org/10.17159/2413-3051/2018/V29I3A5596

Ahmadi, L., Yip, A., Fowler, M., Young, S. B., and Fraser, R. A. (2014). Environmental feasibility of re-use of electric vehicle batteries. *Sustainable Energy Technologies and Assessments*, *6*, 64–74. https://doi.org/10.1016/J.SETA.2014.01.006

Akubuilo, D. U., Ugo, A. C., Ugo, D. C., Ugochukwu, J. I., and Ikehi, M. E. (2019). Extent of Implementation of Social Studies Curriculum in Secondary Schools in Enugu State. *Creative Education*, *10*(11), 2386–2399. https://doi.org/10.4236/CE.2019.1011170

Alexander, M., and Tonachel, L. (2016). Projected Greenhouse Gas Emissions for Plug-in Electric Vehicles. *World Electric Vehicle Journal 2016, Vol. 8, Pages 987-995*, *8*(4), 987–995. https://doi.org/10.3390/WEVJ8040987

Aliu, J., and Aigbavboa, C. (2019). Examining the Roles of Human Capital Theory. What next for Construction Industry? *Journal of Physics: Conference Series*, *1378*(2), 022057. https://doi.org/10.1088/1742-6596/1378/2/022057

Amini, M. H., Moghaddam, M. P., and Karabasoglu, O. (2017). Simultaneous allocation of electric vehicles' parking lots and distributed renewable resources in smart power distribution networks. *Sustainable Cities and Society*, *28*, 332–342. https://doi.org/10.1016/J.SCS.2016.10.006

Andersen, O. (2013). Towards the Use of Electric Cars. *Green Energy and Technology*, *140*, 71–80. https://doi.org/10.1007/978-1-4471-5532-4_6/COVER

Andreoni A, Mondliwa P, Roberts S and Tregenna F (Editors) (2021). Structural Transformation in South Africa. The Challenges of Inclusive Industrial Development in a Middle-Income Country, Oxford University Press

APICS (2009). Supply Chain Manager Competency Model. The Association for Operation management. APICS Supply chain managers career pack. Retrieved from: http://www.apics.org/docs/default source/careers-competency-models/supply-chain-manager-competency-model.pdf

Arbib, J., and Seba, J. (2017). *Rethinking Transportation 2020-2030.* . A RethinkX Sector Disruption Report.

Armstrong, M. (1999). Handbook of Human Resource Management Practice. London: Kogan Page.

Arnoldi, M., (2022). South Africa urged to consider its contribution to the global battery value chain. Creamer Media's Mining weekly. Retrieved from: https://www.miningweekly.com/article/south-africa-urged-to consider-its-contribution-to-the-global-battery-value-chain-2022-08-26

Athey, T. R., and Orth, M. S. (1999). Emerging competency methods for the future. *Human Resource Management*, 38, 215-226.

Audu, R., Igwe, C. O., and Onoh, C. E. C. (2013). Human Capital Development in Technical Vocational Education (TVE) for Sustainable National Development. *Journal of Education and Practice, 4*(7).

Automotive Supply Chain Competitiveness Initiative, ASCCI (2022). Access to Automotive Technology. Final Report. PwC.

Barnes, J. (2017). *Developing a South African automotive Masterplan to 2035 in the context of Global Value Chain drivers: Lessons for second tier automotive economies Digital Industrial Policy Framework for the South African government*. www.oica.net

Barney, J. B., della Corte, V., Sciarelli. Mauro, and Arikan, A. (2012). The role of resource-based theory in strategic management studies: Managerial implications and hints for research. *Handbook of research on competitive strategy.*

Barney, J. B., Ketchen, D. J., and Wright, M. (2011). The future of resource-based theory: Revitalization or decline? *Journal of Management*, *37*(5), 1299–1315. https://doi.org/10.1177/0149206310391805

Batholmeus, P., and Pop, C. (2019). *Enablers of work-integrated learning in technical vocational education and training teacher education*.

Behar-Horenstein, L. S. (2010). *In C Kridel (Ed) Sage Encyclopedia of Curriculum Studies, 2010:615-616.* Sage Encyclopedia of Curriculum.

Berckmans, G., Messagie, M., Smekens, J., Omar, N., Vanhaverbeke, L., and Mierlo, J. van. (2017). Cost Projection of State of the Art Lithium-Ion Batteries for Electric Vehicles Up to 2030. *Energies 2017, Vol. 10, Page 1314*, *10*(9), 1314. https://doi.org/10.3390/EN10091314

Bokopane, L., Kanzumba, K., and Vermaak, H. (2019). Is the South African Electrical Infrastructure Ready for Electric Vehicles? *2019 Open Innovations Conference, OI 2019*, 127–131. https://doi.org/10.1109/OI.2019.8908171

Boyatzis, R. E. (1982). The competent manager: A mode for effective performance. New York: Wiley.

Burgoyne, J. (1989) Creating the managerial portfolio: Building on competency approaches management development. Management Education and Development, 20(1), 56 – 61.

Calitz, J. R., and Bansal, R. C. (2022). The system value of optimized battery electric vehicle charging: a case study in South Africa. *Electrical Engineering*, *104*(2), 843–853. https://doi.org/10.1007/S00202-021-01345-Y/METRICS

Campagnol, N., Pfeiffer, A., and Tryggested, C., (2022). Capturing the battery value - chain opportunity. Mckinsey & Company. Retrieved from: https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/capturing-the-battery-value-chain-opportunity

Campion, M. A., Cheraskin, L., and Stevens, M. J. (1994). Career-related antecedents and outcomes of job rotation. Academy of Management Journal, 37, 1518-1542.

CEDEFOD (2020). Empowering adults through upskilling and reskilling pathways. European Centre for the Development of Vocational Training. Publication office of the European Union, Thermi, Greece.

Chan, C. C. (2013). The rise and Fall of electric vehicles in 1828-1930: Lessons learned. In *Proceedings of the IEEE* (Vol. 101, Issue 1, pp. 206–212). Institute of Electrical and Electronics Engineers Inc. https://doi.org/10.1109/JPROC.2012.2228370

Chege, W.W., (2021). The Electric Vehicle Ecosystem and Associated Value Chains. The role of the city of Cape Town can play in the electric vehicle ecosystems. GreenCape. Retrieved from: https://www.green-cape.co.za/assets/The-Electric-Vehicle-Ecosystem-and-Associated-Value-Chains.pdf

Cheng, Y., Sinha, A., Ghosh, V., Sengupta, T., and Luo, H. (2021). Carbon tax and energy innovation at crossroads of carbon neutrality: designing a sustainable decarbonization policy. *J Environ Manage*, *294*. https://doi.org/10.1016/j.jenvman.2021.112957

Choma, E. F., Evans, J. S., Hammitt, J. K., Gómez-Ibáñez, J. A., and Spengler, J. D. (2020). Assessing the health impacts of electric vehicles through air pollution in the United States. *Environment International*, 144. https://doi.org/10.1016/J.ENVINT.2020.106015

Chung, R. G., and Lo, C. L. (2007). The development of teamwork competence questionnaire: Using students of business administration department as an example. International Journal of Technology and Engineering Education, 55-57.

Co-op Logistics (2009). Behavioral Competency Framework for Supply chain team leaders. Retrieved from: https://assets.ctfassets.net/3pdnpf64gjpg/4kbArEickLe4zaSXslvtiz/7ef15476f1e3dce274dca3d154a24051/Behavioural_Competency_Framework_-_Team_Manager.pdf

Coşkun Yaşar, G., and Aslan, B. (2021). Curriculum Theory: A Review Study. *Uluslararası Eğitim Programları ve Öğretim Çalışmaları Dergisi*, *11*(2), 237–260. https://doi.org/10.31704/ijocis.2021.012

Cubic Transportation systems (2021). Digital Mobility. Uniting the solutions for Tomorrow's Transit Needs. Retrieved from: https://www.cubic.com/sites/default/files/2021-10/20-CTS-WHITEPAPER%20-%20Digital%20Mobility%20-%20FINAL.pdf

Dane, A. (2013). The Potential of Electric Vehicles to Contribute to South Africa's Greenhouse Gas Emissions Targets and other Developmental Objectives How Appropriate is the Investment in Electric Vehicles as a NAMA? *Energy Research Centre (ERC)*. https://www.africaportal.org/publications/the-potential of-electric-vehicles-to-contribute-to-south-africas-greenhouse-gas-emissions-targets-and-other developmental-objectives-how-appropriate-is-the-investment-in-electric-vehicles-as-a-nama/

David, L.O., Nwulu, N.I., Aigbavboa, C.O., and Adepoju, O.O., (2022). Integrating fourth industrial revolution (4IR) technologies into the water, energy and food nexus for sustainable security: A bibliometric analysis. Journal of Cleaner Production, 363(2022). https://doi.org/10.1016/j.jclepro.2022.132522

Deloitte (2017). The future of the Automotive Value Chain. 2025 and beyond. Deloitte. Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/consumer-business/us-auto-the-future-of-the-automotive-value-chain.pdf

Deonarain, B. (2019). *TIPS Report for Department of Trade and Industry*. Technological change and sustainable mobility: an overview of global trends and South African developments. www.tips.org.za

Department of Trade Industry and Competition (2021). http://www.thedtic.gov.za/

De Vos, A., De Hauw, S., and Willemse, I., (2011). Competency Development in organizations: Building an integrative model through a qualitative study. Vlerick Leuven Gent Management School. Vlerick Leuven Gent working paper series 2011/01

Dominković, D. F., Bačeković, I., Pedersen, A. S., and Krajačić, G. (2018). The future of transportation in sustainable energy systems: opportunities and barriers in a clean energy transition. *Renew Sustain Energy Rev*, *82*, 1823–1838. https://doi.org/10.1016/j.rser.2017.06.117

Duque, R. B. (2018). Applying Classical Theory in a Comparative Study of the Information Revolution in the Less Developed World. *https://Doi.Org/10.1177/1206331218807087*, *24*(2), 240–262. https://doi.org/10.1177/1206331218807087

DTIC Auto Green Paper (2021). The South African Road to Production of Electric Vehicles (The Roadmap). Department of Trade, Industry and Competition (DTIC)Retrieved from: http://www.thedtic.gov.za/wp-content/uploads/EV_Green_Paper.pdf

Edokpolor, J. E., and Dumbiri, D. N. (2019). Resource adequacy and utilisation for teaching and learning effectiveness in vocational education programmes in South-South Nigerian Universities. *Journal of Vocational Education Studies*, *2*(1), 1. https://doi.org/10.12928/JOVES.V2I1.727

Eilstrom, P. E., and Kock, H. (2008). Competence development in the workplace: concepts, strategies, and effects. Asia Pacific Education Review, 9(1), 5-20.

Emrullah, T. (2014). Human Capital Theory: A Holistic Criticism on JSTOR. *Journal of Education Research*, 84(3), 411–445. https://www.jstor.org/stable/24434243

Enyekit, E. O., Ubulom, W. J., and Onuekwa, F. A. (2011). Achieving human capital development in Nigeria through vocational education for nation building. *Academic Research International 1*(3). www.savap.org.pkwww.journals.savap.org.pk

Faraz, A., Ambikapathy, A., Thangavel, S., Logavani, K., and Arun Prasad, G. (2021). Battery Electric Vehicles (BEVs). *Green Energy and Technology*, 137–160. https://doi.org/10.1007/978-981-15-9251-5_8

Field, S., Musset, P., and Álvarez-Galván, J.-L. (2014). *A Skills beyond School Review of South Africa*. OECD. https://doi.org/10.1787/9789264223776-en

Francisco, S., and Posada, F. (2017). South Africa's new passenger vehicle CO_2 emissions baseline analysis. *Final Report Prepared for: FIA Foundation*. www.theicct.org

Gazette, G., and Notice, G. (1995). *White Paper on Education and Training*.

Grant, A. (2014a). *Plug-in hybrid and battery electric vehicles in South Africa: market forecasts*. https://open.uct.ac.za/handle/11427/18601

Grant, A. (2014b). *Plug-in Hybrid and Battery Electric Vehicles in South Africa Market Forecasts*.

Guarnieri, M. (2012). Looking back to electric cars. *3rd Region-8 IEEE HISTory of Electro - Technology Conference: The Origins of Electrotechnologies, HISTELCON 2012 - Conference Proceedings*. https://doi.org/10.1109/HISTELCON.2012.6487583

Heinsman, H., de Hoogh, A. H. B., Koopman, P. L., and van Muijen, J. J. (2006). Competency management: balancing between commitment and control. Management Revue, 17(3), 292-306.

High Gear (2020). In - Demand Automotive Manufacturing Competencies. Rapid Research Findings for TVET Educators and Learners. Retrieved from: https://naacam.org.za/wp-content/uploads/2021/04/High-Gear Research-Report-PPP.pdf

Holdford, D. A. (2018). Resource-based theory of competitive advantage – a framework for pharmacy practice innovation research. *Pharmacy Practice*, *16*(3) https://doi.org/10.18549/PHARMPRACT.2018.03.1351

Howard, M., Silverstone, B., Moztarzadeh, H., Shakspeare, P., and Kirkwood, N., (2021). The opportunity for a National Electrification skills framework and forum. Retrieved from: https://hvm.catapult.org.uk/wp content/uploads/2021/11/National-Electrification-Skills-Forum-Brochure-FINAL.pdf

Høyer, K. G. (2007). The battle of batteries: a history of innovation in alternative energy cars. *International Journal of Alternative Propulsion*, *1*(4), 369–384. https://doi.org/10.1504/IJAP.2007.013330

Høyer, K. G. (2008). The history of alternative fuels in transportation: The case of electric and hybrid cars. *Utilities Policy*, *16*(2), 63–71. https://doi.org/10.1016/J.JUP.2007.11.001

Hu, Z., and Yuan, J. (2018). China's NEV market development and its capability of enabling premium NEV: Referencing from the NEV market performance of BMW and Mercedes in China. *Transportation Research Part A: Policy and Practice*, *118*, 545–555. https://doi.org/10.1016/j.tra.2018.10.010

IAEA (2022). The Competency Framework. A guide for IAEA Managers and staff. International Atomic Energy Agency. Retrieved from: https://www.iaea.org/sites/default/files/18/03/competency framework.pdf

IEA. (2022a). *Trends in electric light-duty vehicles – Global EV Outlook 2022 – Analysis - IEA*. Global EV Outlook 2022. https://www.iea.org/reports/global-ev-outlook-2022/trends-in-electric-light-duty-vehicles

IEA. (2022b, May 23). *Global electric car sales have continued their strong growth in 2022 after breaking records last year - News - IEA*. Global EV Outlook 2022. https://www.iea.org/news/global-electric-car sales-have-continued-their-strong-growth-in-2022-after-breaking-records-last-year

INCOSE (2015). INCOSE UK Framework. Systems Engineering Competencies Framework. Retrieved from: https://incoseuk.org/Documents/Groups/UKChapter/SE_Competencies_Framework_Issue_3.pdf

International Labour Organization (2007). Regional Model Competency Standard: Manufacturing Industry. Regional Skills and Employability Programme in Asia and the Pacific (SKILLS-AP). Retrieved from: https://www.ilo.org/wcmsp5/groups/public/---asia/---ro bangkok/documents/publication/wcms_bk_pb_237_en.pdf

Jerman, A., Bertoncelj, A., Dominici, G., Bach, M.P., and Trnavcevic, A., (2020). Conceptual Key Competency Model for Smart Factories in Production Processes. Organizacija, 53(1), Pp 68 - 79. DOI:10.2478/orga-2020-0005

Kates, S. (2018). MAKING SENSE OF CLASSICAL THEORY. *Journal of the History of Economic Thought*, 40(2), 279–283. https://doi.org/10.1017/S105383721700058X

Katz, D., and Kahn, R. (1966). The social psychology of organizations. New York: John Wiley and Sons.

Keränen, J., and Jalkala, A. (2013). Towards a framework of customer value assessment in B2B markets: An exploratory study. *Industrial Marketing Management*, *42*(8), 1307–1317. https://doi.org/10.1016/J.INDMARMAN.2013.06.010

Knapp, B. (1963). Skill in sport: the attainment of proficiency. Routledge.

Koetse, M. J., and Hoen, A. (2014). Preferences for alternative fuel vehicles of company car drivers. *Resource and Energy Economics*, *37*, 279–301. https://doi.org/10.1016/j.reseneeco.2013.12.006

Kozlenkova, I. v., Samaha, S. A., and Palmatier, R. W. (2014). Resource-based theory in marketing. *Journal of the Academy of Marketing Science*, *42*(1), 1–21. https://doi.org/10.1007/S11747-013-0336-7

Kuijpers, M. (2003). Career development. Research regarding 'competencies'. University of Twente, Enschede.

Kuijpers, M. (2003). Loopbaanontwikkeling. Onderzoek naar 'competenties'. [Career development. Research regarding 'competencies'.] Unpublished PhD thesis, University of Twente, Enschede.

Le Deist, F. D., and Winterton, J. (2005). What is Competence? Human Resource Development International, 8(1), 27–46.

Ledwaba, L. P. I., Hancke, G. P., Isaac, S. J., and Venter, H. S. (2019). Developing a secure, smart micro grid energy market using distributed ledger technologies. *IEEE International Conference on Industrial Informatics (INDIN)*, *2019-July*, 1725–1728. https://doi.org/10.1109/INDIN41052.2019.8972018

Li, C., Negnevitsky, M., Wang, X., Yue, W. L., and Zou, X. (2019). Multi-criteria analysis of policies for implementing clean energy vehicles in China. *Energy Policy*, *129*, 826–840. https://doi.org/10.1016/j.enpol.2019.03.002

Li, L., (2022). Reskilling and Upskilling the future-ready workforce for industry 4.0 and beyond. Information systems frontiers. https://doi.org/10.1007/s10796-022-10308-y

Li, W., Long, R., and Chen, H. (2016). Consumers' evaluation of national new energy vehicle policy in China: An analysis based on a four paradigm model. *Energy Policy*, *99*, 33–41. https://doi.org/10.1016/j.enpol.2016.09.050

Liu, L., Kong, F., Liu, X., Peng, Y., and Wang, Q. (2015). A review on electric vehicles interacting with renewable energy in smart grid. *Renewable and Sustainable Energy Reviews*, *51*, 648–661. https://doi.org/10.1016/J.RSER.2015.06.036

Madhani, P. M. (2021). Resource Based View (RBV) of Competitive Advantages: Importance, Issues and Implications by Pankaj M. Madhani :: SSRN. *Journal of Indian Management Research and Practices*, 1(2), 2–12. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1504379

Malinga, S., (2022a). Audi, Gridcars EV Charging network goes live in SA. Retrieved from: https://www.itweb.co.za/content/G98YdMLGxXw7X2PD

Malinga, S., (2022b). SA trails behind global market with 1.5K electric vehicles. Retrieved from: https://www.itweb.co.za/content/wbrpOMg2zza7DLZn

Matthews, L., Lynes, J., Riemer, M., Del Matto, T., and Cloet, N. (2017). Do we have a car for you? Encouraging the uptake of electric vehicles at point of sale. *Energy Policy*, *100*, 79–88. https://doi.org/10.1016/j.enpol.2016.10.001

McClelland, D. C. (1973). Testing for Competence rather than for "intelligence". The American Psychologist, 28(1), 1–14.

Melex Electrovehicles (2023). Electrovehicle for Sale. Retrieved from: https://www.electrovehicles.co.za/

Mersky, A. C., Sprei, F., Samaras, C., and Qian, Z. S. (2016). Effectiveness of incentives on electric vehicle adoption in Norway. *Transportation Research Part D: Transport and Environment*, *46*, 56–68. https://doi.org/10.1016/j.trd.2016.03.011

Miller, J. L. (2010). Maxine Greene. In C. Kridel (Ed.), The Sage encyclopedia of curriculum studies (pp. 417-419). Thousand Oaks, CA: Sage.

Mi Power Electric Bus (2023). e - Mobility Revolution by MiPower Electric Bus. Retrieved from: https://electricbus.co.za/

Moghabghab, R., Tong, A., Hallaran, A., and Anderson, J., (2018). The Difference between Competency and Competence: A Regulatory Perspective. Journal of Nursing Regulation, 8(2), Pp 54 - 59.

Moore, D. R., Cheng, M., and Dainty, A. R. J. (2002). Competence, competency and competencies: performance assessment in organizations. Work Study, 51(6), 314–319.

Muchiri, D. G. (2022). Skilling, reskilling, and upskilling a workforce: a perspective from Kenyan enterprises. The Strategic Journal of Business and Change Management, 9 (4), 190 - 203.

Mwangeka, R. (2020). An introduction to organisation theory and development. *Lecture Series to Bachelor of Commerce Students at The Co-Operative University of Kenya*.

Ngcwangu, S. (2015). The ideological underpinnings of World Bank TVET policy: Implications of the influence of Human Capital Theory on South African TVET policy. *Education as Change*, *19*(3), 24–45. https://doi.org/10.1080/16823206.2015.1085620

OECD. (2003). The Role of National Qualifications Systems in Promoting Lifelong Learning. *An OECD activity Report from Thematic Group 1: The development and use of "Qualification Frameworks" as a means of reforming and managing qualifications systems*.

OECD (2019). OECD Future of Education and Skills 2030. Conceptual Framework, Skills for 2030. Pp 1 - 15.

Önday, Ö. (2016). Classical to modern organisation theory. *International Journal of Business and Management Review*, *4*(2), 15–59.

Pareek, A. (2023, January 17). *Education For Employment - A Step Towards Strengthening TVET Structure In South African Countries*. https://www.tescaglobal.com/blog/education-for-employment-a-step-towards strengthening-tvet-structure-in-south-african-countries/

Pasban, M., and Nojedeh, S. H. (2016). A Review of the Role of Human Capital in the Organization. *Procedia Social and Behavioural Sciences*, *230*, 249–253. https://doi.org/10.1016/j.sbspro.2016.09.032

Payne, J. (1999). All things to all people: Changing perception of 'Skill' among Britain's policy makers since the 1950s and their implications. SKOPE Research Paper No.1, Warwick University.

Penuel, W. R., Digiacomo, D. K., van Horne, K., and Kirshner, B. (2016). A social practice theory of learning and becoming across contexts and time. *Frontline Learning Research*, *4*(4), 30–38. https://doi.org/10.14786/flr.v4i4.205

Perera, F. (2018). Pollution from Fossil-Fuel Combustion is the Leading Environmental Threat to Global Pediatric Health and Equity: Solutions Exist. *International Journal of Environmental Research and Public Health*, *15*(1). https://doi.org/10.3390/IJERPH15010016

Platform for Electro mobility (2020). European Green Deal and Green Recovery: Time to focus on Electromobility. Retrieved from: https://www.platformelectromobility.eu/wp-content/uploads/2018/02/European-Platform-for-electromobility%E2%80%99s-position-on-Green-Deal_FINAL-2.pdf

PwC (2023). Merge ahead: Electric vehicles and the impact on the automotive supply chain. PwC.

Retrieved from: https://www.pwc.com/us/en/industries/industrial-products/library/electric-vehicles-supply-chain.html

Qiao, Q., Zhao, F., Liu, Z., He, X., and Hao, H. (2019). Life cycle greenhouse gas emissions of Electric Vehicles in China: Combining the vehicle cycle and fuel cycle. *Energy*, *177*, 222–233. https://doi.org/10.1016/j.energy.2019.04.080

Robbins, S. P., and Judge T. A. (2016). *Organizational Behaviour. 17th Edition, Pearson Education Limited, Upper Saddle River. - References - Scientific Research Publishing*.

SAQA. (2019). *SAQA Bulletin: Volume 18 Number 1: March 2019*.

SAQA Registered Qualification (2020). Occupational Certificate: Transportation Electrician (Automotive Electrician). Retrieved from: https://regqs.saqa.org.za/viewQualification.php?id=117042

Saravanakumar, A. R. (2019). Organisational behaviour. *Organisational Behaviour,* 53.

Sarode, R., and Eadke, A. (2020). Electric Vehicles (Construction and Working principle). *International Research Journal of Engineering and Technology*. www.irjet.net

Schwab, K., and Zahidi, S. (2020). The future of jobs report 2020. World Economic Forum, October 2020. https://www3.weforum.org/ docs/WEF_Future_of_Jobs_2020.pdf Accessed 5 January 2023.

Sebola, M. P. (2022). The role of Technical Vocational Education and Training Colleges (TVET) in higher education teaching: a higher education provided at basic education standard. *EUREKA: Social and Humanities*, *1*, 50–57. https://doi.org/10.21303/2504-5571.2022.002257

Gishti E. (2021). The role of national qualifications framework in teaching learning practices. *International Journal of Economics, Commerce and Management,* Vol. 9 Issue 6, June 2021.

Sida (2018). Skill Development. Swedish international development cooperation agency. Retrieved from: https://cdn.sida.se/publications/files/sida62134en-skills-development.pdf

Sithole, M. D., Wissink, H., and Chiwawa, N. (2022). Enhancing the Management Systems and Structures of Technical Vocational Education and Training Colleges in South Africa. *Administratio Publica* |, *30*. https://doi.org/10.10520/EJC-ADMINPUB_V30_N3_A7

Sophie Edwards. (2017). Geneva meeting on used cars exporting pollution to developing countries. *Devex*. https://www.devex.com/news/geneva-meeting-on-used-cars-exporting-pollution-to-developing countries-89976

South Africa: Department of Education and Department of Labour. (2002). Report of the study team on the implementation of the National Qualifications Framework. https://www.gov.za/sites/default/files/gcis_document/201409/nqfstudy0.pdf

Southern African Development Community. (2013). Status of TVET in the SADC region: assessment and review of technical and vocational education and training (TVET) in the Southern African Development Community Region and of the development of a regional strategy for the revitalisation of TVET. https://unesdoc.unesco.org/ark:/48223/pf0000225632

Spencer, L. M., and Spencer, S. M. (1993). Competence at work: models for superior performance. New York: John Wiley.

Stone, A., Merven, B., Maseela, T., and Moonsamy, R. (2018). Providing a foundation for road transport energy demand analysis: A vehicle pare model for South Africa. *Journal of Energy in Southern Africa*, 29(2), 29–42. https://doi.org/10.17159/2413-3051/2018/V29I2A2774

Sun, X., Li, Z., Wang, X., and Li, C. (2019). Technology development of electric vehicles: A review. *Energies*, 13(1). https://doi.org/10.3390/en13010090

Swart, G. (2015). Innovation lessons learned from the Joule EV Development. International Association for Management of Technology.

Swart, G., (2016). Learning systems engineering lessons from an electric vehicle Development. 26th Annual INCOSE International Symposium, Edinburgh, Scotland, July 18-21, 2016.

Szutowicz, T., (2022). All the electric cars you can buy in South Africa - with pricing and range. TechCentral. Retrieved from: https://techcentral.co.za/all-the-electric-cars-you-can-buy-in-south-africa-with-pricing-and-range/218215/#:~:text=A

Terblanche, T., and Bitzer, E. (2018). Leading curriculum change in South African technical and vocational education and training colleges. *Journal of Vocational, Adult and Continuing Education and Training*, 1(1), 104. https://doi.org/10.14426/JOVACET.V1I1.16

The Department of Trade, I. and C. (2018). *Geared for Growth South Africa's Automotive Industry Master Plan to 2035*. www.lhedtic.gov.za

Tongwane, M. I., and Moeletsi, M. E. (2021). Status of electric vehicles in South Africa and their carbon mitigation potential. *Scientific African*, *14*, e00999. https://doi.org/10.1016/J.SCIAF.2021.E00999

Transport & Environment (2020). How clean are electric cars? T & E's analysis of electric car lifecycle CO_2

emissions. Retrieved from: https://www.transportenvironment.org/wp-content/uploads/2020/04/TEs-EV-life-cycle-analysis-LCA.pdf

Transport Department: Republic of South Africa. (2020). Green Transport Strategy for South Africa: (2018-2050).

Tsakalidis, A., Krause, J., Julea, A., Peduzzi, E., Pisoni, E., and Thiel, C. (2020). Electric light commercial vehicles: Are they the sleeping giant of electromobility? *Transportation Research Part D: Transport and Environment*, *86*. https://doi.org/10.1016/j.trd.2020.102421

Uwaifo, V. O., and Uwaifo, I. U. (2009). Training Technology and Vocational Education Teachers for the new 9-3-4 education system in Nigeria: Its problems and prospects. International NGO Journal, 4(4), pp 160-166. *International NGO Journal*, *4*(4), 160. – 166.

Van Huyssteen, R. (2002). The Introduction of the South African National Qualifications Framework: A Brief Overview, with Reference to Higher Education.

Vascan, I., and Szabo, L. (2022). A Brief History of Electric Vehicles. *Journal of Computer Science and Control Systems*, *15*(1).

Venter, I., (2013). Electric vehicles make commercial debut in sA as Nissan unveils Leaf. Creamer Media's Engineering News. Retrieved from: https://www.engineeringnews.co.za/article/electric-vehicles-make-commercial-debut-in-sa-as-nissan-unveils-leaf-2013-11-22/rep_id:4136

Wahab S.N., Rajendran S.D., Yeap S.P., 2021. Upskilling and reskilling requirement in logistics and supply chain industry for the fourth industrial revolution. LogForum 17 (3), 399-410. http://doi.org/10.17270/J.LOG.2021.606

Wilson, K. A. (2022, August 17). First Electric Car: A Brief History of the EV, 1830 to Present. https://www.caranddriver.com/features/g15378765/worth-the-watt-a-brief-history-of-the-electric-car 1830-to-present/

Winkler, H., Hughes, A., Marquard, A., Haw, M., and Merven, B. (2011). South Africa's greenhouse gas emissions under business-as-usual: The technical basis of 'Growth without Constraints' in the Long-Term Mitigation Scenarios. *Energy Policy*, *39*(10), 5818–5828. https://doi.org/10.1016/J.ENPOL.2011.06.009

Wong, S.-C. (2020). Competency Definitions, Development and Assessment: A Brief Review. International Journal of Academic Research in Progressive Education and Development, 9(3), 95–114.

World Economic Forum, (2017). Impact of Fourth Industrial Revolutions on Supply Chains. Switzerland.

World Economic Forum, (2018). The Future of Jobs Report 2018. Insight Report, Geneva, Switzerland.

Wuttaphan, N. (2017). Human Capital Theory: The theory of human resource development, implications and future. *Sci. Humanit. Soc. Sci.*, *18*(2), 240–253.

Xie, J., Li, Y. Z., Yang, L., Sun, Y., and Yuan, M. (2022). A review of the recent progress of stand-alone photovoltaic-battery hybrid energy systems in space and on the ground. *Journal of Energy Storage*, *55*. https://doi.org/10.1016/j.est.2022.105735

Yuvaraj, R. (2011). Competency mapping – A drive for Indian industries. *International Journal of Scientific and Engineering Research, 2(8), 1-7*.

Zahiraldinni (2022). Towards a competency framework for bridging skill gaps in the European Li-ion battery industry: A case study on a leading European battery player. *Master of Science Thesis, KTH Industrial Engineering and Management Industrial Management, SE-100 44 STOCKHOLM*. Retrieved from: https://www.diva-portal.org/smash/get/diva2:1668698/FULLTEXT01.pdf

Zhang, C.Q., (2019). Skill. In D. Hackfort, R.J. Schinke, and B. Strauss (Eds.), Dictionary of Sport Psychology: Sport, Exercise, and Performing Arts. London, UK: Academic Press (pp. 270-272).

Zhang, R., and Fujimori, S. (2020). The role of transport electrification in global climate change mitigation scenarios. *Environmental Research Letters*, *15*(3), 034019. https://doi.org/10.1088/1748-9326/AB6658

Zhao, X., Doering, O. C., and Tyner, W. E. (2015). The economic competitiveness and emissions of battery electric vehicles in China. *Applied Energy*, *156*, 666–675. https://doi.org/10.1016/J.APENERGY.2015.07.063