

# The Influence of Lock-in Dynamics and Industrial Policy on the Transition to EV Manufacturing in South Africa

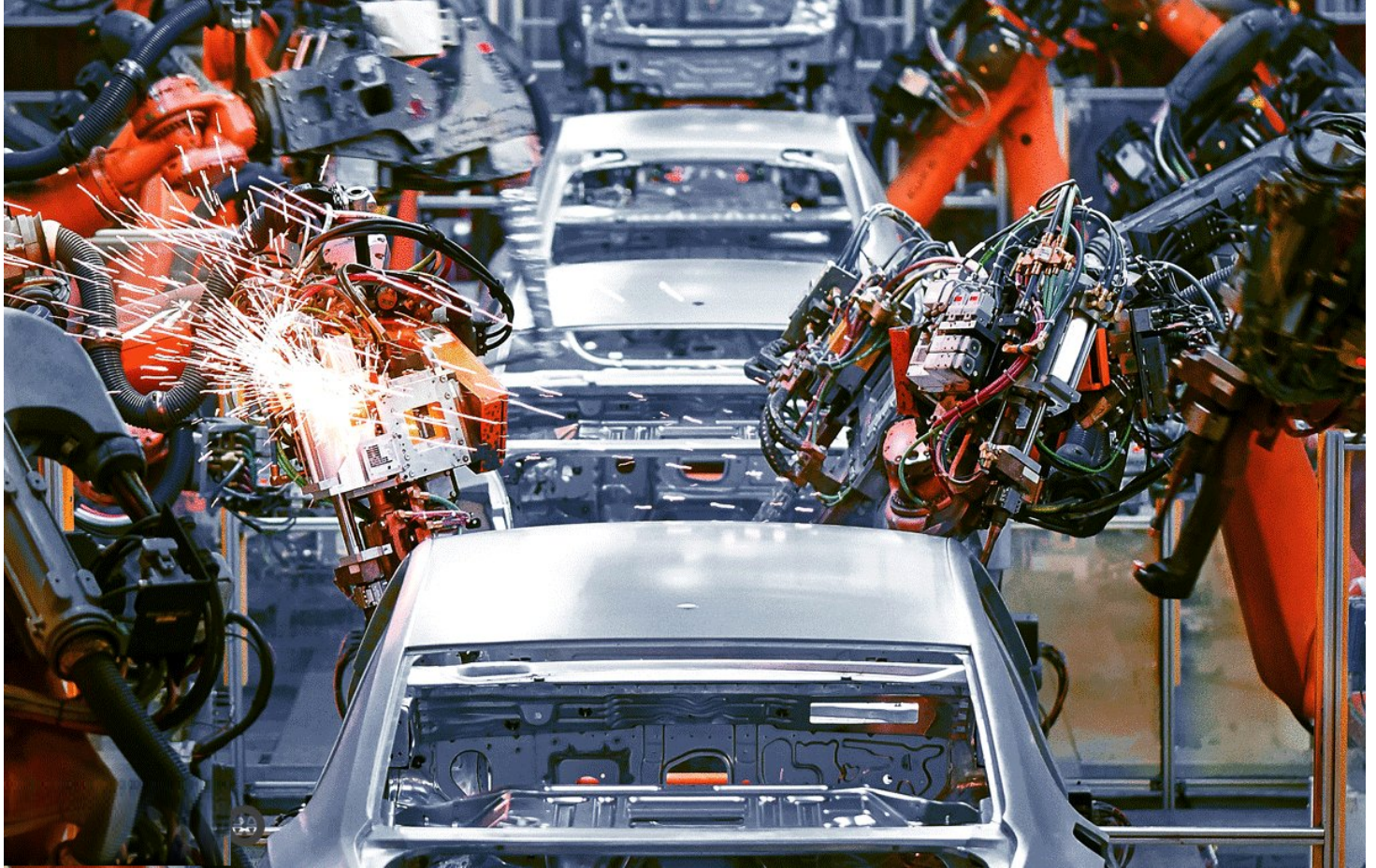


Figure 1: [imotoimoto.co.za](http://imotoimoto.co.za)

Master's Thesis | MSc Management of Technology  
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## Executive Summary

The global pursuit of sustainability is reshaping how industries operate. Across the world, sectors such as energy, transport, manufacturing, and agriculture are shifting their focus toward cleaner technologies and lower emissions. One of the most visible examples of this shift is the automotive industry, where the move from internal combustion engine (ICE) to electric vehicle (EV) manufacturing is now well underway. Major automotive-exporting countries such as Germany, Japan, China, and the United States have begun adapting their production toward EVs to stay competitive in a changing market. South Africa, home to one of the most established automotive manufacturing sectors in the developing world, faces the same pressure. Yet its transition from ICE to EV manufacturing remains slow, and the reasons behind this are not yet well understood.

External pressures are mounting on South Africa's automotive sector to move away from ICE production. Shifting global demand, tightening emissions regulations, and the risk of losing access to key export markets all push the country toward EV manufacturing. Despite this pressure, the response from the sector has been slow. This suggests that the barriers holding the transition back lie within the country itself, in how the industry is built and how it is governed. To examine this, the thesis asks how lock-in dynamics and the industrial policy regime shape South Africa's transition from ICE to EV manufacturing.. Two sub-questions work toward answering this, both adopting the six-domain lock-in framework introduced by Helmrich et al. (2023), which covers the technological, economic, social, individual, institutional, and epistemic domains. The first sub-question identifies which lock-in mechanisms constrain the transition and how they interact across these domains. The second examines how the industrial policy regime reinforces or challenges these mechanisms. The research uses a qualitative research approach, drawing on a systematic analysis of academic literature, industrial policy documents, and sector reports. Five national policy instruments were assessed: the APDP, SAAM 2035, the EV White Paper, Section 12V of the Income Tax Act, and SAREM. Every provision was classified as reinforcing the lock-in, challenging it, or neutral.

The first analysis identifies lock-in mechanisms in all six domains, and it shows that these mechanisms do not stand alone. Several of the barriers found in one domain are sustained by conditions in another, and together they form reinforcing chains that run through the production side, the demand side, and the policy response itself. This interdependence means that the lock-ins cannot be treated as separate problems, as addressing one in isolation leaves it renewed by the others. The analysis also shows that the domains do not carry equal weight: some act as the sources of this reinforcement while others are largely on the receiving end, with the institutional and economic domains emerging as the most consequential lock-ins in the South African case.

The second analysis looks at the policy side, and it finds a regime caught in the middle of its own transition: the direction of policy has changed, but the weight of it has not. The older instruments, which still carry most of the sector's financial support, continue to reward ICE production. The newer instruments push toward EVs, but their reach is narrow. There is also a contradiction within the regime itself, as the state now supports EV production while its tax rules still make EVs more expensive to buy than their combustion equivalents. The two analyses are then placed against each other, and this comparison sorts the lock-ins into three groups. Some are addressed by at least one policy instrument. Some are not addressed at all. And some are addressed on paper yet still persist in practice, which shows that having a policy in place is not the same as the policy taking effect. It is this third group that proves the most revealing about the state of the transition.

The thesis concludes that the transition is held back by a self-sustaining structure of lock-in, which policy has begun to challenge at the edges but not at its sources. In simple terms, the barriers renew one another faster than the current instruments can break them. Based on these findings, recommendations are developed for three groups: policymakers, existing automotive companies, and new EV ventures. The overall message of the research is that no single instrument can carry the transition on its own; what matters is whether the actors involved can be brought to act together. This question falls outside what a document-based study can answer, and the research therefore remains open for further work on the collaboration between these actors, on the implementation of the policies now in force, and on how the same lock-in pattern plays out in other developing economies.

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Anuj Tayade  
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## List of Abbreviations

APDP Automotive Production and Development Programme

DTIC. Department of Trade, Industry and Competition

EU European Union

EV Electric Vehicle

GDP Gross Domestic Product

ICE Internal Combustion Engine

MIDP Motor Industry Development Programme

MOT Management of Technology

MSc Master of Science

NAACAM National Association of Automotive Component and Allied Manufacturers

NAAMSA National Association of Automobile Manufacturers of South Africa

NEV New Energy Vehicle

OEM Original Equipment Manufacturer

PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Rand South African Rand (Currency)

SAAM South African Automotive Masterplan (2035)

USD United States Dollar

R&D Research and Development.

SAREM South African Renewable Energy Masterplan

GVC Global Value Chain

# 1.Introduction

## 1.1 Background and Context

For decades, South Africa has built one of the most successful automotive manufacturing sectors in the developing world. The industry contributes 5.3% to the national GDP and employs around 116,000 people (Macpherson et al., 2022). In 2023, it exported a record 399,594 vehicles and R270.8 billion in components to various markets, with the European Union accounting for over half of export revenue (NAAMSA, 2024). Seven multinational OEMs BMW, Ford, Isuzu, Mercedes-Benz, Nissan, Toyota, and Volkswagen anchor the production system, and two out of every three vehicles manufactured are destined for export (AIEC, 2024).

However, this success has been built entirely on internal combustion engine technology, with over 99% of vehicles produced in the country being ICE models. The difference between the two technologies lies in the powertrain the system that generates a vehicle's power and delivers it to the wheels. An ICE powertrain consists of an engine, a fuel system, a transmission, and an exhaust system; an electric powertrain replaces all of this with a motor, a battery pack, and power electronics. The transition is therefore not a redesign of the vehicle but a replacement of its core, and it is exactly this core that South Africa's plants, component firms, and workforce have specialised in. And while export volumes are large, the industry remains embedded in foreign-controlled production networks, dependent on multinational OEMs for technology, investment decisions, and high-value components (Barnes et al., 2021; Wuttke, 2022). This dependence means that South Africa's automotive future is shaped not only by domestic decisions but by shifts in the very markets it serves.

Those markets are now undergoing a fundamental transformation. The global push toward sustainable energy and urban transport is reshaping the automotive industry, with the emergence of electric mobility challenging the dominance of ICE-based production systems worldwide (Dijk et al., 2013; Sovacool et al., 2019). The European Union South Africa's largest automotive export destination has committed to banning the registration of new ICE vehicles from 2035 (Menyhárt, 2024). But the EU ban is not the only pressure. Global OEMs are accelerating their own electrification strategies: Volkswagen, BMW, and Mercedes-Benz have all announced plans to shift significant portions of their global production to EV platforms, yet none have committed to manufacturing EVs in South Africa (NAAMSA, 2025). At the same time, Chinese EV manufacturers are rapidly expanding into markets that South Africa has traditionally supplied, offering cheaper vehicles that undercut SA's ICE exports (NAACAM, 2025).

The competitive threat is therefore twofold. First, South Africa risks losing its existing ICE export markets. Second, it is being bypassed in the emerging EV market. The effects are already visible: exports fell 22.8% in 2024, 12 component firms were closed, and 4,000 jobs were lost (NAACAM, 2025). Yet despite this mounting pressure, the policy framework particularly the APDP and SAAM remains calibrated to ICE production (Bronkhorst et al., 2013), favouring incumbent producers while excluding potential new EV manufacturers.

The domestic market forms the other side of this picture, and it cannot be left out of the analysis. While production is export-oriented, the home market has historically provided part of the volume base on which plant-level production rests (Barnes et al., 2021), and the state's own transition policy ties the development of local EV manufacturing to the growth of domestic uptake (the DTIC, 2023). That uptake, however, remains minimal: the cumulative passenger EV fleet stood at only a few thousand vehicles by the end of 2024, held back by high prices, sparse charging infrastructure, and an unreliable electricity supply (GreenCape, 2025). A transition under external pressure therefore also depends on conditions at home, which is why this research examines the domestic market alongside the production system rather than treating exports as the whole story.

This situation resembles what the transitions literature refers to as lock-in, where decades of investment in a particular technology create self-reinforcing dynamics that make it progressively difficult to shift toward alternatives, even when the need for change is evident (Arthur, 1989). This dynamic is acutely visible in South Africa, where lock-in has moved well beyond the technological domain: policy frameworks like the APDP have co-evolved with ICE production to the point where restructuring faces resistance at every institutional level (Foxon, 2002).

## 1.2 Problem Statement

The South African automotive industry is built upon years of investment in Internal Combustion Engine (ICE) manufacturing, from production facilities and supplier networks to workforce training and industrial policy (Black, 2009; Damoense and Simon, 2004). This long-term commitment has created an industry that is highly capable but narrowly specialised. The rapid global shift toward electric mobility now places this specialised industry under pressure it was never designed to withstand.

The country lacks the core technologies required for EV manufacturing (Chigbu and Umejesi, 2024; Tongwane and Moeletsi, 2021), the workforce is trained exclusively for ICE production (Macpherson et al., 2022), and the policy frameworks that govern the sector were designed to incentivise ICE production rather than enable a transition away from it (Bronkhorst et al., 2013; DTIC, 2021). The infrastructure to support EVs remains underdeveloped (Moeletsi, 2021; Scholtz et al., 2023; Showers and Raji, 2021). These are not isolated problems they are elements of a system that has been optimised for one technology over decades and now struggles to accommodate another. Helmrich et al. (2023) describe this condition as lock-in, where the legacies of past investment create self-reinforcing pressures that make a system resistant to change even when future needs demand it.

The domestic market offers little counterweight. South Africa's own EV market is growing, but from a very low base (Mordor Intelligence, 2025). It is not the destination for most local production, yet it forms the environment in which manufacturers operate. A home market with few electric vehicles, thin charging, and an unreliable charging grid gives no domestic pull toward electric production. It signals instead that the supporting systems remains built for the combustion engine.

The main issue South Africa must address is the manufacturing transition, and this is where the focus of this research lies. Demand-side conditions, including vehicle prices, charging infrastructure, and consumer awareness, are studied because they directly and indirectly affect this transition: directly, because the domestic market is part of the volume a plant presents when EV production is allocated at parent-company level (Barnes, Black and Monaco, 2021); and indirectly, because a home market that

is not ready for the technology weakens the case for producing it in the country. Consumer behaviour is analysed in this capacity, not as a study of adoption in its own right.

In South Africa's case, these pressures are compounded by the fact that the transition is not domestically driven but externally imposed through tightening EU export market requirements, leaving an industry with limited strategic autonomy facing a deadline it did not set. What makes this a problem rather than a delay is that the shift is technically feasible. Recent research indicates the economic and environmental case for EVs holds across most contexts, provided the energy mix supports it (El Fadar et al., 2026), and technical routes exist, including the conversion of existing ICE platforms to electric drive (Mayingi, Thango and Okojie, 2026). Yet implementation continues to lag behind stated policy ambitions (Mateko et al., 2026). The transition is viable, but stalled. The consequences are already visible in declining exports, firm closures, and job losses that signal a structural crisis the current policy framework is not designed to address.

### 1.3 Objective and RQs

South Africa has a mature automotive sector built over decades, yet it faces considerable challenges in moving from internal combustion engine (ICE) to electric vehicle (EV) manufacturing. There remains a research gap in understanding which barriers hinder this transition and how. This thesis objective is twofold: First, it seeks to identify the lock-in mechanisms that constrain South Africa's transition from ICE to EV manufacturing. Second, it aims to evaluate the industrial policy frameworks currently in place, and to suggest corrections that could strengthen these policies in support of the transition. While the study focuses on South Africa, its findings can also be applied to other countries facing a similar technological transition from ICE to EV manufacturing.

The overarching research question guiding this study is:

*How do lock-in dynamics and the industrial policy regime shape South Africa's transition from internal combustion engine (ICE) to electric vehicle (EV) manufacturing?*

To address the main research question, this thesis breaks it down into 2 interrelated sub-research questions:

1. *What lock-in mechanisms characterize South Africa's transition from ICE to EV manufacturing, and how do they interact?*
2. *How are these lock-in mechanisms reinforced or challenged by the existing industrial policy regime?*

### 1.4 Relevance to MSc. MOT

This thesis aligns well with the MSc Management of Technology (MOT) programme. It examines a technological transition the shift from internal combustion engine (ICE) to electric vehicle (EV) manufacturing within a specific industrial context. The research draws on several themes central to the programme. From the Technology, Innovation and Organisation theme, the thesis analyses how incumbent firms, institutions, and established routines shape the automotive sector's response to technological change. It also examines why these structures resist the transition. This connects directly

to the Technology Dynamics course, which is the central concern of this study. The course studies how technologies evolve over time, and what different dynamics are into play in either supporting the technology or restricting it. Lock-in explains why a technology can persist and resist change, even when alternatives emerge. These dynamics are used to explore development pathways and to inform strategic policy recommendations.

Managing technological transitions sits at the core of the MOT curriculum. It explains how a technology evolves over time, and how a new technology eventually emerges and replaces the incumbent one. This is precisely what the thesis examines, as EVs rise to challenge established ICE manufacturing. Drawing on these courses, the thesis applies the concepts of technological change and lock-in to a real-world transition.

The research's aim is not just limited to academics, it also extends to industry and governance. MOT teaches how firms manage technology as a strategic resource. South Africa's passenger carmakers face such a shift. For them, this is a strategic problem, not just a technical one. Managing that kind of technological shifts is what the programme teaches. This thesis maps the barriers behind this particular shift. It shows where the real friction sits. This reflects MOT's core aim of analysing and managing technology.

## 1.5 Scientific contribution and societal relevance

This research makes two main contributions to the literature. First, it applies Helmrich et al.'s (2023) six-domain lock-in framework to an automotive ICE-to-EV transition, a context where it has not been used before. This extends the framework from its usual energy and infrastructure settings to a new sector. Second, it provides South Africa-specific literature on lock-in and the EV transition, linking these lock-in mechanisms to the country's industrial policy regime and showing how policy can reinforce or weaken the forces that hold a technology in place.

From a societal perspective, this research addresses the challenge of transitioning an established, ICE-dependent automotive sector towards EV manufacturing. The sector is a major source of employment, investment, and export revenue for South Africa. External pressures, such as the EU's 2035 ICE ban, now threaten this position and could place jobs and industrial capacity at risk. The relevance is not limited to the production side. The state's own transition strategy ties local EV manufacturing to the growth of the domestic market (the dtic, 2023), so the conditions facing South African consumers, including vehicle prices, charging access, and the reliability of the electricity supply, are part of the same problem. A transition that succeeds would therefore serve the home market as well, making cleaner vehicles more affordable and accessible to South African buyers. By identifying the barriers to an EV transition and assessing how policy shapes them, the research offers insight that can help policymakers and industry act before the lock-in deepens. While the focus is on South Africa, the findings are relevant to other countries facing a similar transition from ICE to EV manufacturing.

## 1.6 Thesis Outline

This thesis is organized into 6 chapters. Chapter 1 introduces the study, setting out the background and motivation, the problem statement, the research objective and questions, the relevance to the MOT programme, and the scientific contribution and societal relevance. Chapter 2 presents the literature review, situating the study within existing work on lock-in theory, automotive transitions in

developing economies. Chapter 3 outlines the theoretical framework, declaring Helmrich et al.'s (2023) six-domain lock-in framework as the analytical lens and operationalising each domain for empirical application. Chapter 4 details the methodology. It covers the research design and scope, the systematic literature search following the PRISMA protocol, and the selection of the five policy instruments. It also explains the twofold analysis, where lock-in mechanisms and their interdependencies are first identified, and each policy instrument is then assessed against the six domains. Chapter 5 presents the results. It begins with the status of EV manufacturing in South Africa, followed by the lock-in findings per domain and the interdependencies between them. The chapter closes with the assessment of the five policy instruments and the evidence tables that support it. Chapter 6 discusses the findings in relation to the literature and answers the sub-questions and the main research question. It then develops recommendations for policymakers, existing automotive companies, and new EV ventures, and closes with the limitations of the research and the directions for future work.

## Chapter 2

# Literature review

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This chapter positions the research within the existing literature. It first describes the search strategy through which the literature was gathered and narrowed down. The review itself then covers three areas: the pressures that set the EV transition in motion, the lock-in and path dependence literature that explains why industries resist such transitions, and the studies on the South African EV market and industry. The chapter closes by identifying the gap in the literature that this research addresses.

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## 2. Literature Review

### 2.1 Initial Literature Review & Search Strategy

The PRISMA methodology was used to guide the search and selection of literature. This consists of four stages: identification, screening, eligibility, and inclusion (Moher et al., 2009). The primary database used was Scopus, supplemented by targeted searches in ScienceDirect, IEEE Xplore, and the TU Delft repository for relevant theses and working papers. Connected Papers was used to map citation networks around foundational lock-in studies, which surfaced thematically related work not captured through keyword search alone.

The search was conducted in stages, each corresponding to a thematic cluster. The first stage focused on the South African automotive context and the current state of its EV market, using keywords such as "South Africa automotive sector", "electric vehicles in South Africa", "EV adoption South Africa", and "legacy ICE infrastructure". The second stage addressed the technologies surrounding the transition, including EV manufacturing, charging infrastructure, and grid integration. The third stage shifted toward the dynamics of transition itself, using keywords such as "lock-in", "path dependence", "automotive transition barriers", and "ICE to EV manufacturing".

These searches returned 393 records in total. The records were then screened and filtered: literature focusing on environmental impact and carbon emissions was removed first then 162 sources remained, followed by sources not specific to the South African context or not addressing technology transition and lock-in. This reduced the set to the 26 sources that form the basis of this review and 2 sources were provided by the supervisors. Alongside these, grey literature, including industry reports from naamsa, NAACAM, and GreenCape and government policy documents on the South African automotive sector, was consulted separately. This grey literature is not part of the systematic count, but provides the sectoral data and policy detail that the academic sources do not capture. The PRISMA process is visualised below.

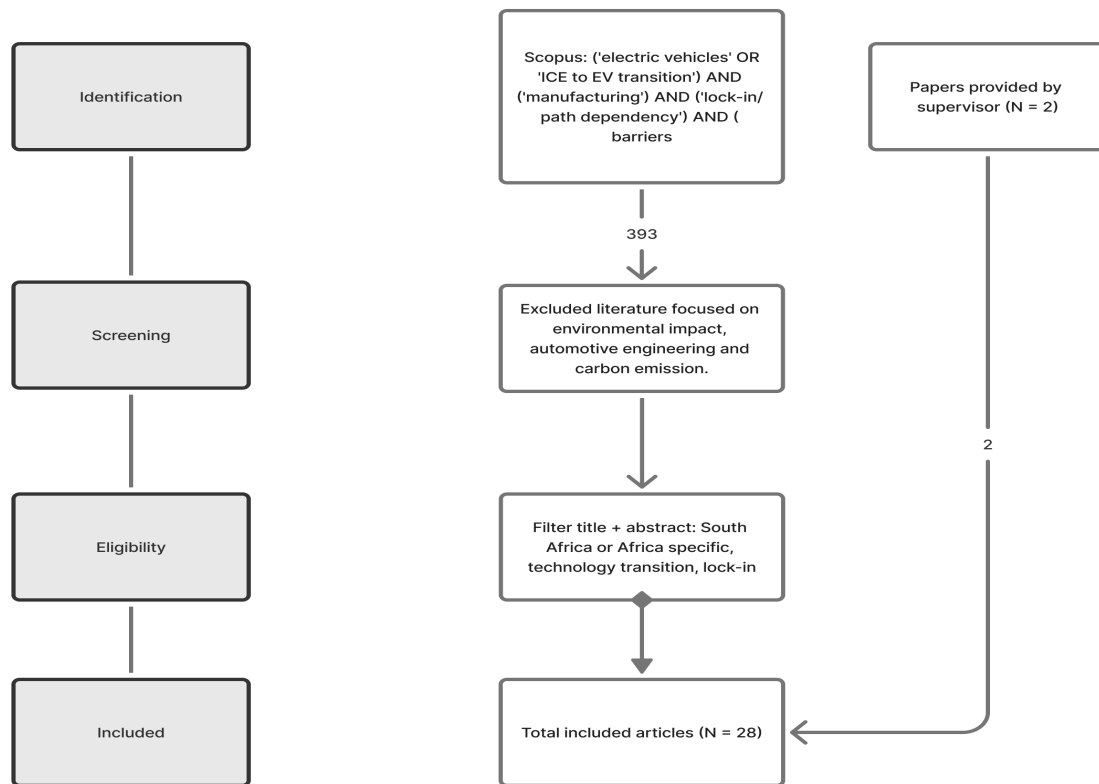


Figure 2.1 PRISMA diagram

## 2.2 Expanded Literature review

### 2.2.1 Lock- In

The concept of lock-in emerged from the economics of technology. Arthur (1989) established the foundational mechanism, showing that increasing returns to adoption can lock a technology into dominance independent of its inherent merit. Cowan and Hultén (1996) applied this insight to the automotive sector, demonstrating that the electric vehicle's historical failure to displace the ICE was not a matter of technological inferiority but of systemic entrenchment: the ICE became embedded in fuel infrastructure, regulatory frameworks, consumer expectations, and industrial supply chains that collectively made alternatives unviable. Foxon (2002) extended this argument to the institutional dimension, showing that path dependence in regulation, policy design, and sectoral governance reinforces incumbent technologies as strongly as physical infrastructure does. Lebeau et al. (2012) traced how the broader societal context training networks, regulations, and cultural acceptance adapted around ICE use. These contributions show that lock-in operates through several mechanisms at once. Klitkou et al. (2015) catalogued nine such mechanisms in Nordic road transport, and Helmrich et al. (2023) synthesised them into a six-domain framework.

A further strand of this literature examines how these mechanisms relate to one another. Unruh (2000) argued that technologies and institutions co-evolve, reinforcing each other in what he termed the

techno-institutional complex. In later work, he suggested that escaping such a condition may require forces from outside the system (Unruh, 2002). Seto et al. (2016) reach a similar conclusion, showing that technological, institutional, and behavioural lock-ins are tightly linked and tend to strengthen one another over time. Simoens, Leipold and Fuenfschilling (2022) examine these interactions directly, finding that deeper lock-ins often reinforce more superficial ones. Taken together, this literature establishes both how lock-in mechanisms form and how they depend on each other

### **2.2.2 South African EV market**

The South African EV market has not been able to grow as expected. Early forecasts projected steady sales growth through the following decade, but that uptake never arrived (Grant, 2014). EVs remain a small share of the market, held back by high purchase prices and an unstable electricity supply (Showers and Raji, 2021). Weak policy support and limited model availability compound the cost problem (Moeletsi, 2021). Awareness of the technology is low among consumers, and the automotive policy framework was never designed with EVs in mind (Huang, 2023). These patterns are not unique to South Africa, as cost, infrastructure, and trust in the technology shape adoption across Sub-Saharan Africa (Ajao et al., 2025). Infrastructure operates as a constraint in its own right, with limited grid capacity, load management problems, and high connection costs restricting where charging can be built (Mpiana and Chowdhury, 2023). The pressure runs in both directions. Existing production volumes are exposed as export markets phase out combustion vehicles, while the domestic charging and generation base is not yet ready to support an alternative (Oni and Longe, 2024). Pricing, policy, and infrastructure therefore each hold this market back.

The literature approaches South Africa's position from several directions. Across Sub-Saharan Africa, absent policies, high prices, and weak charging infrastructure are identified as the primary barriers (Gicha et al., 2024). Within South Africa, a coal-dependent grid limits the environmental gains that electrification would otherwise deliver (Tongwane and Moeletsi, 2021), and charging infrastructure remains thin (Scholtz et al., 2023). The employment risk sits in components rather than assembly, with component manufacturing losing labour under most electrification scenarios, and the extent depending on battery localisation and the reliability of supply (Pillay and Dall-Orsoletta, 2024). The competences the sector holds are not those an EV production system would require, and the frameworks meant to develop them lag behind what the transition demands (Ojo, Kanakana-Katumba and Nenzhelele, 2025). The just-transition angle surfaces through organised labour and policy discussions (ILO, 2025). A second body of work addresses production. The MIDP and APDP frameworks have been examined as industrial policy instruments (Damoense and Simon, 2004; Bronkhorst et al., 2013), multinational strategy is shown to have shaped South Africa's place in the global industry (Black, 2009), and operating within a value chain dominated by multinationals presents its own policy challenges (Barnes, Black and Monaco, 2021). South Africa's position is that of a latecomer reacting to a change it did not set in motion, facing constraints common to emerging automotive economies attempting to follow China's path, though those constraints fall unevenly across countries who have growing economies (Lema, Wuttke and Konda, 2024). Policy uncertainty, unaffordable vehicles, and electricity constraints continue to hold the market back (GreenCape, 2025). The policy landscape has since shifted, with the New Energy Vehicles White Paper (DTIC, 2023) and the Section 12V allowance signalling a change in direction, though practice still lags behind these stated ambitions (Nemeckova et al., 2026). Research attention has thus moved from adoption barriers to the changing policy landscape, yet the production side of the transition remains largely uncovered.

## 2.3 Knowledge Gap

The global push toward sustainability has reshaped how the automotive industry is studied, with a growing body of work examining the shift from ICE to EV technology. Yet when this literature is read against the South African case, several gaps stand out. First, there is no direct study of the ICE-to-EV manufacturing transition in South Africa. Existing work is dominated by environmental analysis, such as carbon-mitigation potential and grid emissions (Tongwane and Moeletsi, 2021), and consumer-side concerns like purchase barriers and charging access (Showers and Raji, 2021; Scholtz et al., 2023). These contributions are valuable, but they leave the production side of the industry and the challenges faced by the industry largely unexamined.

Second, the country's own capability to support this technology has not been assessed. South Africa hosts seven major OEMs but holds no production capability in cells, battery packs, or e-drivetrains. This dependence on foreign principals is acknowledged in passing, but never analysed as a lock-in mechanism shaping what the transition can realistically look like.

Third, although there is a substantial body of work on lock-in, it has not been applied to the South African automotive sector. Mateko et al. (2026) acknowledge lock-in effects in the sector but stop short of identifying the specific mechanisms producing this lock-in, how they reinforce one another, or how they might be overcome. The question of which barriers actually constrain the transition still remains open.

Beyond these gaps lies the question of policy coordination. China's experience shows that breaking automotive lock-in requires coordinated industrial policy directed at manufacturers, suppliers, and consumers simultaneously. Gomes et al. (2023) demonstrate this through three interrelated variables: demand structure, sectoral complementarities, and policy coordination, arguing that effective industrial policy must account for the conflicting interests of all actors, since misalignment across these dimensions has driven uneven NEV deployment even within China. Whether comparable coordination exists in other emerging automotive economies remains largely unexplored. This thesis addresses these gaps by diagnosing the lock-in mechanisms operating in South Africa's automotive sector, mapping how they interact, and assessing whether the current policy mix assembles a configuration capable of breaking automotive lock-in, or whether it inadvertently reinforces the very barriers it was designed to overcome.

## Chapter 3

# The Six Domains of Lock-in

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This chapter develops the analytical framework used in this research: the six-domain lock-in taxonomy of Helmrich et al. (2023), which distinguishes technological, economic, social, individual, institutional, and epistemic lock-in. Each domain is presented in the same way the lock-in is first explained in general terms, and then translated to what it means in the automotive industry. The chapter also examines how the domains interact with one another, since lock-ins rarely operate alone. It closes by operationalising the framework for empirical use, with a summary table that serves as the reference point for the analysis in the chapters that follow.

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### 3. Theoretical Framework

Lock-in represents a fundamental barrier to technological transitions in complex technical systems. Rather than viewing lock-in as a singular technological or economic problem, contemporary scholarship recognises lock-in as a systemic condition operating simultaneously across multiple reinforcing domains. Helmrich et al. (2023) synthesise infrastructure lock-in literature by identifying six analytically distinct domains through which systems resist change: technological, economic, social, individual, institutional, and epistemic. Each of these domains is discussed in detail in the sections that follow.

#### 3.1 Technological Lock-In

Technological lock-in occurs when a particular technology becomes deeply embedded within physical infrastructure systems, making switching to alternatives economically and technically infeasible despite superior alternatives being available (Helmrich et al., 2023). The core problem is not technological superiority but rather the accumulation of physical infrastructure over decades that constrains future choices. Once factories are built for specific technologies, distribution networks are optimised for particular products, and supply chains are structured around incumbent components, switching to alternatives becomes extraordinarily difficult. The physical infrastructure does not simply disappear when a better alternative emerges. For instance, petrol stations cannot instantly convert to charging stations. Manufacturing facilities cannot easily retool from ICE to EV production. Supply chains organised around engine components cannot instantly reorganise around battery systems. In each case, the incumbent technology has become physically embedded in the systems that surround it. This is what Helmrich et al. (2023) call *technological lock-in*.

Arthur (1989) provides the theoretical foundation for understanding how technologies become locked in through self-reinforcing adoption dynamics. When a technology achieves early market penetration, positive feedback mechanisms favour continued investment rather than allowing alternatives to compete. Economies of scale represent one such mechanism as production volume increases, per-unit production costs decline, making the incumbent technology cheaper than alternatives and increasing market share further, which reduces costs even more. Network externalities represent another mechanism as more people use a technology, it becomes more valuable to everyone using it. A fuel distribution network becomes more valuable as more vehicles depend on that fuel type. These feedback mechanisms are self-reinforcing, creating cycles where early dominance perpetuates itself. Historical contingencies early in a technology's development can therefore determine technological dominance for decades, even if alternative technologies would have been superior had they achieved early adoption instead.

Hughes (1983) extends this understanding by demonstrating that large technical systems do not exist in isolation. Large technical systems become deeply embedded within their social, economic, and institutional contexts, developing material interdependencies that make change difficult. The automobile system, for example, encompasses far more than vehicles alone. It includes fuel production infrastructure, fuel distribution networks, service station designs, vehicle design standards, manufacturing facilities, supply chains, safety regulations, and consumer expectations. All these elements are coordinated around a particular technological system. Changing one element cascades through others, creating coordination problems that make system-wide change difficult. Helmrich et

al. (2023) identify three specific mechanisms through which this embeddedness sustains technological lock-in. First, infrastructure accumulation spreads physical infrastructure geographically over time, creating spatial density where infrastructure is distributed across regions rather than concentrated in one location. A petrol distribution network spans countries; individual service stations cannot be replaced without the entire system remaining functional. Second, technical compatibility requirements tightly couple systems through compatibility standards and specifications. Vehicles require compatible fuel systems manufacturing equipment requires compatible component specifications; supply chains require compatible logistics. These compatibility requirements mean changes in one part of the system cascade through other parts, raising the total cost of transition far beyond the apparent cost of replacing individual components. Third, infrastructure design life means that industrial infrastructure is designed to operate for extended periods. Manufacturing facilities typically operate for 25-40 years; fuel distribution infrastructure operates even longer. This long useful life means infrastructure built for incumbent technologies continues operating and shaping system dynamics for decades even after superior alternatives emerge.

These three mechanisms combine to create what Klitkou et al. (2015) call technological interrelatedness, where transport infrastructure, vehicle design standards, and fuel systems become so tightly coupled that modifying any single element requires modifying others. No individual component can be changed in isolation, creating system-level lock-in that cannot be solved through technological innovation alone. Understanding technological lock-in means recognising that infrastructure embeddedness creates genuine technical and coordination barriers that persist independent of technological superiority or the availability of alternatives

### 3.2 Economic lock-in

Economic lock-in refers to cumulative financial commitments to incumbent technologies through capital investments, sunk costs, and financial structures that create incentives for continued incumbency (Helmrich et al., 2023). The fundamental problem emerges from the nature of large-scale capital investment. Once substantial financial resources are committed to incumbent technologies, recovery of those investments depends entirely on continued use of that technology. Switching to alternatives requires absorbing unrecovered capital as financial losses while simultaneously funding entirely new investments in alternative technologies. This dual financial burden writing off old investments while funding new ones creates formidable barriers even when alternatives are technologically superior. Arthur (1994) and Foxon (2002) demonstrate that firms cannot simply abandon billion-dollar investments without facing financial catastrophe. The decision to transition becomes economically irrational from a financial perspective, not because alternatives are inferior but because sunk costs create path dependency where previous commitments constrain future choices.

Three reinforcing mechanisms explain how economic lock-in sustains incumbent technologies. The first is economies of scale and increasing returns (Arthur, 1989, 1994). When a technology achieves large market share, per-unit production costs decline through accumulated production experience and operational efficiency (Klitkou et al., 2015). This cost advantage increases market share further, reducing costs even more and creating a self-reinforcing cycle (Arthur, 1989). Early-stage alternatives lack the production volumes needed to achieve equivalent scale economies. The result is higher per-unit costs and lower adoption, perpetuating cost disadvantages regardless of technological merit (Foxon, 2002). The second mechanism is *switching costs* (Klemperer, 1995). Transitioning to new technologies requires workforce retraining, supply chain reorganisation, and production efficiency

losses during extended transition periods (Klitkou et al., 2015). These costs accumulate during transition phases, making change financially painful regardless of long-term benefits. The third mechanism is *financial structures*. Subsidies, tax codes, and lending frameworks calibrated to incumbent technologies create below-cost pricing for existing technologies (Unruh, 2000). Once established, these structures persist through institutional inertia even after original policy rationales change (Pierson, 2000), perpetuating incumbent advantages (Unruh, 2002).

In the automotive industry, these economic mechanisms combine to create powerful barriers against ICE to EV transitions. Major automobile manufacturers have invested billions in manufacturing facilities optimised for ICE production. A single automotive factory represents \$5-8 billion capital investment with useful lifespans of 25-40 years. Manufacturers built many recent facilities with expectations of decades of ICE production profitability. For these manufacturers, transitioning to EV production while maintaining existing ICE capacity appears economically irrational. They face a choice between two costly options, either write off unrecovered ICE facility investment to transition to EV production, or maintain parallel ICE and EV production systems, which requires separate capital investment while existing ICE capacity remains financially committed (Turnheim and Sovacool, 2012). Supply chain lock-in compounds this problem significantly. Incumbent suppliers have invested in manufacturing equipment, logistics systems, and technical expertise concentrated around ICE components. These suppliers face their own switching costs, retooling production facilities toward EV components electric motors, power electronics, battery management systems requires separate investment in new production equipment. Switching means absorbing losses on unrecovered ICE supplier investments. Economies of scale similarly advantage incumbent ICE production. A century of ICE vehicle production has created unprecedented economies of scale in engine manufacturing, transmission systems, and fuel system assembly. Battery production, despite rapid cost reductions, remains more expensive per unit than ICE engines because global EV battery production remains orders of magnitude smaller than ICE production volumes. This scale disadvantage perpetuates itself through lower EV adoption relative to ICE vehicles, maintaining production volume disadvantages for battery manufacturing.

Economic lock-in thus operates through mechanisms that appear rational from individual firm perspectives but collectively sustain incumbent technologies. Firms making economically rational decisions based on sunk costs perpetuate technological entrenchment. The result is what Seto et al. (2016) identify in infrastructure transitions, rational economic actors making individually rational decisions that collectively sustain system-level lock-in. Breaking economic lock-in requires not merely technological innovation or policy change but coordinated intervention that addresses accumulated sunk costs, reorients financial structures, and creates conditions where switching becomes economically rational despite unrecovered losses on existing investments.

### 3.3 Social lock-in

Communities do not exist in abstract space independent of the technologies they use and produce. Rather, communities organise their entire social structures demographic patterns, occupational expectations, family traditions, and collective identities around the technologies that sustain their livelihoods. Over decades, these social structures become so deeply embedded that communities come to regard existing arrangements as natural and inevitable rather than as contingent choices. This embeddedness creates what Helmrich et al. (2023) call social lock-in. The accumulation of norms, habits, and collective expectations that constrain what alternatives communities regard as socially

acceptable. Intergenerational occupational transmission operates powerfully through this process communities develop occupational pathways wherein children follow parents' trajectories into established occupations, supported by educational institutions, training systems, and family expectations that perpetuate these patterns (Geels, 2005). When technologies change, these occupational pathways become disrupted. Children can no longer follow expected progression into careers their parents occupied. Collective technology identity similarly sustains social lock-in through emotional attachment accumulated over generations. Communities develop social identities connected to incumbent technologies, creating emotional bonds and sense of belonging around shared occupational and technological practices (Tripsas and Gavetti, 2000). These mechanisms operate at collective rather than individual levels, creating community-wide constraints on what alternatives are socially acceptable.

Social lock-in constrains feasible design space through what Helmrich et al. (2023) call implicit service entitlements. Communities come to regard existing service characteristics as normal and expected deviations from these patterns appear as degradations rather than improvements. This means alternatives must not merely be technically and economically viable they must preserve service characteristics around which communities have organised their expectations and social structures. Markard and Truffer (2008) demonstrate this in energy transitions, showing how communities organised around centralised electricity systems resist distributed alternatives despite superior performance because alternatives disrupt established infrastructure expectations and occupational arrangements. Intergenerational occupational transmission creates particularly sticky social lock-in because transitions disrupting these pathways encounter powerful resistance rooted in disrupted family expectations and educational misalignment (Geels and Schot, 2007). Collective technology identity creates emotional attachment making transitions feel identity-threatening rather than progressive (Danneels, 2003). Smith and Raven (2012) note that these social mechanisms often prove more resistant to change than technological or economic factors because they operate through emotional and normative dimensions that rational arguments cannot address.

The automobile manufacturing sector exemplifies how powerfully social lock-in operates. Manufacturing communities organised around ICE vehicle production have built their entire social infrastructure around automotive employment for decades or longer. Population structures, housing patterns, infrastructure investment, educational systems, and family expectations have all developed around automotive manufacturing livelihoods. Communities expect continued manufacturing employment with clear occupational pathways from production worker to supervisory positions. Families expect children to enter automotive sector employment as their parents did, perpetuating occupational traditions across generations. Collective identity develops around automotive production expertise workers and communities take pride in "manufacturing world-class components" or "building engines," identities that become collectively held and passed across generations. Training systems develop to supply skilled workers for incumbent technologies; educational institutions organise curricula around producing workers for automotive occupations; families structure occupational expectations grounded in automotive manufacturing. When technological transitions from ICE to EV production require fundamentally different skills or reduce overall employment, the entire social infrastructure becomes misaligned. Training systems produce workers for occupations that no longer exist or that require entirely different competencies. Families' occupational expectations become unattainable. Educational pathways that once led predictably to automotive employment become obsolete. Communities experience this as social disruption rather than technological progress. Technological transitions threatening these collective identities feel like loss of community identity and disruption of intergenerational occupational transmission rather than progress toward superior

alternatives. Resistance to EV transitions emerges not from opposition to the technology itself but from genuine social disruption rooted in how communities have organised their entire social expectations around incumbent technologies.

Social lock-in thus represents constraints on what transitions are socially feasible, independent of technological or economic viability. Understanding social lock-in means recognising that feasibility encompasses not only what is technically possible or economically rational but what communities regard as socially acceptable within existing identity and occupational frameworks.

### 3.4 Individual lock-in

Helmrich et al. (2023) define individual lock-in as a microscale phenomenon, where the choices of a single decision-maker, or a small group, begin to hold the wider system in place. As a person grows familiar with their role, learning effects push them toward specialisation, which organisations reward as productivity (Klitkou et al., 2015). That expertise creates a tension between sticking with what works and exploring something new, and the familiar option usually wins (Uhl-Bien and Arena, 2018). Network externalities and collective action reinforce the choice, since adopting the same technologies as collaborators increases efficiency (Arthur, 1994; Foxon, 2002). The domain nests within institutional lock-in: institutions shape individuals, and individual decisions stabilise institutional patterns in return (Helmrich et al., 2023). Beneath this lies a personal reality. Individuals build careers and professional identities around incumbent technologies over decades, and that expertise becomes embodied intuitive judgement, not explicit learning. Levinthal and March (1993) call this a competency trap: the skills that make someone effective today become a liability when the technology shifts. Three biases reinforce the trap. Status quo bias favours the familiar even when alternatives are clearly better (Kahneman et al., 1991). Loss aversion weighs potential losses more heavily than potential gains (Kahneman and Tversky, 1979). Risk perception magnifies the asymmetry, since incumbents have known failure modes while alternatives carry uncertain risks (Slovic, 1987). These mechanisms operate below conscious thought.

Beyond rational economic considerations, psychological biases shape how individuals respond to technological transitions. Individuals invest years developing expertise in incumbent systems. They build professional reputations as experts in particular technological domains. They construct career identities around specific technologies and technical competencies (Schumpeter, 1942). When alternatives emerge, switching requires abandoning these accumulated investments years of mastery become less valuable, expertise-based authority diminishes, and professional identity becomes threatened. The certain costs of retraining are therefore substantial, ego costs of beginner status in unfamiliar technical domains, explicit learning effort required to develop new competencies, and temporary loss of technical authority within professional communities. These certain costs are weighted more heavily than uncertain gains from alternative expertise that may or may not materialise within remaining career spans. Tripsas and Gavetti (2000) demonstrate how managers' cognitive frameworks become wedded to incumbent technologies through learning histories, creating organisational inertia despite technological alternatives. Danneels (2003) shows how individual expertise sunk in incumbent technologies creates powerful resistance even among individuals rationally understanding transition imperatives. The mechanisms operate through embodied expertise making alternatives appear to require unrecovered learning investments, status quo bias making uncertain gains from alternatives appear less salient than certain costs of change, and risk perception making alternatives appear riskier despite objective similarity to incumbent system risks. Kahneman

(2011) notes these biases operate robustly across populations, suggesting individual lock-in represents fundamental cognitive constraints rather than individual irrationality.

In the automotive industry, individual lock-in operates powerfully among engineers, manufacturing managers, and supply chain decision-makers who have built careers around ICE technology expertise. Senior engineers have spent years developing embodied expertise in ICE engine design, thermodynamics, combustion optimisation, and transmission systems. This expertise represents substantial personal investment and has been the foundation of professional advancement, technical authority within the industry, and career identity. Learning electric motor design, power electronics, and battery management systems requires starting fundamentally new learning trajectories at career stages where learning returns are lowest. Engineers confront individual-level lock-in where switching expertise feels personally costly in ways economic or technological analyses do not capture. Status quo bias and loss aversion compound this barrier. The costs of retraining are immediate and certain, engineers must become novices, invest time learning, and lose technical authority temporarily. The benefits of EV expertise are uncertain and may not materialise within remaining career years. Rational self-interest therefore favours maintaining incumbent expertise rather than investing in uncertain alternatives.

Manufacturing managers face lock-in through operational mastery developed over decades. They have built sophisticated understanding of ICE vehicle production processes, quality management systems, supply chain coordination, and performance metrics optimised around ICE manufacturing. Converting to EV production requires abandoning this operational mastery and accepting extended periods of lower operational efficiency while new expertise develops. Risk perception amplifies these barriers, new technologies like batteries and power electronics are perceived as less reliable than well-established ICE systems despite being highly reliable technologies. For supply chain managers, individual lock-in creates resistance through decade-long relationships with ICE component suppliers, established quality metrics, and supply chain efficiencies perceived as more reliable than unknown EV supplier networks. Even when rationally recognising EV production necessity, individual psychological mechanisms sustain resistance through familiar expertise preferences, loss aversion around operational mastery, and risk perception biases.

Individual lock-in thus operates through mechanisms that economic incentives or technological innovation alone cannot overcome. These mechanisms reflect deep cognitive patterns in how individuals evaluate technological change, assess risk in unfamiliar domains, and protect expertise and identity investments accumulated over careers. Understanding individual lock-in means recognising that technological transitions require not merely individual motivation or economic incentive but psychological reorientation that addresses sunk expertise investments and shifts risk perception of alternatives.

### 3.5 Institutional lock-in

Governance structures, regulatory frameworks, and policy mechanisms do not happen by accident. They develop over time through decisions made by governments, industries, and other powerful actors. Once these institutions are established, they tend to stay in place even when circumstances change. Institutional lock-in refers to how incumbent technologies become embedded within governance structures and policy mechanisms in ways that make alternatives difficult (Helmrich et al., 2023). Unlike other forms of lock-in, institutional lock-in is often deliberately sustained by actors who

benefit from incumbent technologies. Pierson (2000) shows that political actors accumulate power through relationships with incumbent industries, making it difficult for alternative technologies to gain support. Regulatory capture occurs when industries influence the government agencies that are supposed to regulate them (Stigler, 1971). Once this happens, the rules remain in place to protect incumbent interests. North (1990) defines institutions as "rules of the game" that structure how people interact. Once rules are established around incumbents, they resist change because groups organise their interests around maintaining existing rules. Changing rules threatens these organised interests, creating political resistance to modification

Institutions sustain lock-in through multiple reinforcing mechanisms operating simultaneously across regulatory, policy, and financial domains. Regulatory frameworks become calibrated to incumbent technologies through standards evolved around specific technological characteristics. Safety standards, emissions regulations, and performance metrics reflect incumbent technology features and architectural assumptions (Wajcman, 2012). Modifying these standards appears as weakening protections even when modifications enable superior alternatives creating institutional stickiness where safety concerns override transition imperatives (Geels and Schot, 2007). Tax and incentive structures similarly accumulate around incumbents, creating constituencies whose interests depend on status quo maintenance (Foxon, 2002). Once tax structures are established, modifying them becomes politically difficult because constituencies organise economic strategies around existing frameworks. Licensing and compliance requirements become calibrated to incumbent technologies through path-dependent institutional development (Thelen, 2014). Industrial policy frameworks whether subsidies, tariffs, or sector-specific regulations evolve to support incumbent technologies and the firms producing them. These policies create constituencies, manufacturers who invested based on policy assumptions, suppliers organised around incumbent components, labour organisations expecting continued incumbent employment, and government agencies whose legitimacy depends on policy implementation. Helmrich et al. (2023) emphasise that institutional lock-in is particularly resistant because it operates through multiple reinforcing mechanisms (regulation, taxation, licensing, industrial policy) that cannot be modified in isolation without creating institutional contradictions. Changing one mechanism without modifying others creates gaps and inconsistencies that generate political pressure to reverse changes or revert to previous frameworks. Institutional change therefore requires coordinated modification across multiple mechanisms simultaneously, a coordination problem that makes change difficult even when political will exists.

In the automobile sector, institutional lock-in appears through interconnected government regulations and policies. Vehicle safety standards, emissions procedures, and performance requirements were designed decades ago for ICE vehicles. Converting these standards to accommodate EV characteristics where flat battery packs occupy floors and weight distributions differ requires regulatory modification. However, any modification to safety standards encounters institutional resistance because safety is perceived as non-negotiable. Modifying standards appears as compromising protection even when EV standards maintain equivalent safety levels. Industrial policy frameworks similarly institutionalise lock-in. Policies including local content requirements, employment targets, and tariff structures evolved calibrated entirely to ICE production. These create constituencies whose interests depend on ICE manufacturers who invested based on policy assumptions, suppliers organised around ICE components, labour organisations expecting continued ICE employment, and government agencies whose legitimacy depends on ICE sector dominance. Modifying these frameworks requires reorienting institutional interests, labour agreements, supply chains, and agency priorities a coordination problem of extraordinary complexity. Tax and incentive

structures similarly resist modification. Vehicle excise duties, fuel taxation, and property taxes evolved around ICE production patterns. Changing these to support EV production requires visible tax increases on incumbents while providing uncertain benefits, creating institutional stickiness. Licensing frameworks exhibit similar lock-in behaviour which includes vehicle licensing, manufacturing licensing, and occupational licensing for technicians evolved around ICE vehicles. Establishing EV-specific certifications and new licensing frameworks requires new institutional procedures, encountering resistance from incumbent licensing bodies whose authority and revenue depend on existing frameworks.

Institutional lock-in thus operates through mechanisms that appear rational from a governance perspective but collectively sustain incumbent technologies. Regulators keep safety standards calibrated to incumbents because modifying them appears risky; governments keep industrial policies calibrated to incumbents because constituencies organise around them; tax authorities keep existing structures because change appears to weaken public revenue. This is what Seto et al. (2016) identify in infrastructure transitions: individually rational governance decisions that collectively sustain system-level lock-in. Behind this sits a political dimension. Institutions are not only inherited rules; they are defended by actors whose interests depend on them. Pierson (2000) describes this as policy feedback: a policy in place creates constituencies the firms that invested under it, the workers employed through it, the agencies that administer it and these constituencies organise to keep it. Changing the rules therefore requires bargaining among the state, the incumbent firms, and organised labour, and the outcome of that bargaining decides which rules can change and at what pace (North, 1990; Thelen, 2014). In this research, this political dimension is treated as part of how institutional lock-in operates, not as a separate factor: it explains why an incentive structure can persist after its original rationale has lapsed, and it is the mechanism behind the constraint the social domain places on the institutional one in the findings. Breaking institutional lock-in therefore requires not merely technological innovation or individual policy change but coordinated intervention across regulatory, policy, tax, and licensing domains simultaneously.

### 3.6 Epistemic lock-in

Knowledge does not develop in a vacuum. It develops within institutions like universities and research institutes that decide what is worth studying and which questions matter. Over time, these institutions focus on incumbent technologies and develop deep expertise in improving them. When this happens, new knowledge about alternative technologies struggles to gain credibility. This is not because the knowledge is inferior but because the system is designed to validate incumbent knowledge. Epistemic lock-in refers to how knowledge systems and expertise communities become locked into incumbent technologies, creating barriers against alternative knowledge (Helmrich et al., 2023). Scientific fields operate within dominant frameworks that determine what counts as legitimate knowledge and which research questions deserve attention. Within mature technological fields, knowledge institutions become organised around incumbent paradigms and marginalise alternative knowledge. Alternative knowledge appears as unproven or not mainstream not because it is actually inferior but because validation systems have evolved to privilege incumbent knowledge. The result is that expertise becomes concentrated in incumbent technologies while alternative expertise remains scarce and underdeveloped.

Epistemic lock-in operates through multiple mechanisms that systematically disadvantage alternative

knowledge. First, expertise becomes concentrated in incumbent domains. Professionals are credentialed in incumbent technologies. Researchers develop expertise in how to optimise incumbents. Career advancement depends on contributing to incumbent knowledge. This means alternative expertise remains underdeveloped because institutions do not invest in building it. Second, research funding reinforces this expertise concentration. Funding bodies government and industry have developed research priorities calibrated to established technologies over decades. A century of ICE optimisation research has generated vast knowledge repositories about engines, transmissions, and fuel systems. In contrast, research on battery systems, power electronics, and electric motors is much newer and receives smaller funding amounts. This funding asymmetry means knowledge about incumbents continues to grow while knowledge about alternatives remains thin. Third, knowledge validation systems amplify these asymmetries. Publications in established journals gain credibility and prestige; publications in emerging alternative journals appear less credible. Scientific authority concentrates among individuals with deep incumbent expertise. Senior engineers and industry analysts have spent decades building reputations in ICE systems. Individuals proposing alternative technologies often lack this credentialed authority they have fewer publications in leading journals and fewer presentations at prestigious conferences. When decision-makers seek credible knowledge about technological feasibility, they encounter established authority voices built on incumbent expertise. Emerging alternative expertise, lacking this institutional positioning, appears less credible despite potential technical competence. This creates epistemic authority asymmetries where incumbent knowledge maintains advantage through institutional positioning while alternative knowledge struggles for legitimization.

In automobiles, epistemic lock-in shows up as automotive knowledge concentrated on ICE. Technical education is still ICE focused, they include engine design, thermodynamics, fuel systems, combustion. Universities produce graduates who know ICE deeply but know little about batteries, power electronics, and high-voltage systems. This creates shortages of EV expertise. Research funding historically goes to ICE optimisation. EV research is newer and gets less funding than a century of ICE research. Knowledge about making ICE engines better is vast. Knowledge about making EV systems better is much smaller. People see ICE as "mature" and proven while EVs seem "unproven." Research journals publish mostly ICE work. Conferences focus on ICE topics. In the automotive industry, authority comes from ICE experience. Senior engineers spent decades on ICE engines. Industry experts built reputations understanding ICE. These are the trusted voices people listen to. People proposing EV transitions often lack this authority. They have fewer papers published and fewer conference talks. When decision-makers want credible knowledge about EV feasibility, they hear from ICE experts. New EV experts lack institutional position so they seem less credible even when they know their subject well. Alternative knowledge about EVs seems foreign, unproven, or experimental even when it is actually sophisticated and well-researched.

Epistemic lock-in matters greatly for technological transitions because it works through hidden knowledge legitimization mechanisms hard to recognise as barriers. Understanding epistemic lock-in means recognising that what counts as feasible includes not just what is technically possible or economically sensible but what dominant knowledge systems accept as legitimate and credible. Breaking epistemic lock-in requires changing research funding, rewriting engineering education, and reforming knowledge validation systems that developed around incumbent technologies.

### **3.7 Interdependencies of the Lock ins**

The six domains described above do not operate in isolation. Helmrich et al. (2023) stress that the domains interact and reinforce one another, and that it is this interplay, rather than any single domain on its own, that progressively narrows the space of solutions available to a system. A barrier in one domain can sustain a barrier in another, which means the overall lock-in of a system can be stronger than the sum of its parts. This interaction is also what makes lock-in difficult to escape: an intervention that resolves a mechanism in one domain may achieve little if that mechanism is continuously renewed from elsewhere. Similar arguments appear in the wider literature, where lock-in types are described as tightly linked rather than independent (Seto et al., 2016; Simoens et al., 2022).

In the automotive field, this interdependence takes a recognisable shape. The physical production system of a vehicle manufacturer reflects past investment decisions, so the technological and economic domains are connected from the start: what a plant can build depends on what its owners chose to pay for. Those investment decisions, in turn, respond to the rules and incentives under which the industry operates, linking the economic domain to the institutional one. On the demand side, what consumers are willing to buy depends on prices and infrastructure, which connects the individual domain back to the institutional and technological ones. Employment across the value chain ties the social domain to the pace at which any of this can change, and the knowledge held by the workforce and the industry follows the technology that is actually produced, binding the epistemic domain to all the others. This suggests that in an automotive context, the six domains form a connected system in which change in one place depends on conditions in another. How these interdependencies are identified empirically is described in the methodology, and how they appear in the South African case is presented in the results.

### 3.8 Operationalizing of the Lock-in framework

This study uses Helmrich et al.'s (2023) six-domain framework as its analytical lens. The framework is not tested as a model but in this research its applied as a diagnostic tool. This study draws on systematic desk research. Extensive searching was conducted across scientific databases, namely Scopus and , supplemented by ScienceDirect, IEEE Xplore, and the TU Delft repository. Keywords included "lock-in", "path dependency", "ICE to EV", "electric infrastructure", and "automotive sector". Selection focused on relevance to the South African automotive sector and the identification of transition barriers. Given the multidisciplinary scope of the topic, academic articles were combined with policy documents, industry reports, and grey literature such as NAAMSA and Green Cape publications.

From this desk research, the barriers relevant to South Africa's automotive sector and its ICE-to-EV transition were extracted. Each barrier was categorised by its position within the six lock-in domains (technological, economic, social, individual, institutional, and epistemic) and discussed in terms of how the domains interact and reinforce one another.

In the South African context, these domains take on concrete form. Technological lock-in appears in the physical production system, where plant tooling, assembly lines, and supplier networks are configured around ICE, while charging infrastructure and grid reliability for EVs remain underdeveloped. This feeds directly into economic lock-in, as large sums of capital are sunk into ICE facilities and tooling, and the scale economies of established ICE platforms keep EVs more expensive on both purchase price and total cost of ownership. These material and financial barriers are held in place by institutional lock-in, where the industrial-policy frameworks that govern the sector, chiefly the APDP and SAAM, along with the associated subsidy, tariff, and import-duty regimes, were

calibrated around ICE production and continue to favour incumbent producers. Yet this domain also holds the strongest lever for change. Incentive structures play a central role here: well-designed incentives could attract foreign investors into EV manufacturing in South Africa, which would benefit the OEMs themselves by drawing new business into the country. Such investment would also open a channel for technology transfer, giving the local industry the chance to build EV capability and know-how it does not currently possess. The same institutional instruments that reinforce ICE lock-in, in other words, could be recalibrated to help break it.

The remaining domains operate through people and knowledge rather than hardware or policy. Social lock-in is visible in the manufacturing towns where community identity and livelihoods are tied to ICE employment, and in the brand loyalty and consumer caution toward EVs. Individual lock-in reflects the embodied expertise of engineers and managers whose careers are built on ICE technology, reinforced by risk perception and status quo bias that favour the familiar. Underlying all of these, epistemic lock-in concentrates R&D funding, technical expertise, and the dominant framings of feasibility on ICE, leaving EV knowledge thinner and often treated as less proven. Crucially, these domains do not act in isolation: economic sunk costs are protected by institutional policy, individual expertise is sustained by epistemic concentration, and social identity reinforces resistance at the community level. The indicators used to identify each domain in the South African case are summarised in Table below.

### Six Domains of Lock-In in terms of South Africa.

The table below summarises the application of Helmrich et al.'s (2023) six-domain lock-in lens to the South African automotive sector, stating for each domain its theoretical basis, its boundary with the neighbouring domains, and the indicators through which it is identified in this case. It serves as the analytical instrument of this research

Table 3.1: Six Domains of Lock-in in terms of SA

| <u>Domain</u>     | <u>Theoretical basis</u>                                                      | <u>Boundary demarcation</u>                                                                                                                                        | <u>Indicators/operationalisation</u>                                                                                                                                                                                                                      |
|-------------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Technology</b> | Material entrenchment of incumbent technology in surrounding physical systems | Defined by <i>materiality</i> . Workforce knowledge falls under epistemic, asset values under economic, and the rules governing infrastructure under institutional | <ul style="list-style-type: none"> <li>• Plant tooling and assembly-line configuration</li> <li>• Public charging infrastructure availability</li> <li>• Grid capacity and reliability for charging</li> <li>• ICE-component supplier networks</li> </ul> |
| <b>Economic</b>   | Sunk costs, scale economies, and financial structures favouring incumbent     | Defined by <i>financial cost structures</i> . The physical infrastructure itself sits under technological; fiscal                                                  | <ul style="list-style-type: none"> <li>• Sunk capital in ICE manufacturing facilities and tooling.</li> <li>• EV vs ICE consumer pricing and total cost of ownership</li> </ul>                                                                           |

|                      |                                                                                        |                                                                                                                                                                                                      |                                                                                                                                                                                                                                             |
|----------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                      |                                                                                        | incentives and taxes sit under institutional; informal financial trust sits under social                                                                                                             | <ul style="list-style-type: none"> <li>• Consumer total cost of ownership &amp; its life.</li> <li>• Scale economies favouring incumbent platforms</li> </ul>                                                                               |
| <b>Institutional</b> | Formal governance, regulation, policy, and incentive structures reinforcing incumbents | Defined by <i>formality and codification</i> . Informal community norms sit under social; knowledge institutions themselves sit under epistemic                                                      | <ul style="list-style-type: none"> <li>• industrial-policy frameworks for the automotive sector</li> <li>• Subsidy and incentive structures for manufacturers and consumers</li> <li>• Tax, tariff, and import-duty regimes</li> </ul>      |
| <b>Social</b>        | Collective norms, peer networks, community identity, and shared practices              | Defined by <i>informal and collective</i> behaviour. Intra-personal cognition belongs to individual; codified rules and formal organisations belong to institutional                                 | <ul style="list-style-type: none"> <li>• Brand loyalty and technology familiarity</li> <li>• Community identity tied to automotive employment in manufacturing towns</li> <li>• Public attitudes and consumer norms toward EVs</li> </ul>   |
| <b>Individual</b>    | Cognitive biases and accumulated expertise that anchor decision-makers to incumbents   | Defined by <i>intra-personal cognition</i> . Peer effects and group norms sit under social; codified rules sit under institutional                                                                   | <ul style="list-style-type: none"> <li>• Embodied engineering and managerial expertise in ICE technology</li> <li>• Risk perception of EV technology</li> <li>• Status quo bias and loss aversion among industry decision-makers</li> </ul> |
| <b>Epistemic</b>     | Knowledge systems and dominant framings that privilege incumbent technology            | Defined by <i>knowledge and framing</i> . Physical infrastructure sits under technological; individual cognition sits under individual; formal curricula as policy artefacts sit under institutional | <ul style="list-style-type: none"> <li>• R&amp;D funding allocation</li> <li>• Distribution of technical expertise across stakeholder group</li> <li>• Dominant framings of feasibility in policy and industry reports</li> </ul>           |

## Chapter 4

# Methodology

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This chapter shows how the research was carried out. It describes how the literature was searched and narrowed down to the sources used in this thesis, and how the five policy instruments were selected. It then explains how the analysis was performed: first identifying the lock-in mechanisms and how they interact, and then assessing each policy instrument against the six domains.

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## 4. Methodology

### 4.1 Research Design

This thesis adopts a qualitative single case study design (Creswell & Creswell, 2017; Yin, 2018) to examine lock-in barriers in South Africa's transition from ICE to EV manufacturing. A qualitative approach suits this research because the questions ask how lock-in mechanisms operate within a specific institutional and industrial context, rather than how much or how often. The South African automotive sector is treated as a single, analytically bounded case. It is chosen because it represents a developing-economy automotive industry facing an imminent transition under external pressure, while remaining embedded in policy structures built around the incumbent technology.

The research is desk-based. All evidence is drawn from documents: academic literature, government policy documents, and industry reports. Document analysis therefore serves as the primary research method rather than as a supplementary source of triangulation. This choice fits the nature of the research questions. Both sub-questions concern structural conditions the mechanisms embedded in the sector and the content of the policy regime rather than the perceptions or intentions of individual actors. Such structural questions can be answered through systematic analysis of documentary evidence (Bowen, 2009).

The analysis is twofold, following the two sub-questions. The first part identifies lock-in mechanisms in the South African automotive sector and examines how they interact. The second part analyses the industrial policy regime against those same domains to determine where policy reinforces lock-in, where it challenges it, and where it is silent. Figure 4.1 visualises this flow.

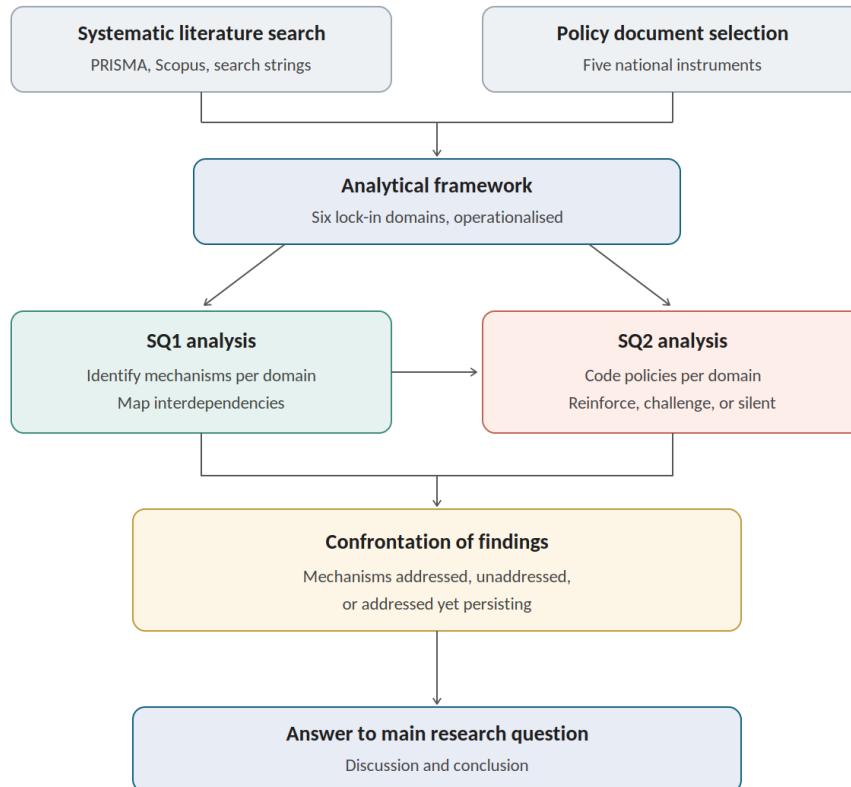


Figure 4.1: Research flow from data collection through the twofold analysis to the answer to the main research question.

## 4.2 Research Scope

The scope of this research is limited in four ways. First, the analysis covers four-wheel passenger vehicles only. Two- and three-wheelers, buses, and heavy-duty trucks are excluded, as these segments involve different technologies, infrastructure requirements, and policy instruments. Second, the geographical scope is national. Provincial and municipal initiatives are considered only where they interact directly with national policy. Third, the policy analysis covers instruments currently in force or formally adopted at the time of writing. Draft regulations and announced but unenacted proposals fall outside the scope. Fourth, the analysis assesses the content and orientation of policy instruments, not their implementation outcomes. Whether an instrument achieves its stated objectives in practice is a separate question that would require different data, and it is treated as a limitation in the discussion chapter.

## 4.3 Data Collection Methods

Data collection proceeded in two streams, corresponding to the two sub-questions. The first stream gathered the academic literature from which the lock-in mechanisms are identified, using a systematic search protocol. The second assembled the policy instruments analysed against those mechanisms, using explicit selection criteria. Grey literature industry reports, market intelligence, and policy-research publications was collected alongside both streams and serves as contextual evidence in the results chapter.

### 4.3.1 Systematic literature search

The academic literature was gathered through a systematic search guided by the PRISMA protocol (Moher et al., 2009), consisting of identification, screening, eligibility, and inclusion. Scopus served as the primary database. Connected Papers was used to map citation networks around foundational lock-in studies, surfacing related work not captured through keyword search alone.

The search was conducted in three stages, each corresponding to a thematic cluster of the review. The first stage focused on the South African automotive context and the state of its EV market. The second addressed the technologies surrounding the transition, including EV manufacturing, charging infrastructure, and grid integration. The third focused on the dynamics of transition itself, using terms such as "lock-in", "path dependence", and "automotive transition barriers". Within each stage, search strings combined the geographical context, the sectoral focus, and the theoretical lens using Boolean operators, so that ("South Africa" AND "automotive" OR "electric vehicle\*") was paired with terms for the transition ("lock-in" OR "path dependent\*") and its barriers ("transition" OR "challenge\*" OR "barrier\*").

These searches returned 393 records in total. The records were then reduced in successive steps. Duplicates were removed first, after which the remaining records were screened on title and abstract, where literature focusing on environmental impact and carbon emissions rather than on the industry and its transition was excluded. The full texts of the remaining records were then assessed for eligibility, with inclusion requiring that a source be a published paper, written in English, specific to the South African or comparable developing-economy context, and directly relevant to at least one of the three thematic clusters. This produced a final set of 28 published papers.

Grey literature was collected separately, industry reports from NAAMSA, NAACAM, and GreenCape, together with government policy documents, were used as contextual evidence in the results rather than in the literature review, since they provide sectoral data that academic sources do not capture. Sectoral statistics were drawn from naamsa publications, including the Automotive Trade Manual 2026 and the quarterly market reviews, which provide production, export, and sales data not available in the academic literature.

### 4.3.2 Policy document selection

The policy analysis draws on five instruments. Selection followed three criteria: the instrument operates at national level; it is currently in force or has been formally adopted; and it directly addresses automotive manufacturing, new energy vehicles, or the value chains supporting them. Applying these criteria produced the following set:

1. The Automotive Production and Development Programme (APDP, 2013; Phase 2, 2021)
2. The South African Automotive Masterplan 2035 (SAAM, 2018)
3. The Electric Vehicles White Paper (the DTIC, 2023)
4. Section 12V of the Income Tax Act, providing a 150% capital allowance for NEV production investment (effective 1 March 2026)
5. The South African Renewable Energy Masterplan (SAREM, 2025)

Together these cover the regime's full function: the APDP is the sector's central incentive mechanism, SAAM 2035 its strategic vision, the White Paper its transition direction, Section 12V its only production-side EV incentive, and SAREM its only adopted link to the battery value chain. The set also spans the regime's development over time: instruments calibrated around ICE production alongside those directed at the NEV transition. This balance prevents selection bias: a set restricted to older instruments would predispose the analysis toward finding reinforcement, while a set restricted to newer instruments would predispose it toward finding challenge.

Instruments that were considered but excluded each fail one of the stated criteria. Economy-wide strategies (IPAP, the Industrial Development Strategy) address the sector only in passing and serve as contextual background. ASCCI is a coordination initiative without codified provisions. The carbon tax and emissions levy affect purchasing rather than production (Montmasson-Clair and Patel, 2024). Provincial and special economic zone programmes fall outside the national scope. Announced but unenacted measures the tariff review, the battery manufacturing policy, and proposed demand-side incentives are excluded by the adoption criterion; their absence from the enacted regime is itself treated as a finding in Chapter 5.

## 4.4 Data Analysis Methods

The analysis applied the six-domain framework in two sequential steps, corresponding to the two sub-questions, using the operationalisation table as the analytical instrument. The first step diagnoses the lock-in, and here the literature serves a second role: the same sources gathered for the literature review are used as the empirical data for the first sub-question. Rather than reading these sources for their arguments alone, the analysis codes the conditions and barriers they document against the six domains, and then maps how the identified mechanisms interact, recording which reinforce which. The second step assesses the policy regime against the same domains, and confronts that assessment with the mechanisms the first step identified. The order matters, as the policy analysis is applied to a diagnosis already established rather than to the domains in the abstract.

### 4.4.1 Identifying lock-in mechanisms (SQ1)

The included literature and contextual sources were analysed deductively against the six lock-in domains, using the indicators defined in the operationalisation table. Each barrier identified in the sources was assigned to a domain based on the boundary demarcations in the table. Where a barrier spanned more than one domain, the demarcation rules determined its primary classification, and the connection between the domains involved was recorded as an interdependency. The output of this step is a structured set of lock-in mechanisms per domain, presented in Sections 5.2.1 to 5.2.6.

#### 4.4.2 Interdependency mapping

Beyond identifying the mechanisms within each domain, the analysis examines how mechanisms in different domains interact. This step follows from the framework, since Helmrich et al. (2023) stress that the domains do not operate in isolation, and that their interplay steadily narrows the options available to a system. The first sub-question therefore asks not only which mechanisms exist, but how they reinforce one another.

Interdependencies are identified where the documentary evidence links one mechanism to another, either by describing them as occurring together or by presenting one as a condition for the other. For example, sunk investment in ICE tooling in the economic domain may be described as sustained by the incentive structure in the institutional domain, or the growth of local EV expertise in the epistemic domain may be described as dependent on the investment decisions of the OEMs in the economic domain. In each case, the direction of the relationship is recorded: which mechanism sustains, enables, or protects which.

These relationships are then compiled into an interdependency map, presented in the results, which shows which domains act mainly as sources of reinforcement and which are mainly reinforced. This map connects the two sub-questions. Where a policy instrument targets a single mechanism whose persistence depends on mechanisms in other domains, the map helps explain why an isolated measure may not be enough.

#### 4.4.3 Policy analysis (SQ2)

Each of the five policy instruments were examined and assessed against the same six domains. The framework diagnoses lock-in, but it does not say how to judge policy against it. So a coding scheme was built for this study. Assessment operated at two levels. At passage level, every provision touching a domain identified through the component indicators of the operationalisation table was extracted with its section reference and coded as reinforcing the mechanisms identified under that domain (R), challenging them (C), or engaging the domain neutrally (N), a scheme of eighteen codes across the six domains. At instrument level, the passage codes were consolidated into a verdict per domain: a cell showing predominantly reinforcing passages is classified as reinforcing, predominantly challenging as challenging, and only neutral passages as neutral. Where no provision in an instrument addressed a domain at all, the cell is recorded as silent. Silence is treated as a finding rather than an absence of data, since domains left unaddressed by the policy regime indicate blank spots in the transition effort. The assessment at domain level used the component indicators from the operationalisation table rather than domain labels alone. Within the technological domain, for example, an instrument was examined separately on battery production, charging infrastructure, and component localisation, since a policy can address one component while ignoring others.

The final analytical step confronts the two parts. For each mechanism identified under SQ1, the analysis determines whether it is addressed by at least one policy instrument, not addressed at all, or addressed

yet still observable in the sector. The third category is analytically the most significant, as it separates gaps in policy coverage from gaps in policy effect.

## 4.5 Validation

Research quality is assessed using the criteria of credibility, dependability, confirmability, and transferability (Lincoln & Guba, 1985). Credibility rests on comparing evidence across source types: academic literature, policy documents, and industry reports are read against one another, and findings are reported only where sources converge or where divergence is itself informative. Dependability rests on a transparent procedure: the search strings, selection criteria, operationalisation table, and classification categories are all reported, so the analysis can be repeated. Confirmability rests on grounding every classified finding in a citable document, with the boundary demarcations constraining interpretive discretion. Transferability is limited by design: the findings describe the South African case, but the procedure is documented in enough detail to be applied to other developing-economy automotive sectors.

Four limitations follow from the design. First, without interviews, the analysis cannot access actor intentions or the informal practices that documents do not record. Second, the analysis assesses policy content, not implementation. Where a policy is in force yet the barrier persists, this research identifies the mismatch but cannot explain it. Third, the document base is bounded by what is publicly available; internal government assessments and OEM investment plans are not accessible. Fourth, the research uses a single method, so methodological triangulation is not possible. Comparing sources reduces the dependence on any one document, but it cannot substitute for testing the findings through a second method, and the findings should be read with this in mind.

## Chapter 5

# Results: Lock-in and Policy in South Africa's automotive sector

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This chapter presents the empirical findings of the research, and it is organised around the two sub-questions.

The first part identifies the lock-in mechanisms operating in the South African automotive sector across the six domains, drawing on the academic literature and the sector's own reporting. It then maps how these mechanisms reinforce one another, showing that they do not act in isolation but connect into three chains that run through production, demand, and the policy response. Together, these findings establish what holds the sector to ICE production. The second part turns to the policy regime. Each of the five instruments is first described on its own terms, and then assessed against the six domains to establish where it reinforces the lock-in, where it challenges it, and where it stays silent. This shows how far the current policy framework engages with the mechanisms identified in the first part.

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## 5. Results

### 5.1 Lock-in barrier identification for EV manufacturing in South Africa per domain

This section presents the lock-in mechanisms identified in the South African automotive sector through the documentary analysis described in the methodology. The findings are organised along the six domains of the framework, and each domain follows the same pattern: the lock-in is briefly recalled, the mechanisms found in the South African case are named, and the evidence behind each mechanism is then discussed. Together, these findings answer the first part of the research: what is holding the sector to ICE production. How these mechanisms relate to one another is addressed at the end of the section, as the interdependencies between the domains prove to be a finding in their own right.

#### 5.1.1 Technological lock-in findings for EV manufacturing in South Africa

In the case of South Africa, four mechanisms were identified under the technological domain: the scarcity of charging infrastructure, the unreliability of the electricity supply, a production base configured around the combustion engine, and the absence of local battery and drivetrain capability.

Charging infrastructure is the most consistently documented of the four, and the numbers show how far behind it is. South Africa had around 300 public charging stations as of 2022, split between slow and fast chargers and concentrated in urban centres and along major highways (Mordor Intelligence, 2025). Several studies have indeed examined this barrier, and they point in the same direction. For instance, Mpiana and Chowdhury (2023) show that connecting charging stations to the national grid faces challenges due to factors like limited grid capacity, load management problems, and high connection costs, while Scholtz et al. (2023) find that the stations that do exist are unevenly spread, leaving most of the country without practical access to public charging. The electricity system compounds this situation. The supply is both unstable and coal-dependent, which undermines the case for electrification in two ways: charging cannot be relied upon, and the environmental benefit that motivates EVs elsewhere is weakened when the electricity itself is carbon-intensive (Showers and Raji, 2021; Tongwane and Moeletsi, 2021).

As our research focus on manufacturing, the relevance of this gap runs through demand. Sparse charging is one of the conditions suppressing domestic EV uptake, and the result is visible in the market: the cumulative passenger EV fleet stood at only 3,543 vehicles by the end of 2024 (GreenCape, 2025). It could be argued that this should not matter for a sector that exports most of its production. Three considerations suggest otherwise. First, the state's own transition strategy ties production to domestic uptake, as the EV White Paper links the development of local NEV manufacturing to the growth of the domestic market (the DTIC, 2023). Second, South Africa's production model has historically rested on domestic and export volumes together, which makes the domestic segment part of the volume base a plant presents when EV models are allocated at parent-company level (Barnes, Black and Monaco, 2021). Third, where the domestic market contributes nothing, allocation becomes a purely export-driven contest, decided on conditions such as energy reliability, logistics, and cost conditions on which the findings in this chapter show South Africa is also weak. Local demand is therefore not the target of production, but it is part of the case for it: a domestic market that is catered to removes one of the barriers the manufacturing transition must clear.

An inherited production base could in principle be retooled; the deeper gap is the capability that retooling would require. No battery electric vehicle is produced locally, and no domestic capability in cells, battery packs, or electric drivetrains has been established (Montmasson-Clair and Patel, 2024). For a manufacturing study, this is the most direct of the four mechanisms, as the battery carries the largest single share of an EV's value. Without local battery production, EV assembly in South Africa would rest on importing the very component that carries the value, which runs against the local-content logic on which the sector's entire support architecture is built. The upstream inputs exist the country holds the minerals the battery chain needs but mineral endowment has not translated into manufacturing capability (Montmasson-Clair and Patel, 2024).

### 5.1.2 Economic lock-in findings for EV manufacturing in South Africa

Economic lock-in arises when invested capital, cost structures, and market conditions make continuing with the incumbent technology the financially rational choice. In the South African case, four mechanisms were identified: sunk investment in ICE production, export dependence on combustion models, a price gap that suppresses the domestic business case, and the location of investment decisions outside the country.

One of the most influential factors driving this lock-in is sunk cost, and it operates in two directions. Decades of incentive-supported capital formation have gone into ICE facilities the plants, assembly lines, and specialised equipment configured for combustion production and this capital is recovered only by continuing to produce at volume. At the same time, a shift to EV production would require substantial new physical investment, since existing equipment and tooling cannot simply be repurposed for electric drivetrains: retooling is a capital decision of its own. Studies of the earlier MIDP era have indeed shown how the first half of this dynamic took hold. For instance, Kaggwa et al. (2009) demonstrate that support programmes deepened commitment to existing production rather than redirecting it, while Black and Mitchell (2002) trace how the incentive structure shaped investment behaviour from the mid-1990s onward. This suggests that the sector faces a double economic barrier: capital already committed that must still pay for itself, and capital not yet committed that no current market signal justifies.

Export dependence reinforces this situation, though it may at first seem to contradict the earlier discussion, where the changing export market was presented as the reason the sector must transition. Both are true, and the difference lies in timing. The European bans take effect in the coming decade; until then, those same markets continue to buy South African-built combustion vehicles, and this remains the sector's main source of income. The scale is considerable: a record 414,271 vehicles were exported in 2025, worth R229.8 billion, with automotive exports making up 15.6% of the country's total exports (naamsa, 2026). Since no EV is produced locally, effectively all of this income is earned on the technology being phased out. Stopping ICE production before an EV model is secured would cut this income with nothing to replace it, so the safest choice for every company, year after year, is to keep building what the export markets still buy. The result is an export paradox: the same markets that force the transition also reward postponing it even as its costs appear, with exports falling 22.8% in 2024, attributed by the industry partly to stricter EU emission rules and competition from Chinese EVs (naamsa, 2024).

There is also the demand side to consider. The price premium on EVs keeps the domestic market too small to justify retooling. The cost gap between electric and combustion vehicles is repeatedly identified as the central barrier to uptake (Moeletsi, 2021; Oni and Longe, 2024; GreenCape, 2025),

and without local demand, there is no market signal for local production. The missing business case is thus partly a demand problem, which is taken up under the individual domain.

The last mechanism concerns who decides. The assemblers in South Africa are subsidiaries of foreign multinationals, and the allocation of models and technology is settled at parent-company level, where South African plants compete with the rest of the group (Black, 2009; Barnes, Black and Monaco, 2021). The same dependence governs knowledge, a mechanism taken up under the epistemic domain. In this case, understanding the economic drivers of the transition is of utmost importance from both a public policy and corporate strategy perspective, since the investment decision the transition requires sits at the intersection of the two.

### **5.1.3 Institutional lock-in findings for EV manufacturing in South Africa**

Three mechanisms were identified in the institutional domain: an incentive architecture calibrated around combustion production, a fiscal structure that treats EVs less favourably than ICE vehicles, and persistent uncertainty about the direction of policy. The argument of this section is that the rules that built the ICE industry are still running: they pay for the old technology, tax the new one, and remain too unsettled to invest against.

The first mechanism is the incentive architecture, and the argument here is that support designed to be technology-neutral becomes, in practice, support for the incumbent. From the MIDP through the APDP, the sector's support instruments have rewarded established production volumes and local value addition without distinguishing the technology being produced. Several studies have examined this architecture, tracing an unbroken calibration back to the mid-1990s. For instance, Black and Mitchell (2002) show how the early incentive design shaped the industry's growth path, while Kaggwa et al. (2009) demonstrate that the programme logic reinforced existing production patterns rather than opening new ones. In a sector where production is almost entirely combustion-based, benefits earned through existing volumes flow to ICE production by construction. As a barrier to EV manufacturing, the effect works through the transition itself: a plant that pauses or reduces ICE production to retool for EVs loses the volumes on which its benefits are earned, precisely in the period when its costs are highest. The rules do not forbid EV production; they make the move toward it the most expensive choice a plant can make.

The second mechanism is the fiscal structure, and here the figures make the argument. Imported vehicles carry a 25% customs duty a protective tariff designed to shield local assembly while vehicles imported from the European Union pay a reduced 18% under the trade agreement between the two markets (naamsa, 2024). This structure was not designed around powertrains, but its effect today is asymmetric. Most imported ICE vehicles enter from the EU at 18%, while battery electric vehicles, none of which are produced locally, enter at 25%. On top of this, the ad valorem tax scales with vehicle price, and since EVs carry higher prices, the same rule taxes them more heavily in absolute terms (Oni and Longe, 2024; the dtic, 2023). It could be asked whether the state's EV incentives offset this. They do not: the only enacted incentive, the Section 12V allowance, operates on the production side, and no incentive exists for the buyer at the point of purchase. The state therefore supports EV supply while taxing EV demand. As a barrier to EV manufacturing, this works through the market a plant would need: higher prices keep domestic demand thin, and a plant arguing for EV production is arguing from a country that barely buys the product it proposes to build.

The third mechanism is policy uncertainty, and the argument is that unresolved rules deter investment as effectively as unfavourable ones, since an investment case cannot be calculated against rules that may change. The transition direction has been announced, but the instruments arrive slowly, and both market intelligence and recent research record the distance between stated ambition and enacted measures as a deterrent in its own right (GreenCape, 2025; Mateko et al., 2026). As a barrier to EV manufacturing, uncertainty strikes at the decision itself: an EV allocation must be argued to a parent company years before production starts, and a plant from a country where the rules are still being settled loses that argument to plants in countries where they are not. This suggests that the institutional domain locks in twice: through what the rules reward, and through what the rules leave unresolved.

#### **5.1.4 Social lock-in findings for EV manufacturing in South Africa**

Social lock-in works through collective interests and behaviour: the livelihoods, communities, and organised groups whose stake in the existing technology raises the cost of change. In the South African case, two mechanisms were documented: the dependence of livelihoods on the combustion value chain, and the position of organised labour in shaping the pace of change.

The livelihood dependence is the broader of the two, and it extends well beyond the assembly plants. Component manufacturing, vehicle servicing, fuel retail, and the platinum value chain that feeds catalytic converter production all rest on combustion technology. Several studies have indeed identified these groups as exposed. For instance, Montmasson-Clair and Patel (2024) map the employment categories at risk across the value chain, from mechanics and fuel-station workers to the mining jobs tied to autocatalyst demand, while Gqoboka et al. (2024) model the exposure of automotive employment under electrification scenarios. This feeds back into manufacturing through cost: because an EV line needs fewer and different workers, any decision to retool carries the cost of reducing and retraining the workforce, and a plant must weigh that cost in the case it puts to its parent company.

That exposure translates into influence. Organised labour holds an established position in the sector, and the just-transition framing that now accompanies policy discussion reflects how firmly workforce protection conditions what the state can propose (ILO, 2025). This constraint also runs upward into policy, since the social cost of disruption is one reason the state's response arrives cautiously. In this case, the social domain does not resist the transition on technical grounds; it resists the distribution of its costs.

#### **5.1.5 Individual lock-in findings for EV manufacturing in South Africa**

In the South African case, the individual domain comes down to a simple pattern: when South Africans buy a car, they still choose a combustion one. The evidence for this is consistent, and the reasons are not hard to find. EVs cost more, there are few places to charge them, and after years of an unreliable power supply, buyers have little reason to trust a vehicle that runs on electricity. The familiar technology remains the safe choice, and the market stays where it has always been.

The main barrier is cost and practicality. Several studies across South Africa and the wider region identify the same factors. For instance, Moeletsi (2021) points to high prices and limited model availability, Huang (2023) finds cost and charging access to be decisive in purchase decisions, and Ajao et al. (2025) confirm that cost, infrastructure, and trust in the technology shape adoption across Sub-Saharan Africa. Two of these barriers come from outside the individual domain: prices are

pushed up by the tax structure of the institutional domain, and charging worries come from the infrastructure gaps of the technological domain.

There is also the electricity factor to consider. Years of load-shedding have taught buyers that supply cannot be assumed, and that experience counts directly against a vehicle that depends on it (Showers and Raji, 2021; Oni and Longe, 2024). Awareness plays a part as well, since buyers cannot choose a technology they do not understand, and the studies that examine the demand side find knowledge of EVs to be limited (Huang, 2023; Ajao et al., 2025). This consumer behaviour feeds back into manufacturing through demand. A home market that does not buy EVs gives a plant little reason to build them locally, and the domestic market is part of the volume a plant weighs when its parent company decides where to place EV production (Barnes, Black and Monaco, 2021; the DTIC, 2023). In this case, individual choices are shaped as much by the surrounding system as by personal preference, and their effect reaches manufacturing through the demand a local plant can point to.

### **5.1.6 Epistemic lock-in findings for EV manufacturing in South Africa**

Epistemic lock-in concerns knowledge: the skills, expertise, and shared understandings that have formed around the incumbent technology and are missing for its alternative. In the South African case, three mechanisms constitute this domain: a skills base formed around combustion technology, the location of technology development abroad, and thin knowledge of the alternative across the sector and the market.

The skills base reflects the installed technology. From production work to vehicle servicing, competence has accumulated around the combustion engine over decades, and assessments of the transition point to retraining on a large scale as a precondition for electrification (Montmasson-Clair and Patel, 2024; ILO, 2025). This suggests significant room for capability development before the workforce can support an electric trajectory.

Knowledge generation itself sits elsewhere. Technology development is conducted by the foreign parent companies, which means learning about EV industrialisation arrives only with investment decisions that South Africa does not control. Studies of the sector's position in global value chains have indeed noted this structural limit on local capability building. For instance, Kaggwa et al. (2009) show how the programme era left technology choices with the multinationals, while Black (2009) traces how the sector's position in global production networks shaped what could be learned locally. There is also the demand side of knowledge to consider. Low consumer awareness extends the gap to the market itself, so neither the industry nor its buyers have yet built the understanding on which a transition depends (Huang, 2023; Moeletsi, 2021). In this case, knowledge follows investment, and investment waits on the other domains.

### **5.1.7 Interdependencies between the lock-in domains**

What holds the sector to ICE production is not any single lock-in, but the way the six sustain one another (Helmrich et al., 2023; Seto et al., 2016). Each domain has a role in the structure. The institutional and economic lock-ins are the sources, the technological, individual, and epistemic lock-ins are on the receiving end, and the social lock-in acts as a constraint from outside. These roles connect into three chains, and together the chains explain why the transition is not moving despite the pressure on the sector.

The first chain is about production, and it explains why the sector keeps investing in the old technology. Government incentives make ICE production more profitable (Black and Mitchell, 2002; Kaggwa et al., 2009), which makes the money already spent on combustion plants worth keeping in place. And because that money stays where it is, none of it goes into batteries, drivetrains, or the capability an electric future would need (Montmasson-Clair and Patel, 2024). Each lock-in leads to the next. The sector is not failing to see the transition; the way the incentives are set up simply makes waiting the sensible choice.

If producers will not move, buyers might be expected to push the change from their side. The second chain, about demand, shows why they do not. Taxes and duties make EVs expensive (Oni and Longe, 2024; naamsa, 2024), and poor charging and an unreliable grid make them impractical (Scholtz et al., 2023; Showers and Raji, 2021), so few people buy them (Moeletsi, 2021; GreenCape, 2025). Weak demand gives manufacturers no reason to build EVs locally (Barnes, Black and Monaco, 2021), and with no local production there is no reason to invest in charging either, which keeps demand low. The chain feeds back on itself. Weak EV demand is therefore not simply a matter of consumer choice; it is created by the tax rules and the missing infrastructure, and the effect lands back on the production side.

Normally, a lock-in is broken by policy or by new EV technology but that's not the case we see in South Africa. The third chain, about constraints, shows that both are held in place. Policy moves slowly because so many jobs depend on combustion technology (Montmasson-Clair and Patel, 2024; Gqoboka et al., 2024), and protecting those jobs shapes what the state feels able to propose, which is visible in the just-transition language now used in the policy debate (ILO, 2025). Knowledge stays limited because the technology is developed by the foreign parent companies (Black, 2009), so EV expertise builds up only where they choose to invest, and the local skills base stays formed around the old technology.

Taken together, the chains show the shape of the problem. The institutional and economic lock-ins are the source in every chain, one setting the rules that reward the old technology and the other setting the financial logic that keeps it in place. The other domains mostly follow from these two, while the social lock-in sits to one side and slows the response. This is what makes the lock-in self-sustaining: any single barrier that might be fixed on its own is kept alive by another part of the structure. It also points ahead to the policy analysis, since an instrument that addresses a downstream barrier without touching its source can only treat a symptom, and this is the standard against which the next section tests the regime.

The structure discussed above is visualised in Figure 5.1, where the three chains and the role each lock-in plays within them are brought together. The production chain is shown in red, running from the institutional lock-in through the economic to the technological. The demand chain is shown in green, and it is the one that closes into a loop: the institutional and technological lock-ins press on the individual, the individual feeds the economic, and the economic leads back into the technological. The constraint chain is shown in purple, with the social lock-in holding the institutional and the economic holding the epistemic. The dashed lines mark the domains of the lock-ins, and the figure also records the position of each domain in the structure: the institutional and economic as the source in all chains, the technological, individual, and epistemic as receiving, and the social as constraining.

**Production chain:** institutional → economic → technological

**Demand chain :** institutional + technological → individual → economic → technological

**Constraint chain:** social → institutional; economic → epistemic

domain of lock-in (dashed line - - -)

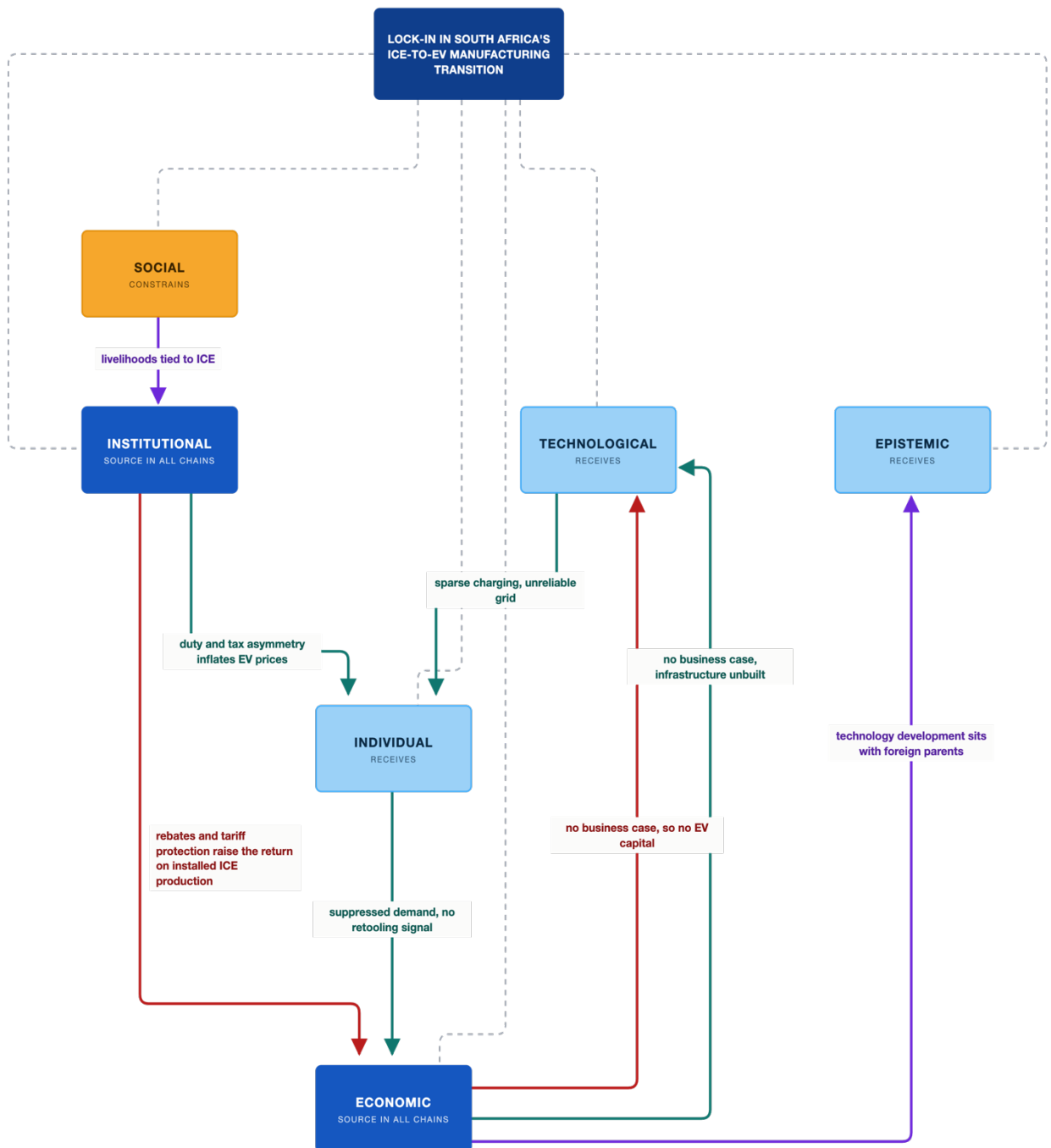


Figure 5.1 Interdependency mapping in lock-ins

## 5.2 The influence of industrial policy in South Africa on lock-in for EV's

To assess the influence of the industrial policies on the lock-in mechanisms identified in this research, five instruments are examined against the six domains: the APDP, SAAM 2035, the EV White Paper, Section 12V of the Income Tax Act, and SAREM. Together, these form the policy framework that

governs the sector's production and its transition. The assessment follows the eighteen-code scheme of the methodology, where every provision touching a domain is coded as reinforcing the lock-in (R), neutral (N), or challenging it (C), and the passage codes are then consolidated into one verdict per instrument and domain. Where an instrument contains no provision touching a domain, that domain is recorded as silent, which is treated as an observed absence rather than a code. Every coding is grounded in the text of the instrument itself. To make the development of the regime visible, the instruments are presented in chronological order, moving from the production-support architecture built around ICE manufacturing to the transition instruments adopted from 2023 onward.

### **5.2.1 The Automotive Production and Development Programme (APDP)**

The APDP is the sector's central support instrument. It was introduced in 2013 and extended as Phase 2 to run from 2021 to 2035. The programme supports vehicle assembly and component manufacturing through tariff protection, a volume-based assembly allowance, a production incentive earned on local value addition, and investment support (Barnes, Black and Monaco, 2021; Montmasson-Clair and Patel, 2024).

The design of these benefits determines where the support ultimately goes. The assembly allowance is earned by producing vehicles at volume, the production incentive is earned on the value added in current manufacturing operations, and the tariff protection shields the production that already exists. In other words, every benefit in the programme flows from doing more of what the sector already does. The programme does not distinguish between powertrain technologies, and this is where the problem lies. On paper, the rules are neutral: an EV plant would earn the same benefits as an ICE plant. In practice, the sector produces almost only combustion vehicles, so the money flows to the ICE plants and supplier networks that exist. Nothing in the programme requires a shift toward EVs, and nothing rewards one either a plant that reduced ICE output to retool for electric production would lose the very volumes on which its benefits are calculated, making the transition costly under the programme's own rules. This is not only the finding of this research. The DTIC's own assessment accompanying the EV White Paper states that the current APDP2 package "does not fully support the shift to EVs" (the DTIC, 2024).

### **5.2.2 The South African Automotive Masterplan 2035 (SAAM)**

SAAM 2035 is the sector's strategic vision. It was adopted in 2018 and sets the direction that the APDP is meant to serve. Its ambitions are growth-oriented: a larger share of global vehicle production, deeper local content, and a doubling of employment in the industry (the DTIC, 2018).

None of these targets is tied to a powertrain technology, and this is what makes the masterplan part of the picture. The plan sets out how much the sector should grow, but not what it should build. When it was adopted, the production base was almost entirely combustion-based, so a growth path defined in these terms is in practice a plan to build more of the same. Its strongest commitment lies with the workforce: the employment and transformation objectives are the regime's main protection of the people whose livelihoods depend on the sector, and they address the cost of change rather than the technology that creates it. On the technology of production, on the demand side, and beyond generic skills ambitions on the knowledge the transition would require, the masterplan says little.

### **5.2.3 The Electric Vehicles White Paper**

The White Paper, published in 2023, is the regime's change of direction. It names the export risk directly and commits the state to a transition in production: extending the APDP to explicitly include electric

vehicles without internal combustion engines, developing the battery value chain, scaling up charging infrastructure, and supporting grid capacity (the DTIC, 2023; the DTIC, 2024). Its economic measures point the same way, with investment funding targeted at battery and fuel-cell vehicles and temporary duty relief on batteries used in domestic production. Institutionally, it does something unusual for a policy document: it codes its own regime as inadequate, stating that existing interventions are insufficient, and commits to amending them (the DTIC, 2024). On the social side, it adopts a just-transition framing with job retention and skills training as focal areas, and it engages the epistemic domain through reskilling objectives and targeted R&D support. Its limit lies in the individual domain. Consumer incentives are only to be considered, and only in a fiscally neutral manner the demand-side barriers the White Paper itself lists are, in effect, deferred. The instrument thus challenges the lock-in across five domains on paper, while the domain that feeds the missing business case remains engaged but unresolved.

**5.2.4 Section 12V of the Income Tax Act**

Section 12V is the regime's first enacted production-side EV incentive: a 150% capital allowance on qualifying investment in new energy vehicle production, taking effect on March 2026 (National Treasury, 2024). It attacks the retooling cost barrier head-on, and in doing so directly challenges the economic lock-in identified in Section 5.2.2 the first fiscal provision to distinguish NEV production favourably within the incentive architecture. Its reach, however, is exactly one mechanism wide. The allowance can reward an investment decision, but it cannot cause one: the decisions it presupposes are made at parent-company level abroad, and nothing in the provision touches the demand, infrastructure, or knowledge conditions that inform them. The instrument is silent on the social, individual, and epistemic domains, which makes it the sharpest but narrowest challenge in the regime.

**5.2.5 The South African Renewable Energy Masterplan**

SAREM, approved in 2025, is the only adopted instrument addressing the value chains on which local EV manufacturing would ultimately depend. It targets the renewable energy and battery storage industries, aiming to build domestic production capability and reverse the import dependence in batteries and components, and it carries an explicit skills and industrialisation dimension for that chain (SAREM, 2025; Montmasson-Clair and Patel, 2024). Read against the six domains, its challenges are real but adjacent: it works on the technological and epistemic base beside the automotive sector rather than inside it, and its effect on vehicle manufacturing depends on a linkage that no instrument yet codifies. Its economic and institutional provisions engage without automotive direction, and it is silent on the social and individual domains of the vehicle transition. SAREM is thus best read as a necessary upstream complement whose automotive payoff remains contingent.

Taken together, the five instruments trace the movement of the policy regime over time. To make this pattern visible, the assessments discussed above are consolidated into two tables. Table 5.1 presents the verdict matrix. Each row shows one instrument, each column one lock-in domain, and each cell holds the verdict for that pairing. The colours make the pattern readable at a glance: green indicates that the instrument reinforces the lock-in, yellow indicates neutral engagement, red indicates that it challenges the lock-in, and a grey dash marks silence. Table 5.2 then reports the evidence behind every verdict. For each coded cell, it states the provision on which the classification rests, so that no verdict stands without a traceable basis in the policy text. Reading Table 5.1 row by row shows what each instrument does across the domains. Reading it column by column shows how well each domain is covered by the regime as a whole. It is this second reading that reveals the pattern taken up in the

discussion: the challenges cluster in the newer instruments and in the production-related domains, while the individual domain shows no challenge in any row.

**Table 5.1: Policy instruments assessed against the six lock-in domains**

| Instrument                 | Technological | Economic | Institutional | Social | Individual | Epistemic |
|----------------------------|---------------|----------|---------------|--------|------------|-----------|
| APDP (2013; Phase 2, 2021) | R             | R        | R             | N      | —          | —         |
| SAAM 2035 (2018)           | —             | R        | N             | C      | —          | N         |
| EV White Paper (2023)      | C             | C        | C             | C      | N          | C         |
| Section 12V (eff. 2026)    | N             | C        | C             | —      | —          | —         |
| SAREM (2025)               | C             | N        | N             | —      | —          | C         |

*Table 5.1 Policy instruments assessed against the six lock-in domains*

*R = reinforces the lock-in (green); N = neutral engagement (yellow); C = challenges the lock-in (red); — = silent, no provision found. Verdicts rest on the provision-level evidence in Table 5.2.*

**Table 5.2: Provision-level evidence for each coding**

Table 5.2 reports the evidence on which the entire policy assessment rests. A verdict matrix on its own shows the outcome but not the basis; this table provides the basis. For every coded cell in Table 5.1, it states the instrument, the domain, the verdict whether the instrument reinforces the lock-in (R), challenges it (C), or engages it neutrally (N) and the provision of the policy text that produced the classification.

| Instrument | Domain        | Code | Evidence provision quoted or referenced                                                                                                                                     |
|------------|---------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| APDP       | Technological | R    | Benefits earned through existing production activity; no NEV-specific provision. Confirmed by the DTIC (2024): the APDP2 package “does not fully support the shift to EVs”. |
| APDP       | Economic      | R    | Duty rebates and production incentives raise the return on installed ICE production; import tariff shelters domestic ICE output.                                            |
| APDP       | Institutional | R    | Codifies the ICE-calibrated reward structure; Phase 2 commits it to 2035; unbroken continuity with MIDP since 1995 (Black and Mitchell, 2002; Kaggwa et al., 2009).         |

|                |               |   |                                                                                                                                                                                                                                 |
|----------------|---------------|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| APDP           | Social        | N | Employment retention a stated objective; protects jobs within the existing configuration; no transition provision.                                                                                                              |
| SAAM 2035      | Economic      | R | Targets of 1% of global production and 60% local content ride the installed base: production almost exclusively ICE at adoption, so the growth path is operationally an ICE growth path.                                        |
| SAAM 2035      | Institutional | N | Establishes Executive Oversight Committee governance; engagement without technological direction (the DTIC, 2024).                                                                                                              |
| SAAM 2035      | Social        | C | Employment doubling and transformation objectives constitute the regime's main protection of the workforce stake.                                                                                                               |
| SAAM 2035      | Epistemic     | N | Generic skills ambitions without technology direction.                                                                                                                                                                          |
| EV White Paper | Technological | C | Commits to extending the APDP to explicitly include EVs without internal combustion engines, battery value chain development, charging infrastructure scale-up, and grid capacity support (the DTIC, 2024, policy actions 1–6). |
| EV White Paper | Economic      | C | Investment funding targeted at BEV and FCEV via amended AIS guidelines; temporary reduction of import duties on batteries for domestically produced vehicles; duty rebates for domestic-market production (the DTIC, 2024).     |
| EV White Paper | Institutional | C | The instrument codes its own regime as inadequate, stating that existing interventions are insufficient and committing to amend the APDP Regulations and Guidelines (the DTIC, 2024).                                           |
| EV White Paper | Social        | C | Just-transition framing: distributive, restorative and procedural justice principles; job retention and skills training as focal areas (the DTIC, 2024).                                                                        |
| EV White Paper | Individual    | N | Consumer incentives only to be considered, and only in a fiscally neutral manner; demand-side measures deferred to a later phase (the DTIC, 2024).                                                                              |
| EV White Paper | Epistemic     | C | Reskilling and upskilling of the workforce and strategically targeted R&D investment among overriding objectives; R&D tax incentives under s11D proposed (the DTIC, 2024). Mechanisms thin 10 coded C with partial reach.       |
| Section 12V    | Technological | N | Enables capability investment but builds nothing itself; effect conditional on OEM allocation decisions made abroad.                                                                                                            |
| Section 12V    | Economic      | C | 150% capital allowance on qualifying NEV production investment, effective 1 March 2026 the regime's only enacted production-side EV incentive (Taxation Laws Amendment Act; National Treasury).                                 |
| Section 12V    | Institutional | C | First fiscal provision distinguishing NEV production favourably within the incentive architecture.                                                                                                                              |

|       |               |   |                                                                                                                                                                       |
|-------|---------------|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SAREM | Technological | C | Targets renewable energy and battery storage value chains the upstream capabilities EV manufacture requires; aims to reverse battery and component import dependence. |
| SAREM | Economic      | N | Value-chain investment ambitions not automotive-specific.                                                                                                             |
| SAREM | Institutional | N | Coordination architecture across energy and industrial departments.                                                                                                   |
| SAREM | Epistemic     | C | Skills and industrialisation dimension for the battery chain, aimed at energy rather than vehicles coded C with adjacent reach.                                       |

*Table 5.2 Section-level references to the primary policy texts are to be added upon full-text verification of the APDP Phase 2 Regulations, SAAM 2035, the Taxation Laws Amendment Act, and SAREM. White Paper evidence is drawn from the primary briefing text (the dtic, 2024). Silent cells carry no row: silence is recorded in Table 5.1 as the absence of provision.*

What the evidence in above table shows is an asymmetry in the regime. The reinforcing verdicts rest on enacted, operative provisions the rules that allocate the APDP's benefits, confirmed by the DTIC's own briefing while most of the challenging verdicts rest on commitments the instruments make rather than rules in force, with Section 12V as the one enacted exception. The silent cells are confirmed absences rather than gaps in the search, since each instrument was examined in full. The reinforcement in the regime is therefore structural and in force, while much of the challenge remains announced, and this asymmetry is what the following chapter interprets as the regime's mid-pivot.

## Chapter 6

# Discussion and Conclusion

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This chapter interprets the findings and closes the thesis. It begins by discussing the results in relation to the literature, showing where the findings confirm existing work and where they add to it. The chapter then answers the two sub-questions and the main research question, and translates the findings into recommendations for policymakers, for existing automotive companies, and for new EV ventures. It closes with the limitations of the research and the directions that remain open for future work.

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## 6. Discussion and Conclusion

### 6.1 Discussion

The findings of this research speak to the lock-in literature in three ways. First, they confirm, in a developing-economy manufacturing setting, what the interaction-focused literature has argued conceptually: that lock-in mechanisms co-evolve rather than operate alone. The chains identified in interdependency mapping are a case-level counterpart to the techno-institutional complex described by Unruh (2000), in which technologies and institutions reinforce one another, and to the tightly linked lock-in types described by Seto et al. (2016). The South African case adds specificity to this picture: it shows which domains act as sources and which are reinforced, a directionality that the conceptual literature describes but rarely locates empirically.

Second, the findings qualify the adoption-focused reading of the South African situation. The existing literature explains slow EV uptake through consumer barriers: price, charging access, and awareness (Moeletsi, 2021; Huang, 2023; Ajao et al., 2025). The present analysis does not contradict those findings, but repositions them. The demand-side barriers are themselves partly manufactured upstream, by a fiscal structure and an infrastructure gap that originate in the institutional and technological domains. What looks like a consumer problem is, at its source, a policy and production problem, and this reordering matters for where intervention can be expected to work.

Third, the policy findings resonate with the coordination argument in the transition literature. Gomes et al. (2023) show that China's NEV deployment depended on aligning demand structure, sectoral complementarities, and policy coordination, and that misalignment produced uneven outcomes even there. The South African regime displays the misaligned configuration: a production incentive without demand measures, a transition direction without amended instruments, and value-chain ambitions without codified linkage to the vehicle sector. The mid-pivot pattern identified in this research can be read as the institutional signature of a transition attempted without coordination across domains, and the assessment matrix locates where that coordination is missing.

The findings also permit an ordering of the domains by how reachable they are for policy. The regime has reached the economic domain first: the only enacted challenge, Section 12V, targets retooling capital. The technological and epistemic domains are reached partially, through commitments and adjacent instruments whose effect remains contingent. The individual domain is not reached at all, although its central mechanism, the fiscal asymmetry, lies entirely within domestic control. And the deepest mechanisms, the foreign location of investment and knowledge, are reached by no instrument and may not be reachable by domestic policy alone. This ordering follows directly from the interdependency structure: policy has so far addressed downstream mechanisms while the upstream sources of reinforcement remain in place.

### 6.2 Conclusion

#### 6.2.1 Answer to sub-research question 1

*What lock-in mechanisms characterise South Africa's transition from ICE to EV manufacturing, and how do they interact?*

Lock-in mechanisms were identified in all six domains.

On the technological side, the sector is held by a production base and component industry built for the combustion engine, by scarce charging infrastructure, by an electricity supply that is both unreliable and coal-dependent, and by the absence of any local capability in batteries and electric drivetrains. Economically, the sunk investment in ICE facilities, the dependence on combustion exports, the price gap that keeps EVs out of reach for most buyers, and the location of investment decisions with foreign parent companies together make continued ICE production the rational choice. Institutionally, an incentive architecture that has been calibrated around combustion production since the mid-1990s, a fiscal structure that taxes EVs more heavily than their ICE equivalents, and persistent uncertainty about the direction of policy reward the incumbent technology and deter the alternative. Socially, the livelihoods that depend on the combustion value chain and the position of organised labour raise the cost of change. In the individual domain, the judgement of the managers and engineers who prepare investment cases has been formed on ICE production, while price, low awareness, and distrust of the electricity supply hold consumers to the familiar technology. And epistemically, a skills base built around the combustion engine and technology development located abroad leave the sector without the knowledge an electric trajectory would require.

These mechanisms do not stand alone. They interact in three reinforcing chains.

The first chain runs through production (institutional → economic → technological). Government incentives make building ICE vehicles more profitable. That profit justifies keeping the money already spent on combustion plants working. And because the money stays there, nothing is invested in batteries, drivetrains, or the capability an electric trajectory would need.

The second chain runs through demand (institutional and technological → individual → economic, and back again). Tax rules make EVs expensive and poor charging infrastructure makes them impractical, so few people buy them. A market this small gives manufacturers no reason to build EVs here. And with no manufacturing and no buyers, there is no reason to invest in charging either, which keeps demand low. This is the only chain that closes into a full loop, feeding back into where it started.

The third chain holds the escape routes shut (social → institutional, and economic → epistemic). Because so many jobs depend on the combustion value chain, moving quickly is politically costly, so policy moves slowly. And because the parent companies abroad develop the technology, EV knowledge only arrives here when they decide to invest, so it never builds up locally.

Taken together, these chains show a structure rather than a list. The institutional and economic domains mostly generate the reinforcement, the technological, individual, and epistemic domains mostly receive it, and the social domain constrains the policy response itself. The claim that the institutional and economic domains are the most consequential rests on one explicit criterion: their position in the documented relations. Of the directional relations identified in the evidence, every chain begins in one of these two domains, and they account for all but one of the outgoing relations, while the technological, individual, and epistemic domains appear almost exclusively on the receiving end. Consequential is therefore used here in a structural sense, meaning the domains from which the documented reinforcement originates, and not as a claim about causal weight, which the document evidence cannot establish. It is also what makes the lock-in self-sustaining: a mechanism addressed on its own is renewed by another domain. Every lock-in identified here therefore translates into a challenge that South Africa must resolve, and few of them can be resolved alone.

## 6.2.2 Answer to sub-research question 2

*How are these lock-in mechanisms reinforced or challenged by the existing industrial policy regime?*

The policy regime does both, and this in three ways.

The first is a divide between the old and the new instruments. The older instruments, the APDP and SAAM 2035, carry most of the sector's financial support, and they reinforce the lock-in. Their benefits are earned through existing production at existing volumes, and their growth targets were set for an industry that was almost entirely combustion-based. The newer instruments, the EV White Paper, Section 12V, and SAREM, push in the opposite direction and challenge the lock-in. The problem is one of weight. The instruments that reinforce hold the money, while the instruments that challenge are recent and financially small in comparison.

The second is where these challenges land. Section 12V, the only enacted production-side challenge, targets one mechanism only: the cost of retooling a plant. The White Paper makes broader commitments, but most of them are left for later. SAREM supports the battery value chain, which sits next to the vehicle industry rather than inside it. And no instrument in the set does anything about the individual domain, even though the demand conditions found there are part of what makes the investment case for EV production so weak. Such a domain is recorded as silent, meaning that the instrument contains no provision touching it at all, neither reinforcing the lock-in nor challenging it. Silence is treated as a finding rather than missing data, since a domain the policy regime never addresses is a blank spot in the transition effort. The regime therefore challenges the lock-in where it is easiest to reach, and stays silent where the sources of reinforcement are.

The third comes from checking each lock-in mechanism against the policy set, one by one, and asking whether any instrument addresses it. Three answers emerge. Some mechanisms are addressed: the cost of retooling, the battery value chain, and the exposure of the workforce. Some are not addressed by any instrument: the tax disadvantage on EVs, low consumer awareness, distrust of the electricity supply, and the foreign location of technology development. And one mechanism is addressed on paper yet remains in place: the 150% allowance for NEV production investment is in force, but no manufacturer has committed to building battery electric vehicles in South Africa. This is a finding about the reach of the instrument rather than its administration, since an allowance can reward an investment decision but cannot cause one, and that decision is made at parent-company level on conditions the allowance does not touch. This last group matters most, because it separates two different problems: a barrier that policy has never touched, and a barrier that policy has touched without effect.

### **6.2.3 Answer to the main research question**

*How do lock-in dynamics and the industrial policy regime shape South Africa's transition from internal combustion engine (ICE) to electric vehicle (EV) manufacturing?*

The two sub-answers combine into a single account, and placed together they explain each other. The lock-in structure explains why the newer policy instruments have achieved so little so far, since each of them addresses one part of a chain and leaves the rest of it standing. The policy pattern explains why the lock-in remains in place, since the instruments that carry most of the sector's financial support still reward what the sector already does.

The answer is therefore that the lock-in dynamics and the industrial policy regime shape the transition together, and in the same direction. The lock-ins hold the sector to ICE production, and the policy regime has not yet reached the mechanisms that do the holding. This suggests that the transition is not being slowed by a lack of intent, but by a structure the current instruments do not yet reach. There is also the source of movement to consider: where change is visible at the moment of writing, it comes mostly from outside the domestic policy framework, through the pressure of the export markets and the decisions taken by the groups that own the plants.

## 6.3 Recommendations

### 6.3.1 For policymakers

The recommendations are addressed to the national government, principally the DTIC and National Treasury, which between them own the five instruments analysed. The findings do not support a single decisive intervention; they show a structure in which isolated measures are absorbed. Five recommendations follow, ordered by how directly each lies within the state's control.

First, remove the fiscal asymmetry. The duty and tax structure treats EVs less favourably than their combustion equivalents the one upstream mechanism entirely within domestic control. Its persistence alongside a production incentive means the state supports EV supply while suppressing EV demand. Aligning the treatment of the two technologies corrects the demand chain at its institutional source.

Second, enact the deferred demand side. The individual domain is challenged by no instrument in the set, yet the demand chain shows weak uptake is what removes the market signal for retooling. Demand-side measures are not a later phase of the transition but a precondition for the production phase already legislated.

Third, complete the 150% allowance. Section 12V addresses a real barrier, but it rewards a decision made at parent-company level abroad, on the basis of demand, infrastructure, and capability conditions the allowance does not touch this research's clearest case of an instrument in force without effect. The solution is not a larger allowance but a stronger bid: delivering the demand and infrastructure conditions on a stated timetable, so that a subsidiary can present its group with committed conditions rather than announced intentions.

Fourth, place the long-term instrument where it lies: the successor to the APDP after 2035. The findings show the APDP's calibration is what makes technology-neutral support flow to the incumbent. Calibrating the successor programme around NEV platforms from its first day is the most consequential design choice available an allowance can open a door; only the successor programme keeps it open. Any such design should state when support ends, since this research shows how yesterday's support instruments became today's lock-in.

Fifth, provide for skills and research before investment arrives. Knowledge follows investment in this sector, so a skills strategy that waits for committed production will arrive late by construction. Extending SAREM's skills logic into the automotive value chain, and codifying the linkage no instrument currently makes, addresses the domain the regime reaches last.

Sixth, govern the transition as a moving target. EV technology is still in its era of ferment: the dominant design has not settled, and the technology is changing faster than policy cycles usually move. Domestically, this means the state cannot wait for the technology to stabilise before acting.

Instruments should be reviewed on a regular cycle, and the skills system should be built ahead of demand rather than after it. Internationally, the requirements of the export markets are themselves still taking shape, so the state should track their regulatory direction. emissions rules, content requirements, carbon measures and align the domestic framework with what continued access will demand. There is also room for more than monitoring. The markets South Africa exports to and the parent companies that own its plants largely belong to the same region, so the channels for collaboration already exist. Structured engagement on regulatory alignment, on the conditions for EV model allocation, and on the value-chain linkages both sides need would turn the export relationship from a source of pressure into a shared planning space.

### **6.3.2 For existing automotive companies**

For the OEM subsidiaries, the findings identify the shape of the internal task: EV allocation is won at parent-company level, and the bid is only as strong as its surrounding conditions. Subsidiaries can strengthen it on two fronts within their control building demonstrable local capability through workforce reskilling ahead of allocation, and using transitional production, as the existing hybrid and plug-in hybrid activity shows, to prove electrified capability within group networks before full BEV platforms are contested. Engaging collectively with government on the timetable for demand and infrastructure conditions serves the same end: committed conditions are what convert the Section 12V allowance into a winnable case.

For component manufacturers, the exposure is asymmetric: the sector's specialisations include products that disappear with the combustion engine. The findings point toward repositioning along two lines toward the component categories that survive electrification, and toward the battery and renewable value chains that SAREM targets, which stand adjacent to the regime's stated ambitions and to the localisation commitments of the White Paper. Early skills investment is the common requirement, since capability is the constraint the policy regime reaches last.

### **6.3.3 For new EV ventures**

For new entrants, three implications follow. First, the demand environment cannot be assumed: thin retail demand is manufactured upstream by fiscal and infrastructure conditions, so viable entry points lie in fleet-based and export-linked demand rather than the consumer market. Second, the enacted incentive landscape favours the profitable incumbent a capital allowance is worth least to a venture without taxable profits so new ventures should position where support reaches them: the battery, storage, and component value chains that SAREM targets, and the charging infrastructure whose scarcity this research documents as a standing gap. Third, capability is the scarce asset. Because the local skills and knowledge base is formed around the incumbent technology, ventures that invest early in training and technical capability address the constraint the regime reaches last, and position themselves for the linkages the White Paper commits to but has not yet built.

## **6.4 Limitations**

The research has the following limitations, and each one marks the boundary of what this thesis can claim.

The first is that the research is desk-based. It cannot reach the intentions of the actors involved, the informal practices inside the sector, or the negotiations that documents do not record. The analysis is limited to what the sector and the state have put in writing.

The second is that the research looks at what the policies say, not at how they are carried out. Where an instrument is in force but the barrier it targets remains, this research can point out the mismatch but cannot explain why it exists. It also does not consider the political and economic factors that shape an industry of this size, such as the bargaining between the state, the manufacturers, and organised labour, or the wider economic conditions under which investment decisions are taken.

The third is that only publicly available documents could be used. Internal government assessments and the investment plans of the manufacturers are not accessible, and either of these could change individual findings.

There is also the scope to consider. This research covers four-wheel passenger vehicles only. Commercial vehicles, buses, trucks, and two- and three-wheelers fall outside the analysis, and these segments involve different technologies, different infrastructure needs, and in several cases different policy instruments. Whether the same mechanisms hold there cannot be claimed from this research.

The fifth concerns the framework itself. The six domains decide what this research looks for, and a different framework would have brought different aspects of the transition into view. The boundaries between the domains also required judgement, since several mechanisms could reasonably be placed in more than one.

The sixth is that the assessment describes a moving target. Several instruments were under review at the time of writing, and the market itself continues to change. The findings should therefore be read as a diagnosis of the regime as it stands today.

Finally, the political and economic dimension deserves a closer statement. The automotive sector is among South Africa's largest manufacturing industries and a major source of exports, which makes its transition a matter of high political and economic stakes. Powerful actors, including the manufacturers and their parent companies, organised labour, component firms, and several government departments, negotiate the sector's direction through channels that documents only partially record. This research analyses what the policies say and what the literature documents, not the interests or bargaining power of these actors. Where the findings show a policy in force without effect, or a domain that no instrument addresses, the explanation may lie in exactly this dimension.

## **6.5 Future Research Directions**

This research has mapped the lock-in mechanisms and assessed the policy regime against them, but it has only scratched the surface of the problem. Several directions could follow from it. Research based on interviews with the manufacturers, the component firms, and the policymakers would test whether the mechanisms and the chains identified here correspond to how the actors themselves describe their situation, and would reach the intentions and negotiations that a document study cannot. A complementary direction would be to follow the instruments into practice, since policies that are in force can still be examined for what they actually produce, and the newer instruments of this regime are only now beginning to take effect. The analysis could also be widened in scope, both toward the vehicle segments that fall outside this research, which carry much of the country's transport demand and operate on different economics, and toward other developing automotive economies, where

applying the same six-domain assessment would show whether the structure found here is particular to South Africa or common to sectors in a similar position.

The direction that follows most directly from the findings concerns collaboration between the actors involved. This research points to coordination as the missing element of the transition, since the instruments exist but nothing aligns them, and the domains left untouched are those that fall between the responsibilities of different actors. How such coordination could work in practice, among the government departments, the manufacturers, organised labour, and the energy sector, and what South Africa might learn from countries that have managed their transitions through structured cooperation between the state and the industry, is a question this research could not answer. In this case, the question shifts from what the policy regime contains, which this thesis has addressed, to how the actors behind it could be brought to act together.

South Africa built its automotive industry once, under conditions that were not easy either. The barriers identified in this thesis are real, but none of them is permanent. Each lock-in described here was created by decisions, and what decisions have created, decisions can also undo. If the actors involved find a way to act together, the same industry that is now held to the old technology could become the place where the new one takes root.

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## AI Statement:

In accordance with TU Delft's policy on the responsible use of AI, I acknowledge the use of AI tools (Claude and ChatGPT) in the preparation of this thesis. As English is not my first language, I used these tools mainly to refine my thoughts into clear academic writing and to check sentence structure, grammar, and readability. I also used them to review draft sections for consistency, to verify a few claims against the sources I had collected, and to check whether my reasoning came across the way I intended. The research design, the analysis, the findings, and the conclusions are my own. Example prompts I used include:

- Check whether the sentence structure in this section is correct and natural.
- Does my reasoning in this paragraph follow logically from the findings I have presented?

Grammarly was used for a language check across the document, to improve grammar, clarity, and readability. No prompts were used for this; the text was checked and corrected where needed.