Framework to manage change complexity when introducing high voltage technology to automotive production lines

by

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Dissertation presented for the degree of
Doctor of Philosophy in Industrial Engineering
in the Faculty of Engineering at
Stellenbosch University

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December 2019

DECLARATION

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SUMMARY

Manufacturing has evolved over the centuries, shifting from one manufacturing paradigm to the next. Competition is now truly global, with companies needing to adapt to market requirements and needing to adopt new technologies at an ever-increasing pace. Mega-trends like climate change, the ever-increasing demand for mobility and the threat of Peak Oil, are driving change in the automotive sector to new heights – particularly in the directions of e-mobility solutions. These changes, together with the current manufacturing paradigm of 'Mass Customisation' are bringing constantly increasing levels of complexity to manufacturing plants around the world. There often remains a gap though, between the inherent values of a technology and the ability of organisations to effectively put it to work. With mounting global competition the gap between a technology's promise and achievement is a major concern for all companies. Despite the globally competitive nature of automotive manufacturing and its importance for industry, there is no framework currently whereby automotive manufacturers can introduce complex technological changes safely, effectively and efficiently.

Daimler AG recently decided to introduce Hybrid vehicles to the East London factory of its subsidiary, Mercedes-Benz South Africa (MBSA). The C350e would pioneer 'high-voltage automotive manufacturing' in South Africa as it would be the first hybrid vehicle mass manufactured in the country. The new variant would introduce to MBSA a powerful Lithium-Ion battery, capable of producing 60kW and operating at a potentially lethal 300 Volt. The factory was given less than a year to prepare and to integrate this dangerous new technology at a level meeting the stringent international safety and quality standards of Mercedes-Benz. No local automotive OEM had any experience with 'high voltage automotive manufacturing' prior to the implementation decision taken in Germany and the safety risk initially prompted significant resistance in the South African factory. The risk and the associated resistance had to be carefully managed by the Implementation Team against the backdrop of a lack of applicable safety legislation in the country.

Prompted by the introduction of Hybrid Vehicles in Mercedes-Benz South Africa's East London plant and by the likelihood of further Hybrid and eventually full Electric Vehicle production in South Africa, this study sought to create a framework for the safe, effective and efficient introduction of high voltage technology. The author sought to firstly obtain through a Literature Study a holistic understanding of Change Management and Complexity Management, as well as Implementation Theory within the context of High Voltage automotive technologies. The aim being to develop a conceptual framework to introduce High Voltage technological change in production lines of automotive manufacturers. The conceptual framework was verified against all research requirements and then validated with data from Mercedes-Benz South Africa's pioneering C350e Plug-in Hybrid Project.

The Implementation Framework for Automotive Technology conceptualised, verified and validated in this study is the first practical and measurable framework specifically aimed at the automotive industry and provides unique guidance for manufacturers in introducing High Voltage technology into their production lines.

OPSOMMING

Namate vervaardiging deur die eeue heen ontwikkel het, het dit van die een vervaardigingsparadigma na die volgende oorgeskakel. Mededinging vind nou werklik wêreldwyd plaas, en ondernemings moet by die markvereistes aanpas en nuwe tegnologieë teen ’n al hoe sneller pas aanwend. Mega-tendense soos klimaatsverandering, die toenemende vraag na mobiliteit en die bedreiging van piek-olie, dryf verandering in die motorvoertuigsektor tot nuwe hoogtes – veral in die rigting van e-mobiliteitsoplossings. Hierdie veranderings, tesame met die huidige vervaardigingsparadigma van ‘massa-pasmaking’, lei tot verhoogde kompleksiteitsvlakke by vervaardigingsaanlegte oor die wêreld heen. Daar bly egter steeds ’n gaping tussen die inherente waardes van ’n tegnologie en organisasies se vermoë om dit effektief te laat werk. Met die toenemende wêreldwye mededinging is die gaping tussen die belofte en die sukses wat ’n tegnologie bied, ’n groot bron van kommer vir maatskappye. Ondanks die wêreldwye mededingende aard van motorvoertuigvervaardiging en die belang daarvan vir die nywerheid, is daar tans geen raamwerk waarvolgens motorvoertuigvervaardigers ingewikkelde tegnologiese veranderings veilig, effektief en doeltreffend kan instel nie.

Daimler AG het onlangs besluit om hibriedvoertuie by die Oos-Londense fabriek van sy filiaal Mercedes-Benz South Africa (MBSA) bekend te stel. Die C350e moes ’n baanbreker vir ‘hoëspanningsmotorvoertuigvervaardiging’ in Suid-Afrika wees, aangesien dit die eerste massavervaardigde hibriedmotorvoertuig in die land sou wees. Die nuwe variant wat by MBSA bekendgestel sou word, beskik oor ’n kragtige litiumioonbattery wat 60 kW lewer en teen ’n potensieel lewensgevaarlike 300 Volt werk. Die fabriek het minder as ’n jaar gehad om vir hierdie gevaarlike nuwe tegnologie voor te berei en dit te integreer op ’n vlak wat aan die streng internasionale veiligheids- en gehaltestandaarde van Mercedes-Benz voldoen. Geen plaaslike vervaardiger van oorspronklike toerusting (original equipment manufacturer [OEM]) het enige ervaring gehad van ‘hoëspanningsmotorvoertuigvervaardiging’ vóór die implementeringsbesluit wat in Duitsland geneem is nie, en die veiligheidsrisiko het aanvanklik aansienlike weerstand in die Suid-Afrikaanse fabriek veroorsaak. Die implementeringspan moes die risiko en die gepaardgaande teenstand sorgvuldig bestuur, gegewe die agtergrond van ’n gebrek aan gepaste veiligheidswetgewing in die land.

Gesien die bekendstelling van hibriedvoertuie by MBSA se Oos-Londense aanleg, en die moontlikheid van verdere hibried- en uiteindelik volledig elektriesevoertuig-vervaardiging in Suid-Afrika, was hierdie studie daarop gemik om ’n raamwerk te skep vir die effektiewe en doeltreffende bekendstelling van hoëspanningstegnologie. Die outeur poog eerstens om deur middel van ’n literatuurstudie, ’n holistiese begrip van veranderings- en kompleksiteitsbestuur, sowel as ’n implementeringsteorie, binne die konteks van hoëspanningvoertuigtegnologie te bekom. Die doel is om ’n konsepsuele raamwerk te ontwikkel waarvolgens hoëspannings-tegnologiese verandering in die vervaardigingslyne van motorvoertuigvervaardigers ingestel kan word. Die konsepsuele raamwerk is ooreenkomstig al die navorsingsvereistes geverifieer en daarna ooreenkomstig data van MBSA se baanbrekers- C350e-inprophibriedprojek gevalideer.

Die Implementeringsraamwerk vir Motorvoertuigtegnologie wat in hierdie studie gekonsepsualiseer, geverifieer en gevalideer is, is die eerste praktiese en meetbare raamwerk wat spesifiek op die motorvoertuigbedryf gemik is en bied unieke leiding aan vervaardigers wat betref die bekendstelling van hoëspanningstegnologie in hul produksielyne.

ACKNOWLEDGEMENTS

I would like to thank the following people for their contribution to this study and dissertation:

- Prof. Tiaan Oosthuizen, for starting me on the PhD journey and helping me draw from both industry and academia, for the enhancement of both.

- Prof. Corne Schutte and Dr. Theuns Dirkse-van Schalkwyk, for selflessly jumping in to supervise my final year, remodelling where needed and helping me over the final hurdles.

- My employer, Mercedes-Benz South Africa, for trusting me with the pioneering C350e Plug-in Hybrid Project and for making this study possible.

- My family, friends and colleagues, for their support and encouragement.

- My brother, for a lifetime of positive sibling one-upmanship, pushing us both to excel.

- My mother, for her unwavering belief and life guidance.

- My wife, for making the last few years truly the best of my life.

- My father, for teaching me that our only true competition is against our own potential. This study, and the title that goes with it, is dedicated to you.

"For unto whomsoever much is given, of him shall be much required"

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LIST OF ABBREVIATIONS

AC	Alternating current
C350e	Plug-in Hybrid version of the W205 C Class
CATS	Changing as Three Steps (Change Management model by Kurt Lewin)
CATWOE	Acronym: Customers, Actors, Transformation, Worldview, Owners and Environmental
CEO	Chief Executive Officer
CES	Chief Electrical Specialist
CFIR	Consolidated Framework for Implementation Research
CPS	Cyber-Physical-Systems
DC	Direct current
EBP	Evidence Based Practices
ECE	Economic Commission for Europe
EDI	Electronic Data Interchange
ET	Engineering Trial
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
fph	Faults per hundred (vehicles)
HV	High Voltage
ICE	Internal combustion engine
IFAT	Implementation Framework for Automotive Technology
KERS	Kinetic Energy Recovery System
KPI	Key Performance Indicator
MBSA	Mercedes-Benz South Africa
MIT	Massachusetts Institute of Technology
NNMI	National Network for Manufacturing Innovation
OAP	Open Architecture Products
OEM	Original Equipment Manufacturer
PDCA	Plan-Do-Check-Act
PT	Production Trial
R&D	Research and Development
SIP	Strategic Innovation Promotion Program
SOP	Start of Production
SSM	Soft Systems Methodology
SST	Stratified Systems Theory
SUV	Sport Utility Vehicle
SWI	Standard Work Instruction
VDE	Verband der elektrotechnik elektronik informationstechnik e.V)
VoCA	Voice of the Customer Audit
W205	Current generation C Class

1. INTRODUCTION

1.1 The Importance and Evolution of Manufacturing Systems

A scholar wrote an interesting anecdote some time ago [1]:

> "Once there was an economic power that dominated the world's industrial production… a time came when this country began to decline relative to its international competitors and was challenged by another, which happened to be west across the ocean… At first, the dominant country had nothing to fear from the other one. This country focused only on the low-end, where margins were smaller… But then this upstart continued to gain market share, fears arose that it would eventually overwhelm its larger ally with its imports, putting firms and maybe entire industries out of business".

It would be easy to assume the author was speaking about the United States of America losing power to China, but the anecdote was in fact referring to 19th century Britain losing its dominant position to America. The USA adapted much quicker to the manufacturing paradigm of Mass Production and Britain never regained its former status. Countries and companies that do not adapt quickly enough to ongoing paradigm or technology changes risk the same fate today.

Having a strong manufacturing base is important for societies, as it stimulates all other sectors of the economy. Manufacturing has been fundamental to prosperity around the world for centuries. It has contributed and continues to contribute to the growth of wealth, power and position of nations [2]. It has been the development pathway of many leading nations, like 19th century Britain, Germany, Japan and the USA in the 20th century and China and South Korea today. It is the backbone of modern industrialised society and an important cornerstone of the world's economy.

Manufacturing systems have evolved over the centuries though, shifting from one paradigm to the next. Figure 1 highlights the scale and scope priority changes of the various paradigms, starting with the 1st Industrial Revolution. In recent years, competition has become truly global. The speed with which companies need to adapt to market requirements and with which they need to adopt new technologies is unprecedented. Companies that do not adapt quickly enough risk their continued existence [3].

One needs only look at Nokia for an example of a once market-dominating company who could not keep pace with changing requirements and never recovered. From its glory days around the year 2000, the company lost two-thirds of its market capitalisation in two years and when it was eventually sold to Microsoft, it was worth less than a tenth of its peak value (Figure 2). At the same time mega-trends like climate change, the ever-increasing demand for mobility (especially in China) and the threat of Peak Oil, are driving change in the automotive sector to new heights – particularly in the direction of e-mobility solutions [4]. These changes, together with the current paradigm of 'Mass Customisation' have brought constantly increasing levels of complexity to manufacturing plants around the world. A new paradigm of "Social Manufacturing" is emerging and will likely bring even more complexity and further increase the pressure on companies to 'adapt or die'.

There often remains a gap though, between the inherent values of a technology and the ability of organisations to put it to work effectively. With mounting global competition, the gap between a technology's promise and achievement is a major concern for all companies.

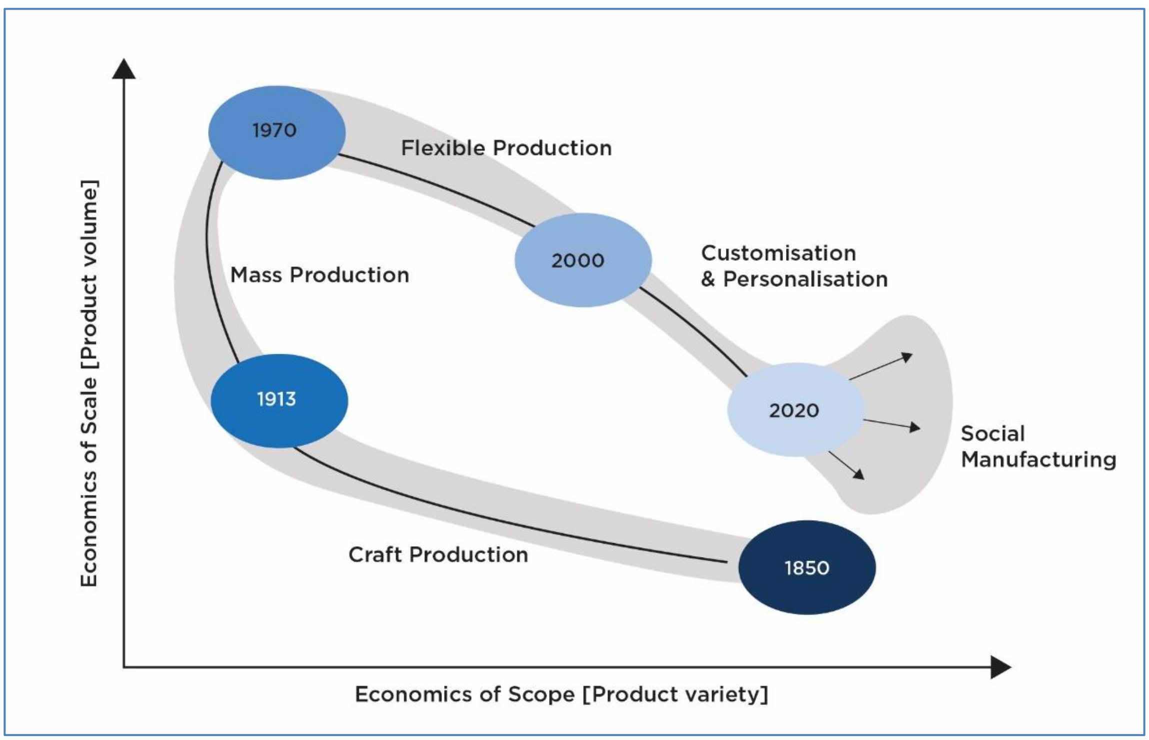


Figure 1: Revolutions of manufacturing, affecting product variety and volume
(Adapted from [5])

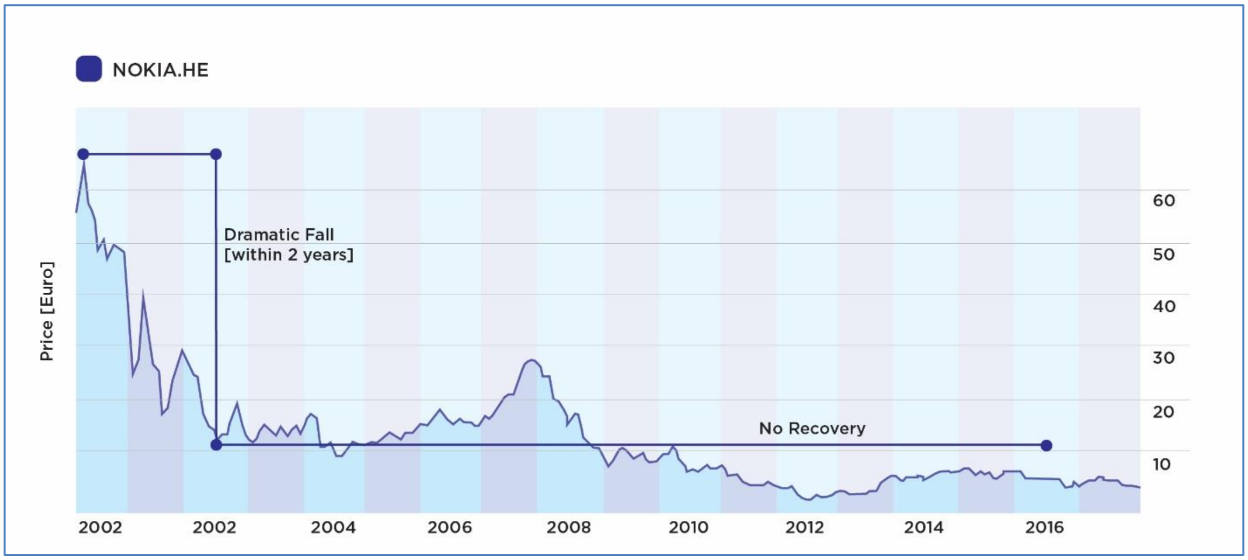


Figure 2: The dramatic fall of Nokia

(Adapted from [6])

According to Koren et al. [7], changes in the paradigms are caused by changes in market and societal imperatives, as well as the development of new enabling technologies. Paradigm changes are a source of global competition, where nations adapting quickly to the changing milieu can greatly improve their position and status, while lagging nations risk their downfall. Similarly, companies that do not embrace change risk their competitiveness and their continuity.

The same also holds true for production sites, so the ability to build and sell any configuration of its company's products is a competitiveness strategy for many manufacturing plants, specifically automotive plants. Where the same model is built in multiple global locations, a manufacturing plant that cannot produce a certain variant or configuration is at a distinct disadvantage, as it cannot compete with the other plants to produce those orders [8]. Managing product and process variety therefore is an enabler towards improving perceived value [9]. The associated rise in complexity for those production locations can be viewed as a direct result of a strategy for competitiveness. What most automotive manufacturing plants lacked until recently was a way to implement new products or technologies safely, effectively and efficiently to ensure their survival in the fast-paced world of modern, globally competitive manufacturing.

1.2 The Rise of the Electric Vehicles

Petrol and Diesel engines, for all their differences, both convert chemical energy into propulsion. Nikolaus Otto's engine does this by spark ignition, where Rudolf Diesel's does it by compression, but both ignite an air and fuel mixture to create momentum. Since 1876 and 1892 respectively, these have been the main means to generate propulsion in the automotive industry. While electric vehicles (EVs) were available and even common in the early days of automotive manufacturing, the advances made by Henry Ford changed everything and the electric vehicle was all but forgotten until the 21st century, when rising environmental awareness again popularised the technology. The global fleet of EVs is now growing at an incredible pace. From approximately 200,000 units in 2013, the global EV fleet grew to more than six times that only three years later (Figure 3), though still largely concentrated in the 'Developed World'. While South Africa's own fleet is quite modest (believed to be less than 400 units as of January 2018 [10]), the South Africa automotive industry and similar ones in many developing countries, can greatly benefit from this trend if they position themselves to be ready for the new technology being demanded in major automotive markets.

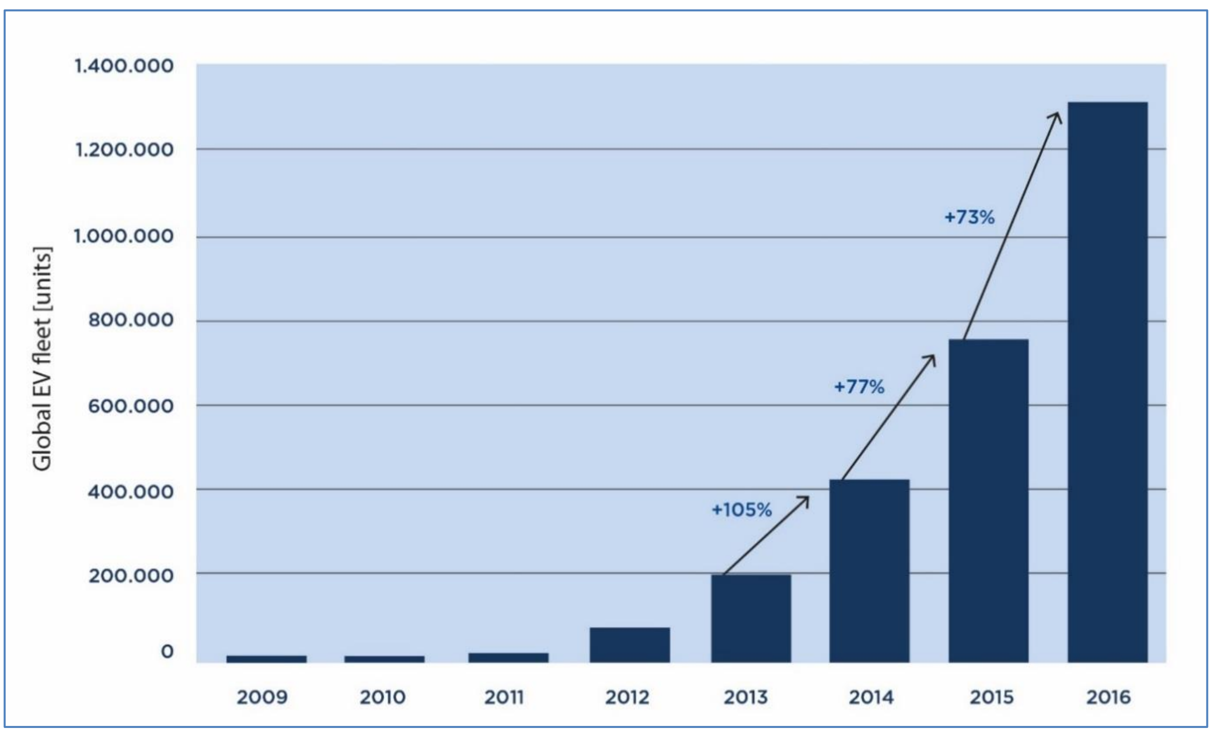


Figure 3: The global fleet of electric vehicles is rising rapidly

(Adapted from [11])

1.3 The first hybrid in South Africa

The South African manufacturing sector is in decline. Figure 4 shows employment in the sector contracting across the majority of provinces. With the automotive sector forming a substantial part of overall manufacturing in the country, it would be a boon to the country if this sector could be supported and grown. The sector is responsible for significant employment, specifically in the Eastern Cape Province and bolstering it could have wide-ranging benefits to the local community and the wider region.

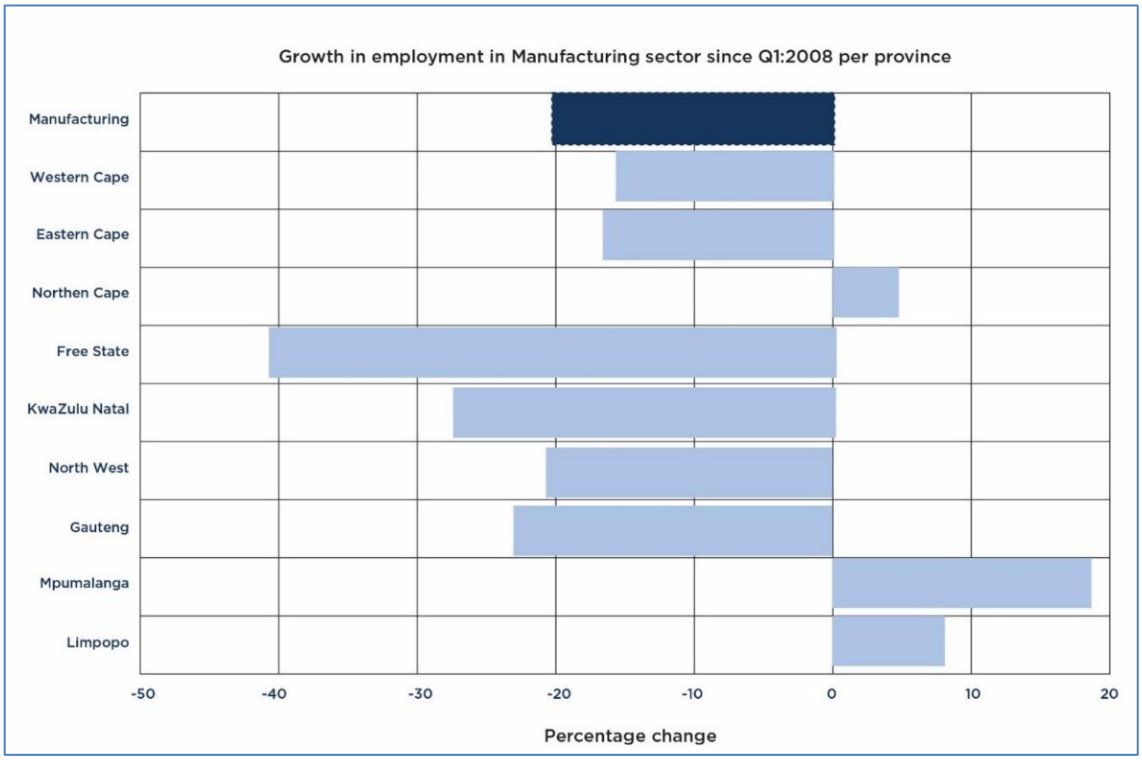


Figure 4: South African Manufacturing in decline
(Adapted from [12])

There are seven automotive Original Equipment Manufacturers (OEMs) producing passenger cars and light commercial vehicles in South Africa, with production sites Gauteng, KwaZulu-Natal and the Eastern Cape (Figure 5). They were all producing conventional vehicles powered by internal combustion engines (Table 1) until Mercedes-Benz South Africa's C350e Plug-in Hybrid Project was announced.

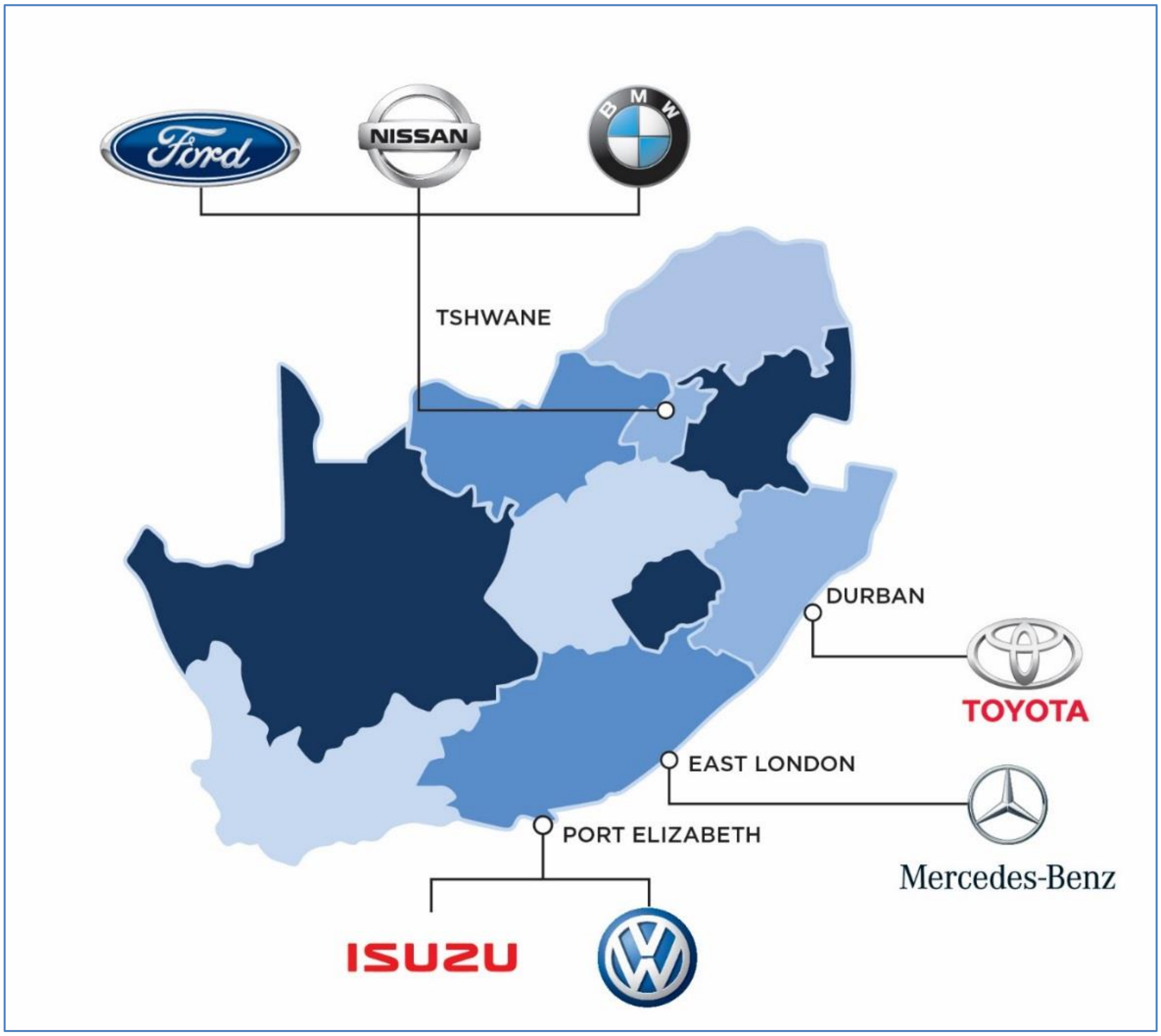


Figure 5: Passenger car and light commercial vehicle OEMs in South Africa (Adapted from [13]**)**

With the global trend toward electrification of the drivetrain, it was perhaps inevitable that at some point a South African OEM would be asked to move in this direction too, whether they were ready or not. In November 2015, to meet increasing global demands, Stuttgart-based Daimler AG instructed its local subsidiary, Mercedes-Benz South Africa (MBSA), to start producing the Plug-in Hybrid variant of its popular C Class model (Figure 6). This multi-million Euro project was kicked off a few days later in MBSA's East London factory, with the goal of delivering units to market by the 3rd Quarter of 2016, giving the factory less than a year to introduce a complex, potentially dangerous new technology and to deliver a product meeting international Mercedes-Benz quality and safety standards.

MBSA’s East London factory is one of four plants worldwide producing the Mercedes-Benz C Class, along with Bremen in Germany, Tuscaloosa in the United States and Beijing, China. The South Africa factory produces in excess of 100,000 C Class units every year and it was on its existing production lines that the Hybrid variant had to be implemented. Though the C350e variant formed part of the global configuration mix of the W205 C Class model from its initial launch in 2014, the South African production plant was set up to exclude this variant, as the project’s planning premise was that it would not be built in the East London facility.

Table 1: Passenger cars and light commercial vehicles produced in South Africa

OEM	MODEL	VOLUME / YEAR (Approx)
	C-Class	100,000
BMW	X3	75,000
	Polo / Polo Vivo	120,000
ISUZU	KB / D-Max	20,000
TOYOTA	Corolla / Quest	30,000
	Hilux / Fortuner	140,000
NISSAN	NP200 Quantum	20,000
	NP300	35,000
Ford	Ranger / Everest	90,000

(Adapted from [14])

While manufacturing plants may want to introduce new models and variants precisely for the competitive advantage mentioned, they often face implementation challenges. It has been reported that nearly 90% of projects across all economic sectors fail as a result of human error, specifically miscommunication between the various project links - often the project sponsor and project manager [15]. Other factors that complicate complex change projects include not only the scope and technical complexity, but also conflicting stakeholder objectives, standardised processes that don’t accommodate the flexibility required and pressure from external parties e.g. government. It is known that the size of the organisation, the resources available to it and the support of its management has a demonstrable impact on the adoption of new technologies [16]. Once an adoption decision has been made, the attitude of management and the ultimate users’ perceptions of the technology play a large role in the implementation success [17]. Part of the reason for this is that the adoption of new technologies affects not only the tasks of the users, but often changes the interdependencies between different teams and areas [18].

It has been shown that after organisations develop new technologies they generally hand them off to users who, though knowledgeable and experienced in the areas of planned application, are less technically skilled in the technology itself. The user organisation (e.g. manufacturing plant) is often not able to take over responsibility for the new technology at the time that the development team (e.g. a centralised Research and Development division) wants to hand it over and is also often not yet able to optimally put it to work [19]. New technologies are frequently developed in isolation, separate from the area of application and the user organisations regularly do not have input into the development process, nor are they given time to test the new technology in their area before there is an implementation decision. Once the decision is made and the user organisation needs to implement, they are faced with the task of doing so before they fully understand the technology and its risks and complexities, though not doing so risks their competitiveness.

As global demands rapidly shifted, Daimler AG needed MBSA to produce the state-of-the-art C350e variant and to do so in record time. While not the first Hybrid to be sold in South Africa, the C350e would be the first Hybrid locally (mass) manufactured. At the time of the implementation decision, no other automotive OEM in the country were assembling High Voltage enabled vehicles or using High Voltage (HV) components.

There was also no specific South African legislation governing how technology of this kind should be treated in the workplace, nor any framework on how such a technology could be introduced safely, effectively and efficiently. The risk and the associated resistance had to be carefully managed by the Implementation Team against the backdrop of this lack of applicable safety legislation or regulations [20] [21]. What made the C350e different from any vehicle previously produced by MBSA, or in fact any automotive OEM in South Africa, was the unique and powerful 'High Voltage' Lithium-Ion battery. This 100kg battery produced 60kW, more power than some vehicles' engines (e.g. the 1.2-liter engine in a Datsun Go [22]). The battery, when combined with a patented Mercedes-Benz 4-cylinder petrol engine, enabled the C350e to produce 275 horsepower and delivered a 0-100km/h time of 5.9 seconds. It also allowed the car to drive up to 30km in the fully electric "E-mode", not using any petrol whatsoever, making it "not only a very fast and powerful, but also a very environmentally-friendly addition to the C Class range" [23]. It was the High Voltage nature of the battery though that created the concern and the significant change resistance. The battery operated at 300V, a potentially lethal voltage and the East London plant was pioneering "High Voltage automotive manufacturing" in South Africa [8].

The introduction required an innovative approach, as the production lines could not be stopped in order for the facilities and equipment to be upgraded to accommodate the additional components and work-content. While some of the new content of the vehicle could be done modularly, separate from the existing production lines, some had to be done on the existing lines, due to the nature of the vehicle design and the practicalities of vehicle assembly. As HV cabling and electronics form an integral part of Hybrid vehicles, they could not simply be added after the vehicles were assembled, but needed to be built into the cars in a practical assembly sequence.

The need for a framework to facilitate this type of rapid implementation was clear. MBSA was the first, but probably not the last South African OEM to be asked to implement HV technology. It can safely be assumed that with the global shift toward e-mobility, many automotive manufacturing plants around the world will soon face that same challenge.

The purpose of this study was to develop a framework to introduce HV technological changes in production lines of automotive OEMs safely, effectively and efficiently, to allow them to react quickly to changes in paradigms and technologies and in doing so remain competitive in the face of mounting global pressure.

Figure 6: The C350e Plug-in Hybrid

(Adapted from [24])

1.4 Developing the Implementation Framework for Automotive Technology

The words theory, model and framework are often used interchangeably in literature, although they are distinct concepts. Where a theory normally implies a level of predictive capacity, a model is commonly created to describe a process and a framework points to factors believed/found to influence outcomes. Both models and frameworks typically contain a checklist of factors or aspects relevant to the implementation being described. Models often "present an ideal view of implementation practice", while many frameworks draw extensively from the originators' own experience implementing new practices.

It can be argued though that as there is significant overlap, what matters most is not the nomenclature of the construct, but rather to identify potential enablers and barriers to the implementation and to describe ways to deal with them effectively.

There is a wave of optimism currently (specifically in Implementation Science) that thinks theoretical approaches can contribute to narrowing the research-practice gap. Some critics believe theory is not necessarily better than ‘common sense’, which itself could arguably be said to be a form of non-codified theory [25]. It is the author’s belief that the answers lie in a combination of codified and non-codified theory, supported by practical implementation experience. In 2009, a Consolidated Framework for Implementation Research (CFIR) was developed for the healthcare profession [26]. In this study the researcher started the development of a similar framework for the automotive sector. The Implementation Framework for Automotive Technology (IFAT) consolidates a myriad of different yet overlapping concepts and bridges their individual shortcomings to offer an overarching solution to introducing a new technology (specifically High Voltage technology) to an automotive OEM’s production lines safely, effectively and efficiently and offers countermeasures to the additional complexity originating from such an introduction.

The Plug-in Hybrid variant of MBSA’s popular C350e’s “High Voltage manufacturing” project was used as the core case study to validate the proposed framework and to set the platform for its further development. It is the author’s ardent hope that this dissertation will serve to better enable companies and managers to react to these types of market pressures and that it stimulates corporate, political and academic discussion to enhance South Africa’s manufacturing capabilities, to ultimately contribute to sorely needed job creation in the automotive sector and the country. The research aim and objectives will be further detailed in the following chapter.

2. PROBLEM STATEMENT, RESEARCH AIM AND OBJECTIVES

2.1 Problem statement

Although the instruction to implement a technological change is typically initiated at a strategic level, the implementation of that decision often occurs at a lower stratum, necessitating a more practical than theoretical or strategic approach. Current change management methodologies found in literature are too conceptual and abstract for the rapid implementation required by globally competitive automotive OEMs, specifically in their manufacturing plants.

When Daimler AG instructed Mercedes-Benz South Africa to start producing the C350e Plug-in Hybrid, the East London factory was given less than a year to introduce a complex, potentially dangerous new (high voltage) technology and to deliver a product meeting international Mercedes-Benz quality and safety standards. While there have been many frameworks put forward to manage change and complexity, there was no practical and measurable framework available to guide an automotive OEM to introduce high voltage technological change, like the introduction of the C350e, to its production lines and the Implementation Team needed a framework with which to implement it safely, effectively and efficiently. Noted journals including the International Journal of Automotive Technology, as well as the International Journal for Automotive Innovation were scrutinised for keywords including “high voltage”, “hybrid vehicle”, “electric vehicle”, “implementation” as well as “introduction”, yet no mention of such framework could be found in any, nor in the broader narrative search for relevant literature.

2.2 Research aim

The aim of this research was to create the first practical and measurable linear framework to facilitate rapid implementation of high voltage technology in automotive manufacturing plants to support global competitiveness. To do this the researcher needed to understand the intracacies of change management and complexity management, specifically the aspects applicable to introducing technological change to automotive production lines. Key elements necessary to aid manufacturers with these type of implementation projects were identified and focus placed on the high voltage technological change needed to produce hybrids and electric vehicles in order to formulate the conceptual framework.

It was the objective of this dissertation to conceptualise, verify and validate a practical and measurable linear (step-by-step) framework to facilitate rapid implementation of this type of technology, supporting competitiveness in the global automotive industry. It is hoped that this will be the foundations for a framework for the automotive sector, similar to what the Consolidated Framework for Implementation Research (CFIR) [26] is in the healthcare sector. The approach, similar to that of the CFIR, was to embrace rather than replace the existing literature and body of knowledge. The Implementation Framework for Automotive Technology (IFAT) developed in this study consolidates a myriad of different yet overlapping concepts and bridges their individual shortcomings to offer an overarching solution to introducing High Voltage technology to an automotive OEM's production lines safely, effectively and efficiently.

2.3 Research objectives

By creating a practical and measurable Implementation Framework, it was the intention of the author to help equip manufacturers to participate competitively in the global automotive manufacturing and supply chains of high voltage hybrid and electric vehicles and to strengthen the high voltage manufacturing abilities of these manufacturers.

The research objectives can be summarised as follows:

- Obtain a comprehensive understanding of Change Management, Complexity Management and Implementation theory within the context of High Voltage automotive technology.
- Develop and verify a conceptual framework to introduce high voltage technological change in the existing production lines of automotive manufacturers.
- Validate the framework with data from Mercedes-Benz South Africa's pioneering C350e Plug-in Hybrid Project.
- Provide a validated, practical framework to introduce and implement High Voltage technology, maintaining the identified pre-requisites and automotive standards, while measuring associated impacts to production.

2.4 Unique contribution

The unique contribution of this study is therefore a practical and measurable framework whereby automotive manufacturers can implement high voltage technological change, like the introduction of Hybrid or Electric Vehicles, in their production lines in a safe, effective and efficient way to strengthen global competitiveness. The design of the research will be discussed in the following chapter.

It is the author's sincere hope that the framework developed this dissertation will stimulate further discussion and advancement by the academic community. Ultimately, the ambition is to contribute to the further development of high-end, high voltage manufacturing competence and to strengthen the automotive sector, specifically in the author's home country of South Africa.

3. RESEARCH DESIGN

3.1 Introduction and purpose

To address the aforementioned research aim and objectives in an approach that was both highly probable to produce useful results, as well as sufficiently scientific in nature, it was of great importance that the research be organised and steered in a proven and reputable systematic manner. Having stipulated and clarified the author's understanding of the research problem, the research design will be discussed in this chapter. The approach taken for the development of the IFAT, as well as the intended outcomes will be addressed. Key concepts of the methodology will also be clarified, specifically the seven stages of the Soft Systems Methodology (SSM) technique utilised in this research. SSM will be outlined and expanded on before the ethical implications of the study are detailed.

3.2 Research methodology selection

'Systems Thinking' (Table 2) is an approach that offers techniques to improve our grasp of human behaviour and conflict situations. In Systems Thinking, a system can be described as "a device used in a learning process to define desirable and feasible action to improve" [27].

Machine-based or mechanistic worldviews still dominate much of society and research. Some fundamental elements of 'mechanism' are subject/object dualism (the separation of the subject and the object), as well as reductionism. The central philosophy of Systems Thinking is to reject a mechanistic worldview and to recognise emergence in favour of reductionism, which can be expressed as that 'the whole is greater than the sum of its parts'. Another central philosophy of modern Systems Thinking is favouring intervention to observation, believing that observation is not possible neutrally, but is rather an intervening practice. Within Systems Thinking exists the concept of 'methodological pluralism', in which different yet often complementary methodologies can be used together to address complexity in a system [28].

Table 2: Systems Thinking Waves

Waves of Systems Thinking	**Selected systems approaches**
First Wave of Systems Thinking (Hard) est. 1945	General systems theory [29] Operations research [30] Systems engineering [31] Socio-technical systems [32] System dynamics [33]
Second Wave of Systems Thinking (Soft) est. 1972	Inquiring systems design [34] Soft systems methodology [35] Strategic assumptions surfacing and testing [36] Interactive management [37]

(Adapted from [38])

Soft Systems Methodology (SSM) has proven a popular "Second Wave" systems thinking technique that guides a researcher in approaching complex systems or situations in a systematic manner [38] [39]. SSM can be viewed as a multidisciplinary approach to problem-solving and an action-orientated method of inquiry into difficult situations, whereby the user learns by investigating the situation and then defining the necessary actions to improve the said situation.

The scale and complexity of the author's research necessitated a SSM approach rather than a mechanistic Systems Engineering worldview, as it dealt primarily with *soft* human activity, rather than *hard* systems that could be engineered in a vacuum.

3.3 Soft Systems Methodology (SSM)

Soft Systems Methodology (SSM) was born out of Systems Engineering as developed by Bell in the 1950's and 1960's [40]. Where Systems Engineering focused on techniques and methods of engineering *hard* systems to meet necessary objectives, SSM was specifically developed to handle the complexities of social/human situations, the so-called *soft* systems that cannot effectively be addressed by a *hard* Systems Engineering approach.

Soft Systems Methodology is very well suited to management-related problematic situations in the organisational context [41]. It has been described as "an organised, flexible process for dealing with situations which someone sees as problematical, situations which call for action to be taken to improve them, to make them more acceptable, less full of tensions and unanswered questions. The 'process' referred to is an organised process of thinking your way to taking sensible 'action to improve' the situation; and, finally, it is a process based on a particular body of ideas, namely *system* ideas" [42].

Von Bulow describes SSM as a

> "methodology that aims to bring about improvement in areas of social concern by activating in the people involved in the situation a learning cycle which is ideally never-ending. The learning takes place through the iterative process of using systems concepts to reflect upon and debate perceptions of the real world, taking action in the real world, and again reflecting on the happenings using systems concepts. The reflection and debate is structured by a number of systemic models. These are conceived as holistic ideal types of certain aspects of the problem situation rather than as accounts of it. It is taken as given that no objective and complete account of a problem situation can be provided" [43].

Checkland and Poulter outline it as:

> "an action-oriented process of inquiry into problematic situations in the everyday world; users learn their way from finding out about the situation to defining/taking action to improve it. The learning emerges via an organised process in which the real situation is explored, using as intellectual devices – which serve to provide structure to discussion – models of purposeful activity built to encapsulate pure, stated worldviews." [42]

SSM evolved mainly from two pairs of systems thinking ideas. The first pair of systems thinking ideas is 'emergence' and 'hierarchy', the second pair being 'communication' and 'control'. *Hard* systems thinking could not account for the real-world impact of often poorly understood human activities and so led to the creation of *Soft* systems thinking and SSM. The development of the Soft Systems Methodology signalled a shift away from 'hard' ideas to 'soft' systems thinking (Figure 7).

Models were used to facilitate discussion and debate about improving the status quo, rather than trying to perfectly represent reality. The objective changed from trying to create a system that can achieve a pre-determined goal, to learning about the real-world situation in order to effect an improvement to that situation. SSM shifted the focus from a systemic world to that of a systemic process of inquiry. SSM consists of seven sequential stages (Figure 8), though the steps can and do repeat themselves in iterative loops. Stages two, three and four form one such iterative loop and stages four, five and six another.

3.3.1 Stages 1 and 2 – Expression

Stage 1 and Stage 2 attempts to create the most holistic picture of the situation perceived to be problematic, rather than simply defining the problem upfront. This initial situational analysis is conducted by noting slow-to-change elements and continuously-changing elements, as well as the interconnectivities between them, while emphasis is placed on not imposing any specific structure to the holistic view.

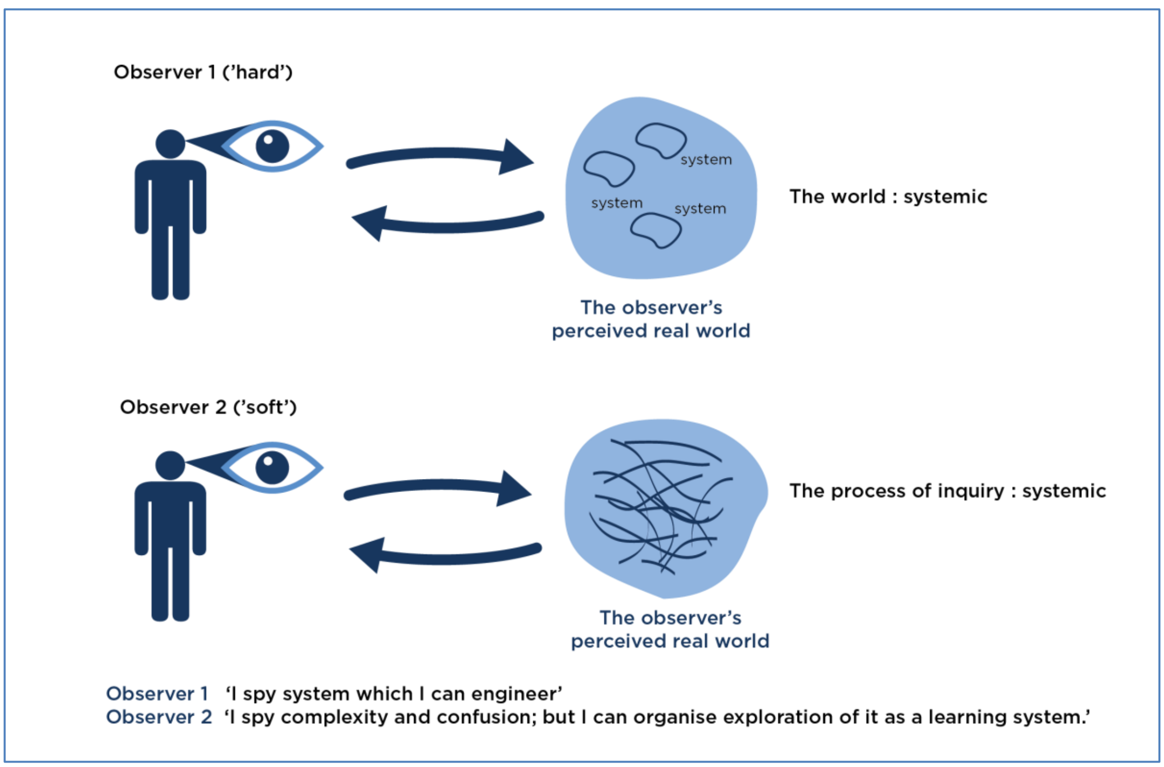


Figure 7: Hard and Soft Systems Thinking

(Adapted from [42])

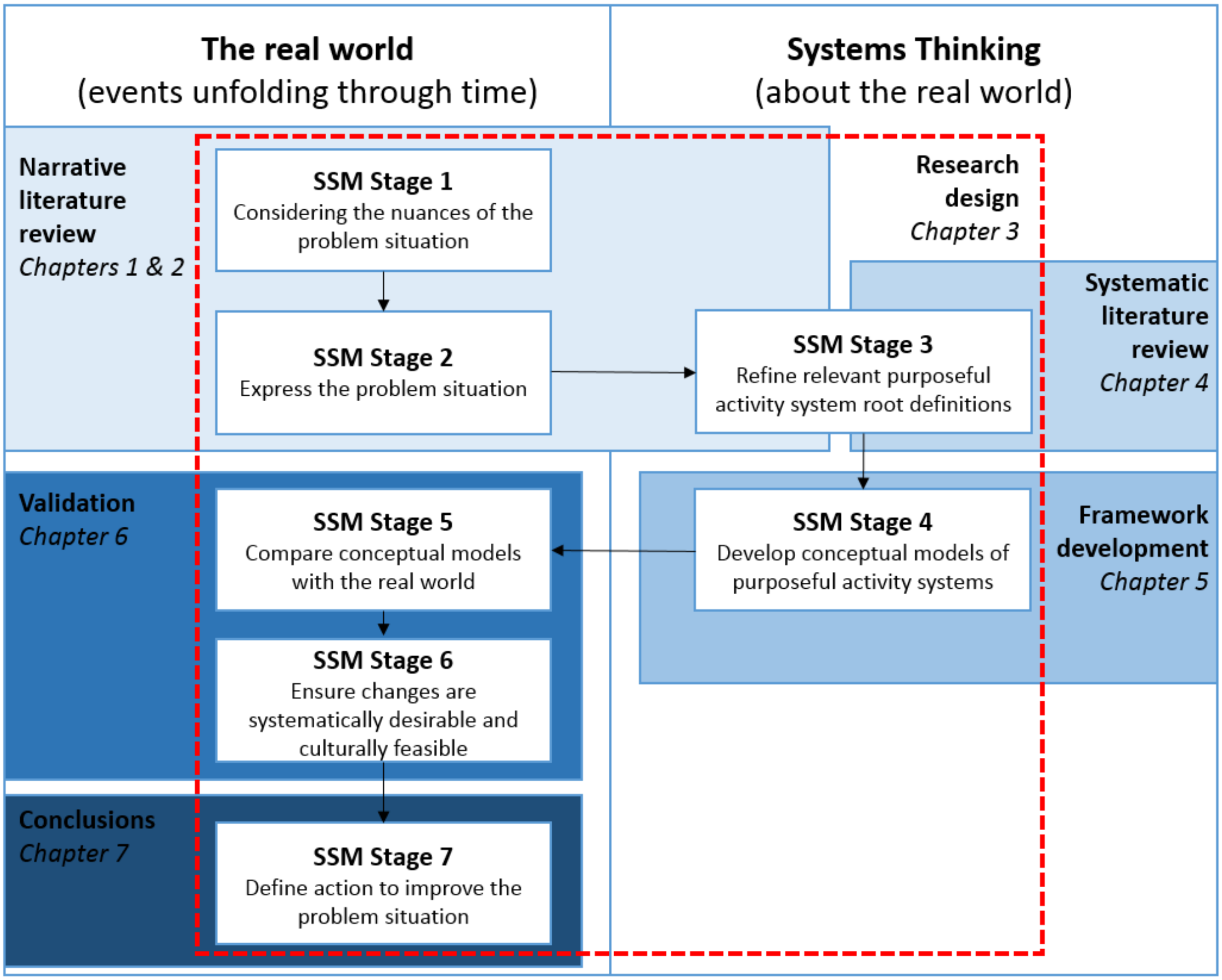


Figure 8: The stages of SSM, adapted from Checkland and Scholes
(Adapted from [27])

3.3.2 Stage 3 – Root definitions of relevant systems

Stage 3 seeks to name the systems perceived to be relevant to the identified problem and then define what the systems are, rather than what they do. This will generally be achieved with a systematic literature review, often coupled with interviews. This is done to acquire unambiguous statements about the nature of the systems. The concept of *root definition* here points to the fact that the definitions are supposed to be the most elemental character of the chosen systems. The mnemonic CATWOE supports defining the root definitions.

A CATWOE analysis, as seen in Figure 9, is often done to ensure a comprehensive and rigorous *root definition*. CATWOE is an acronym for Customers, Actors, Transformation process, Worldview, Owners and Environmental constraints. Stimulating multiple approaches and perspectives often yield surprising results (Table 3).

By using this type of analysis, the researcher can clarify exactly what is trying to be accomplished. Explicitly acknowledging these various perspectives forces one to reflect on the possible consequences and impact of any proposed changes on all parties involved.

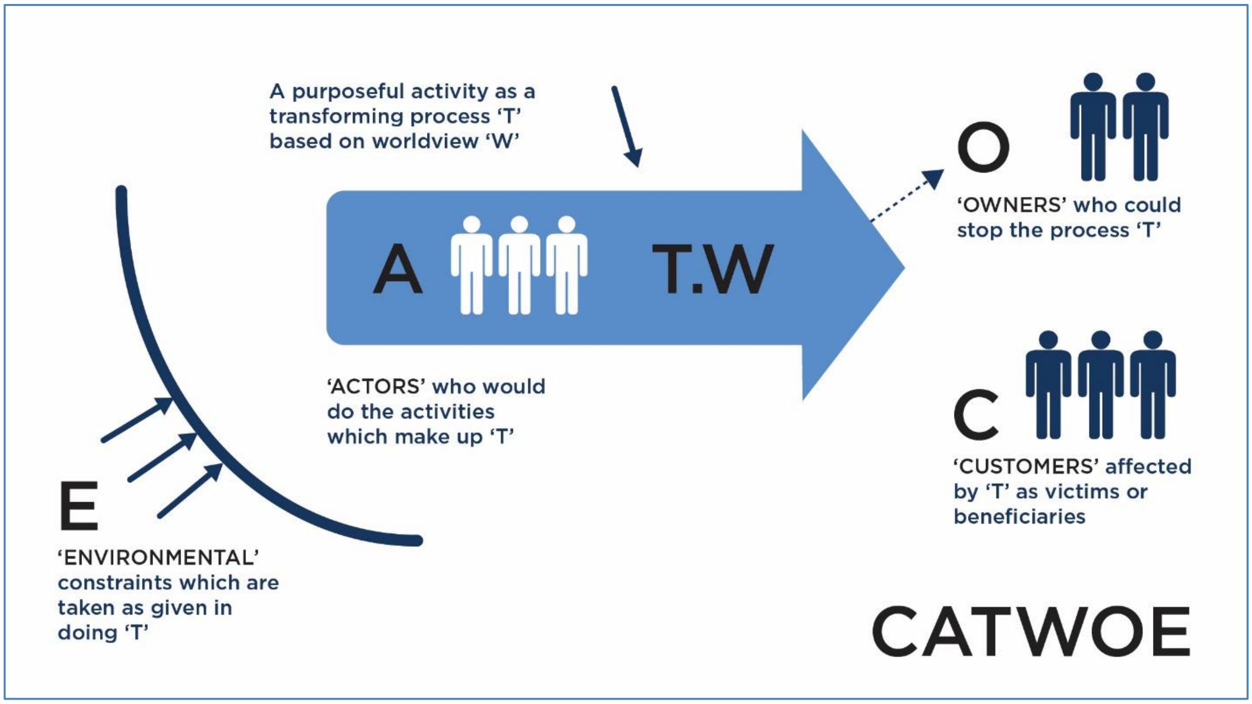


Figure 9: The CATWOE Model

(Adapted from [38])

Table 3: A CATWOE analysis

Root definition view	Leading question	Further information
Customers	Who benefits or suffers from this system and/or its operation?	These are typically the customers of an organisation, business unit or project. They are stakeholders and users of the system and will benefit if the system is positively influenced. The first step of a CATWOE analysis is to look at who the customers are and to understand how the system affects them.
Actors	Who implements this system or who performs the activities that make it work?	These are typically the employees of the organisation, business or project. They are stakeholders, but not users. They are the ones that ensure the transformation process and are responsible to implement changes in the system. The CATWOE analysis should look not only at who they are, but understand their abilities, interests and qualities to formulate a clearer picture of the system.
Transformation	What transformation is effected by this system?	This is the process by which inputs (e.g. materials, time or effort) is changed by the organisation, business or project into outputs (e.g. products or solutions). It is the change that the system or process effects. The CATWOE analysis should look at the input and outputs, but also very importantly at the intermediate steps.
Worldview	What is the bigger picture and how is this system justified?	This considers all the possible interested parties and/or stakeholders in the organisation, business unit or project and their collective influences - that of the system on them and them on the system. The CATWOE analysis should specifically look at their often different viewpoints and interests to better describe the whole.

Root definition view	Leading question	Further information
Owner	Who can change the system or its measurements?	This generally refers to the owner of the organisation, business or a project leader, but can also refer to investors, supervisory boards, etc. These people make decisions that can start or stop the systems and typically have the highest authority in and over the system.
Environmental constraints	What external constraints does the system account for?	This looks specifically at environmental elements that can affect the organisation, business unit, or project, rather than focussing on the larger worldview. Constraints can be ethics, laws or regulations, financial limitations, pure environmental factors like climate or topography, etc. The CATWOE analysis should specifically look at environmental constraints as they are uniquely situation dependent and can easily be overlooked when focussing on the bigger picture

3.3.3 Stage 4 – Making and testing conceptual models

Once the root definitions are listed, the focus shifts to conceptual models of activity systems. This is done by defining the action-orientated processes or steps necessary for the model to function. It requires that activities by ordered logically and that dependencies are understood and shown. After development, the models are verified with the requirements obtained in Stages 1 to 3.

3.3.4 Stages 5 and 6 – Validating the conceptual models

Once a model is built, it is tested in Stage 5 by comparing its perceptions to what exists in the real world. This is done to initiate a stakeholder debate in the perceived problem situation, to enable the obtaining of possible improvements to the conceptual model in Stage 6.

In Stage 6, for a proposed change to be deemed appropriate it must at the same time be culturally feasible and arguably desirable. In this context, culturally feasible would be in terms of dominant attitudes at that point in time and in terms of the power structures associated with the history of the problematic situation. It means that for those involved the outcome must be sensible in relation to the problem's history, real or perceived. The key here is to depict a version of the situation that various people with differing worldviews could all deem acceptable.

3.3.5 Stage 7 – Defining action to improve

Stage 7 defines actions to improve the problematic situation. Inevitably, this will create additional questions and problems that needs to be addressed in the iterative process.

3.4 Ethical implications

The research conducted by the author fully adheres to Stellenbosch University's ethical guidelines for scholarly and scientific research. This study was developed theoretically and supplemented by the author's practical experience implementing high voltage technology in a local automotive context. The research and development of the framework presented in this study did not negatively affect any staff of Mercedes-Benz South Africa and was conducted with the company's approval. The intention of creating the framework is to strengthen the automotive industry to sustain and enhance employment opportunities in the industry, hence the developed framework is ethically grounded and does not pose an ethical threat.

In addition to the research approval from MBSA, ethical clearance was also obtained from the Research Ethics Committee of the Division of Research Development at Stellenbosch University. The protocol number of the ethics clearance is **ING-2018-8788**.

The use of the framework once published cannot be restricted and it should be expressly noted that it implies reasonable boundaries of application, specifically including that users shall not break any laws or applicable regulations and that the framework should not be used to put any individuals at undue risk.

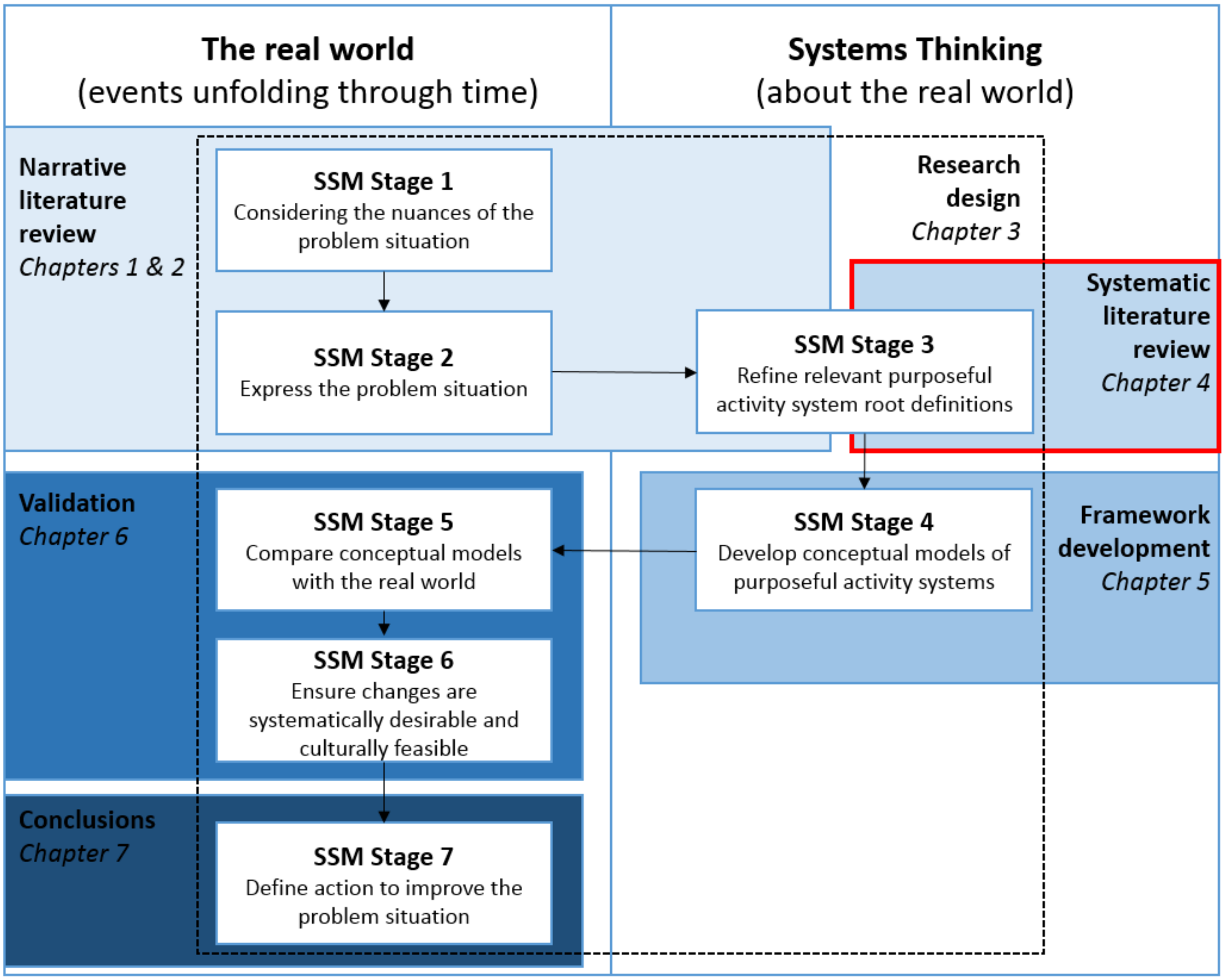
3.5 Research method

The method chosen was critical to the success of the research as it provided a practical approach to the progression of the study to arrive finally at an appropriate solution to the research aim and objectives. A progressive approach of different analysis methods was used in order to create a framework that addresses the research aim and objectives. To start, a narrative literature review was done to summarise the existing body of knowledge and literature related to the dissertation topic and to define the problematic situation. It also sought to gain a general understanding of the complexities involved with this type of implementation. A systematic literature review was then utilised to delve deeper into the topics, to facilitate a comprehensive review of the relevant and related literature. This provided the majority of the theoretical foundation that the framework is built on. The conceptual framework was verified against the research requirements and validated against the case study of the only High Voltage introduction by a South African OEM to date, namely MBSA’s Plug-in Hybrid C350e Project. A Pilot and four Production Trials served as iterations. Having validated the framework, conclusions were made through reflection and recommendations for further research discussed.

3.6 Conclusion

Soft Systems Methodology was selected as the guiding methodology for the research, due to its proven effectiveness at dealing with social problems like Change Management. SSM consists of seven ordered stages, from identifying problems to defining possible actions to improve the problematic situation. The ethical implications of the research were discussed and the methods of analysis detailed. Having thoroughly clarified the research aim and objectives, as well as the methodology, the next steps was to fully understand the complexities of technology implementation, starting with the literature review.

4. SYSTEMATIC LITERATURE REVIEW



4.1 Disruptive Manufacturing Paradigms and the need for Change

In order for manufacturers (specifically in developing countries) to stay competitive in the global market, their manufacturing strategies need to be innovative and resource efficient. As a result, there has been a shift in research in recent years to focus on enhancing the resource efficiency of the entire value chain [44]. Dramatic changes can be seen in customer behaviour and expectations. Customers can now source their products globally and there is ever-increasing environmental awareness. The unfolding paradigm shift will likely be a problem for manufacturers who are not able to adapt to the change in market forces quickly enough. Research suggests that it is no longer sufficient to adapt and control manufacturing by short-term effectiveness targets, but rather through long-term strategies capable of surviving paradigm shifts [45] [46] [47].

Figure 10 shows the four recognised Industrial Revolutions, each having a profound influence on the prevalent manufacturing paradigm at the time. A paradigm can be described as "an accepted model or pattern that establishes an informational framework and set of rules by which its practitioners view the world" [1]. The basic elements of a manufacturing paradigm include the design (developing the product), make (manufacturing) and sale of a product [7]. The sequence of these elements differ in each paradigm due to the changes in societal needs.

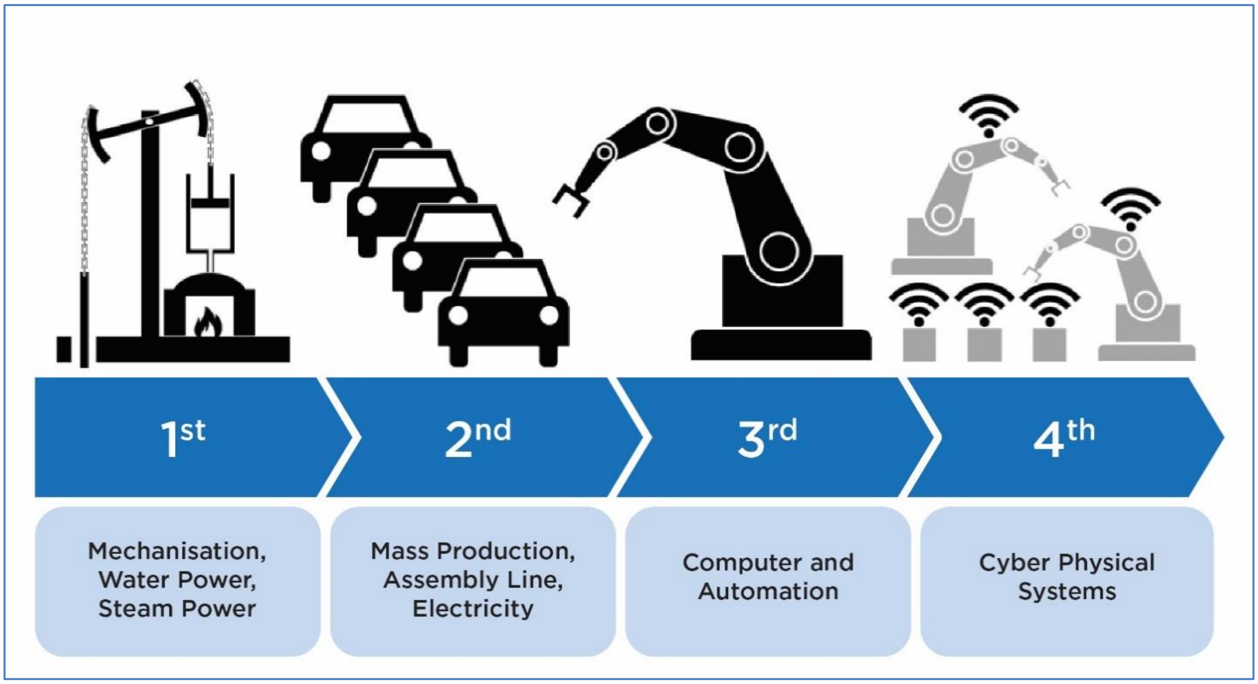


Figure 10: Industrial Revolutions shifting the paradigms
(Adapted from [48])

For countless centuries, everything that was produced was made by the hands of a person with the prerequisite skills, tools and materials. Craftsmen were known as 'artisans' and they were the ones who turned raw materials into finished goods. The Craft Production paradigm required highly skilled workers to manufacture products by hand. Examples of craft producers included carpenters, masons and silversmiths. This business model was based on a pull (sale-produce-assemble) system, since society demanded small batch individual products. Once the customer paid for the product, the craftsman would design it and only afterward would it be made. The enabling technology for this paradigm was electricity and the key technology was machine tools. Craftsmen already weaved baskets and made flint knives thousands of years ago, but the peak of this paradigm was reached with the production of automobiles, where each individual part was produced using general purpose machine tools (from the tool and die sector), before they were manually assembled by skilled labourers.

'Mass Production' as a paradigm likely started around 1870, with the Cincinnati slaughter-houses, though it is commonly believed to have taken off in 1913, when Henry Ford realised that the prices of automobiles needed to decrease to make it more affordable to the population. Society demanded lower prices, necessitating higher productivity. To accommodate this change in societal needs Ford invented the moving assembly line, or at least applied it to automotive production for the first time. The technology significantly lowered production costs and changed the prevalent manufacturing paradigm to that of Mass Production [7]. Mass production typically means producing a high volume of identical products [49]. The business model was based on a push (develop-produce-assemble-sale) system. The enabling technology for this paradigm was interchangeable parts and the key technology was moving assembly lines. The introduction of interchangeable parts made the production process significantly easier. Highly skilled workers were no longer needed and labour costs decreased. The guiding principle was that "the cost of making any particular good could be dramatically reduced if only machinery could be substituted for the human skill needed to produce it" [1].

Where before highly skilled workers were producing goods, machines were now taking their place and substituting their skills at a lower cost. As production processes were standardised, workers were being focussed on only a small piece of the whole process. While they lost a certain amount of responsibility and eventually a level of skill, the 'division of labour' increased the levels of efficiency and productivity and in so doing, reduced the production costs substantially. As production costs decreased, so could product prices. Division of labour lowered the responsibility of each individual worker, which in turn led to the need for greater oversight, the hierarchical organisation structures so prevalent today and the concept of 'professional managers'. Before the Industrial Revolution, most companies were small, family-owned enterprises that did not require full-time administration and had no need for organograms. With the rise of Mass Production, these structures became necessary to govern the ever-increasing size of the companies and their output.

Managers used a concept called 'scientific management' to increase efficiency, by meticulously studying the times and motions of workers and thereby eliminating any and all inefficiencies. It is reported that when Henry Ford introduced the moving assembly line to the production of the Model T the average labour time required to produce a single car dropped from 12 hours and 8 minutes, to 2 hours 35 minutes. Six months later, it was down to around an hour and a half. Ford's moving assembly line could produce 1000 Model T's in a day, surpassing in a week what was previously done in a year [1]! Even in the days of the Model T though, mass-produced goods were not as standardised as Henry Ford would have liked, as eventually customer demands forced him to introduce model changes annually. As mass-produced products started saturating the market, people started to demand a greater variety of products. Flexible production was introduced and lot sizes were decreased in order to satisfy customers' needs [49]. In this context Duguay *et al.* defined flexible as "the capacity to deploy or redeploy production resources efficiently as required by changes in the environment" [50]. The product quantities that customers demand might rise and fall, requiring the company to be flexible concerning production volume. Society demanded a variety of products and so the manufacturing paradigm of Flexible Production started around the year 1970, after the first programmable logic controllers (PLCs) were introduced. The business model was based on a push/pull (develop-produce-sale-assemble) system. The enabling technology for this paradigm was digital computers and the key technology flexible manufacturing systems. In Flexible Production, the parts are still manufactured on a similar basis as mass production, but the final product is only assembled once the customer has bought the product [49].

A study by MIT revealed that the automotive industry was among the sectors most prone to market turbulence, needing to react swiftly to factors like changing oil prices, quality awareness, service levels and environmental consciousness. The shift to the Flexible Production paradigm was largely due to these factors and already by 1980 it was seen that automotive OEMs were greatly increasing the number of different models produced and decreasing product lifecycles. The change to the Mass Customisation paradigm was again predominantly due to a change in societal need, this time to customisable products and optional features. Customers were no longer satisfied with simply a wide range of products, but wanted their product to be distinct and unique. The Mass Customisation paradigm required manufacturing companies to make a couple of changes to the way they ran their businesses. Companies would manufacture standard products, but give the customer a variety of optional extras to co-create the products that are within the company's manufacturing capabilities.

The business model was based on a pull (sale-produce-assemble) system. The standard products (without extras) were mass produced to reduce production costs, but only once the customer had bought and selected the extras they liked, would assembly of the products be completed [51]. It can be argued that the key to Mass Customisation is standardisation - the standardisation of components that can be configured in a wide array of possible end products. The components provide the necessary economies of scale, while the end products provide the scope and allows the customer the required flexibility and option of customisation. A computer, for example, can be customised to have any combination of different hard drive sizes, processor speeds, memory and other features, but their interfaces are all standardised and the final product can be assembled in a 'plug-and-play' process according to the customer's requirements.

Figure 11 and Table 4 summarise the goals and differences between the manufacturing paradigms of Mass Production, Mass Customisation and Personalisation. While the paradigms of Mass Production and Mass Customisation each strived toward the economies of scale and scope, the Personalisation paradigm can be viewed as sacrificing some economies or efficiencies, in favour of value differentiation.

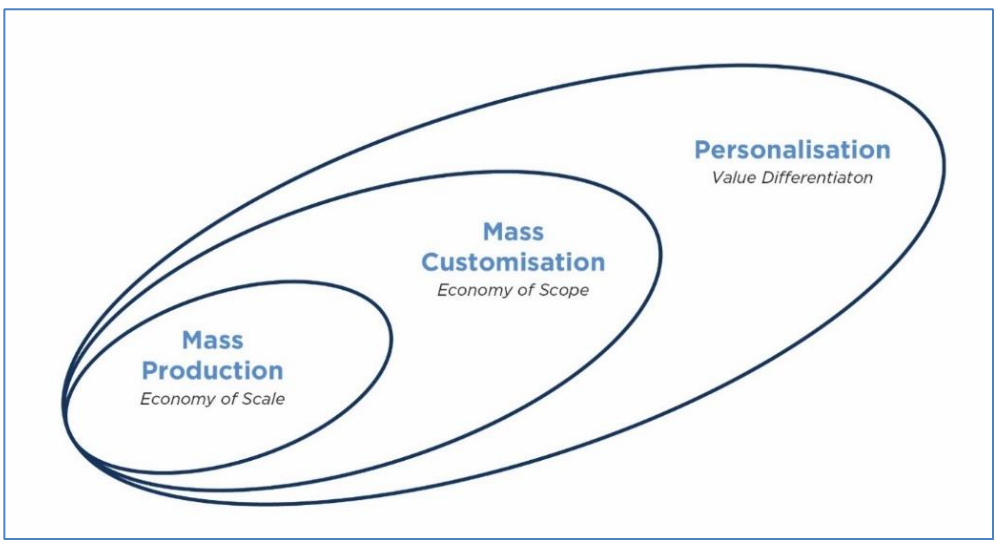


Figure 11: The goals of the manufacturing paradigms

(Adapted from [52])

Table 4: Key differences between the paradigms

	Mass Production	Mass Customisation	Personal Production
Production Goal	**Scale**	Scale **Scope**	Scale Scope **Value**
Desired Product Characteristics	Quality **Cost**	Quality Cost **Variety**	Quality Cost Variety **Efficacy**
Customer Role	Buy	**Choose** Buy	**Design** Choose Buy
Production System	Dedicated Manufacturing System (DMS)	Reconfigurable Manufacturing System (RMS)	On-Demand Manufacturing System (OMS)

(Adapted from [52])

Open Architecture Products (OAP's) are a new class of products comprising a fixed platform and modules that can be added to and/or swopped. According to Koren et al. [53], customers can adapt OAP's to their needs by integrating modules into the platform. Manufacturers will produce these platforms, while new small companies and customers themselves will likely develop the modules for the platforms. This change is part of what is often called the 4th Industrial Revolution that has ignited several manufacturing strategies on a national level such as the NNMI (USA), Catapult (UK), Industry 4.0 (Germany) and SIP (Japan).

Kagermann et al. [54] describes this revolution as the convergence of the physical world and the virtual world (cyberspace) in the form of Cyber-Physical-Systems (CPS). This era is bringing changes in value creation, customer expectations and production methods. Figure 12 shows the changes in the value chain in this new world. Where previously companies tended to be vertically integrated and managed all aspects of the value chain in-house, many now tend to specialise in only one niche aspect, choosing to contract or 'outsource' other functions to companies that specialise in those. All of this leads to greater complexity for companies. Research shows though that very few companies are able to directly measure and attribute the associated increased costs directly to the increase in complexity [55].

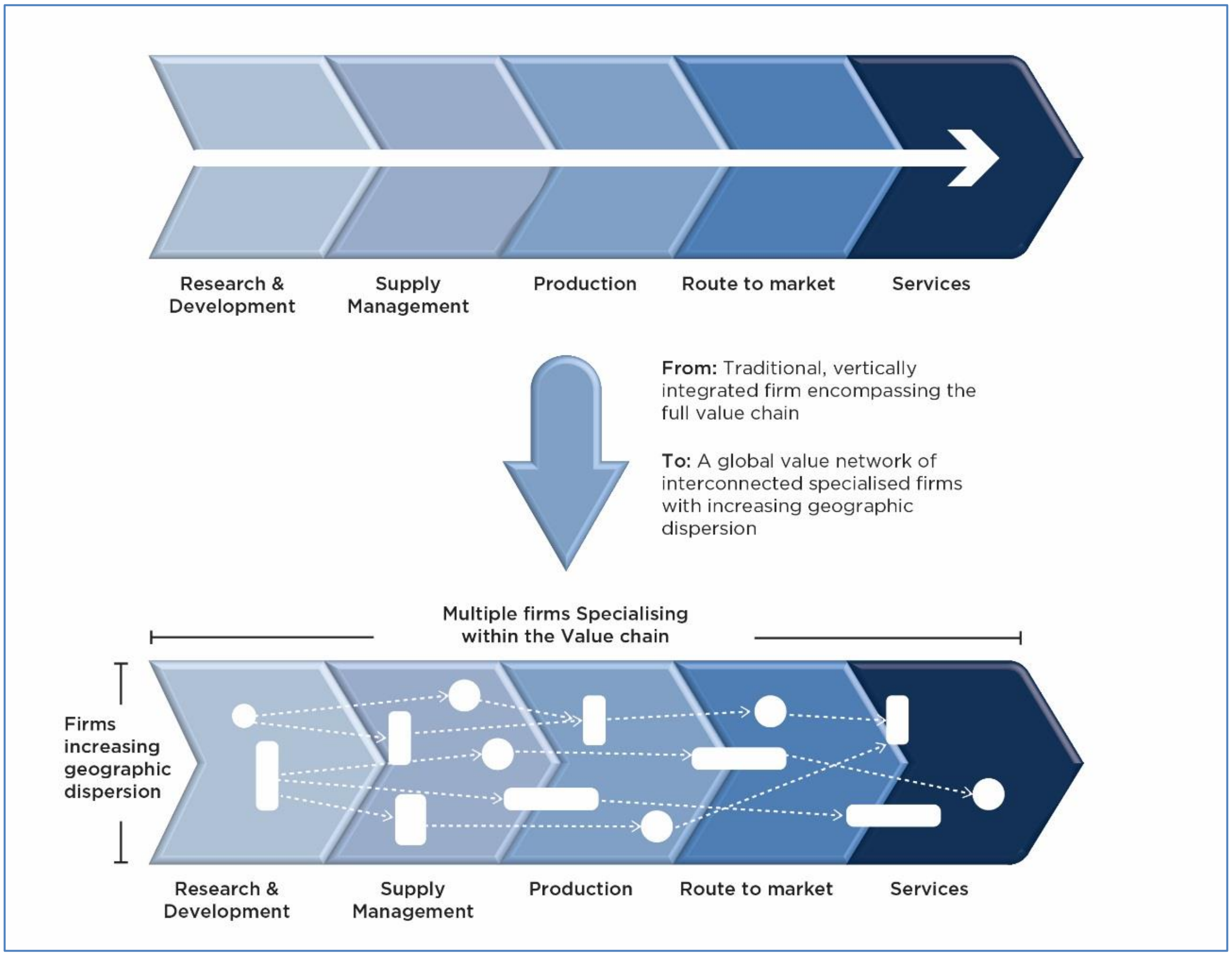


Figure 12: Evolution of the value chain
(Adapted from [56])

4.2 The CFIR as inspiration for the IFAT

Implementation Science is "the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices (EBPs) into routine practice, and, hence, to improve the quality and effectiveness of health services" [57].

It was recognised that healthcare interventions that were proven effective in research studies often failed to translate to correlating improvements in real patient treatment and care across various contexts. Researchers identified several barriers for successful implementation at various levels, including the level of the organisation, the level of the implementation group, at the policy level and also at the level of the patient himself/herself. To understand why interventions failed to translate to results, it was important to not only study the summative endpoints of the healthcare outcomes, but also to do determinative assessments of the implementation process. By understanding the extent to which the process of implementation affects the success of that implementation, researchers would be able to optimise the end benefit to the patient and prolong or sustain the intervention in that specific context – and promote disseminating it to other contexts.

There were many implementation theories described in Implementation Science that promote the effective implementation of healthcare interventions and many different definitions and terminologies emerged. Significant overlap could be seen when comparing these theories, but each in its own right lacked crucial elements of some of the others. The CFIR was intended to facilitate the identification of all the relevant constructs and to create a consolidated, comprehensive framework from this broad array of peer-reviewed theories. It was intended to incorporate all the common concepts from the published work in Implementation Science, as well as the unique ones from the various articles and theories to create a multi-dimensional framework that the authors claimed would embrace rather than replace the existing research. It was aimed at advancing the field of Implementation Science by providing common definitions and terminologies which the field's knowledge base could be further built on.

The CFIR was built on the premise of five major domains [58]. The domains, as seen in Figure 13, were not intended to be viewed in isolation. It should rather be understood that they interact on a myriad of points and holistically influence the effectiveness of the intended implementation.

The **intervention** itself is the first major domain of the CFIR. This is the tool, equipment, technique or process that is targeted for implementation. The interventions themselves could take a number of forms, but are often complex and multi-faceted. These are to be viewed or conceptualised as having an inalterable core, being the essence of the intervention, as well as an "adaptable periphery". Without being adapted to local conditions, the intervention is often seen as an imperfect fit and resisted by those affected by the change, necessitating active engagement with these individuals in order for the implementation to proceed. In this context, 'local' does not necessarily mean country or region, but rather location and could mean a specific town, hospital or even ward [26].

The second and third major domains of the CFIR are the **inner setting** and the **outer setting**. The inner setting generally includes factors like the organisational structure, local politics and local culture, while the outer setting is a broader version of the inner, including regional or national politics, culture and even the economy. Needless to say, the lines between the inner and outer settings are often blurred and are context dependent. They could be homogenous, but they could also be vastly different and should be viewed on a case-by-case basis.

The **individuals involved** in the implementation process and/or the intervention itself are the fourth major domain of the Consolidated Framework for Implementation Research. Individuals carry the local structure, politics and culture as described in the inner setting, but they also have individual norms, interest, ideas and affiliations. They make decisions and can have great influence over the effectiveness of the implementation, choosing whether to assist or resist the intervention's implementation. Depending on their relative strength and influence they can "make or break" an implementation.

The last major domain of the CFIR is the **process** of implementation. Most successful implementations generally have an active process that is aimed at achieving both individual, as well as institutional level use of the planned intervention as it was designed. The individuals described in the previous domains have a major impact on this domain, as they are the ones actively promoting or hindering the implementation process, coming with the mind-set and factors described in the inner and outer setting. The inter-dependency and inter-relatedness of the various domains are clearly evident here. The domain of the process could comprise many interacting and related, but not necessarily sequential sub-processes. Often sub-processes are aimed at various levels of the organisation, to achieve the best outcome for the whole implementation's effectiveness.

The CFIR's overarching structure sets out the major domains and sub-factors that need to be considered for effective Implementation Science and creates a guideline for how this can be achieved in the healthcare sector.

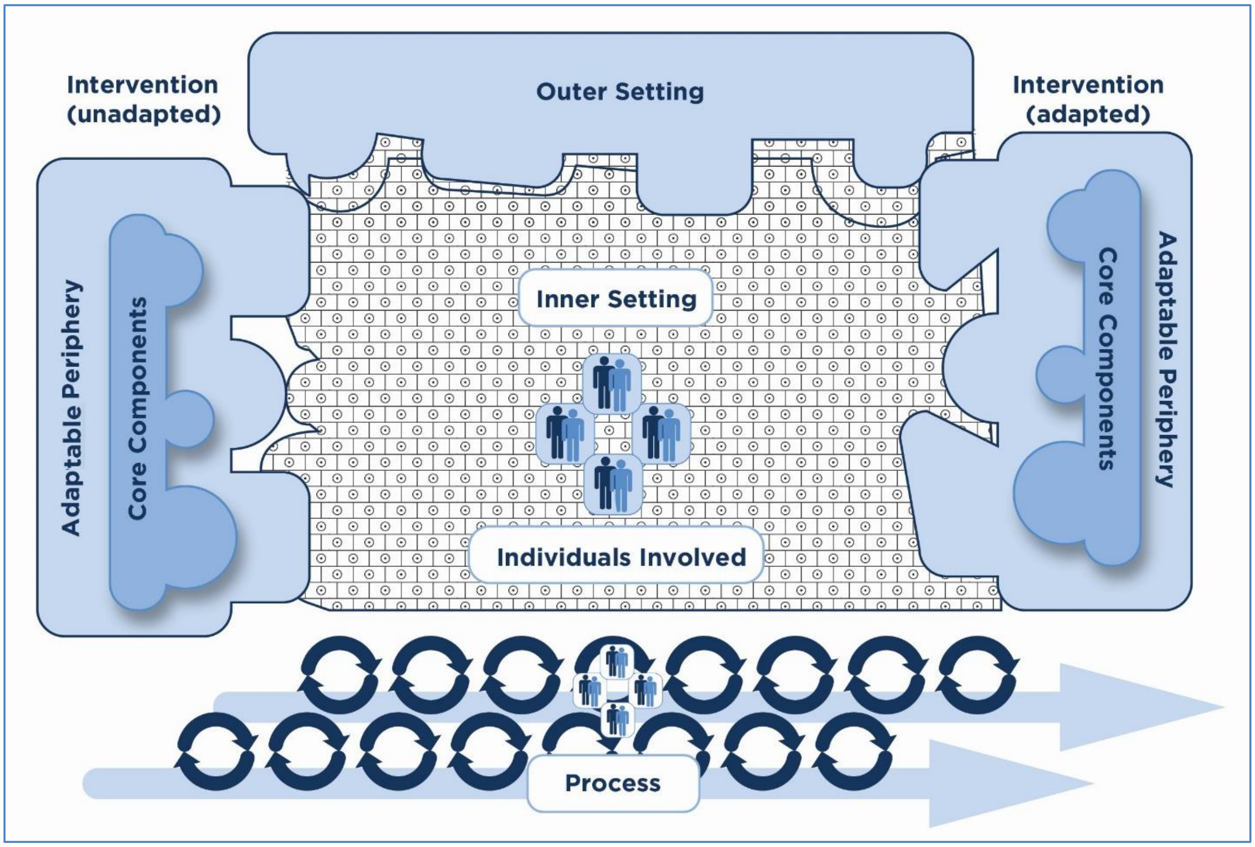


Figure 13: The Consolidated Framework for Implementation Research (CFIR)
(Adapted from [58])

4.3 Origins and overlaps of Change Management

The introduction of new technologies into the workplace necessitates new knowledge and new skills [59]. Most people react to new technologies with resistance, stemming from uncertainty, anxiety or even fear [60]. 'Change Resistance' is a natural reaction and is regarded as one of the biggest, if not the biggest, hurdles companies confront when introducing new technologies and change in general [61].

Change can be driven internally or externally and can be viewed as 'push' or 'pull'. When a company or organisation develops a new technology or process, whether for continuous improvement or competitive advantage, it 'pushes' its implementation.

An organisation ‘pulls’ an externally created process or technology when it is superior to what they are currently using and will result in improved service, efficiency or customer-perceived value [62]. The MIT90 Framework (Figure 14) clearly shows that companies can best be viewed as complex systems, comprising structures, technologies, people and their roles, strategies and management processes [63] [64]. Not only is the organisation itself complex, but the environment in which it operates is also complex and always in flux. The Framework highlights that due to the complexity, changing something in one of the elements can have unforeseen and often unintended impacts elsewhere.

Change management can be viewed as the “process, tools and techniques to effectively manage people and the associated human resource issues that surface when implementing change” [61], but it is important to note that a holistic approach is required and not to focus on just one or two of the elements of any Framework. Change, although it can often be emergent, can also be managed. Change Management is the study of “moving an organisation from an old state to a new one in a planned way” [65].

Companies are under increasing pressure to continuously change, leading to the term “permanent white water” [66]. Change literature though indicates continuously high levels of failure in large companies and organisations [67] [68]. The increasing need to change, coupled with the continued failure, necessitates further research into this field to better equip individuals, leaders, companies and organisations in change activities.

Change Management as a field of study is widely accepted to have stemmed from the pioneering work of Kurt Lewin (Figure 15). His unfreeze-change-refreeze, or ‘Changing as Three Steps’ (CATS) model, is believed to be at the core of almost all modern Change Management theory [69] [70] [71] [72]. Most academics believe CATS is the pre-eminent model on which all Change Management is built, though not all agree with his ideas [69].

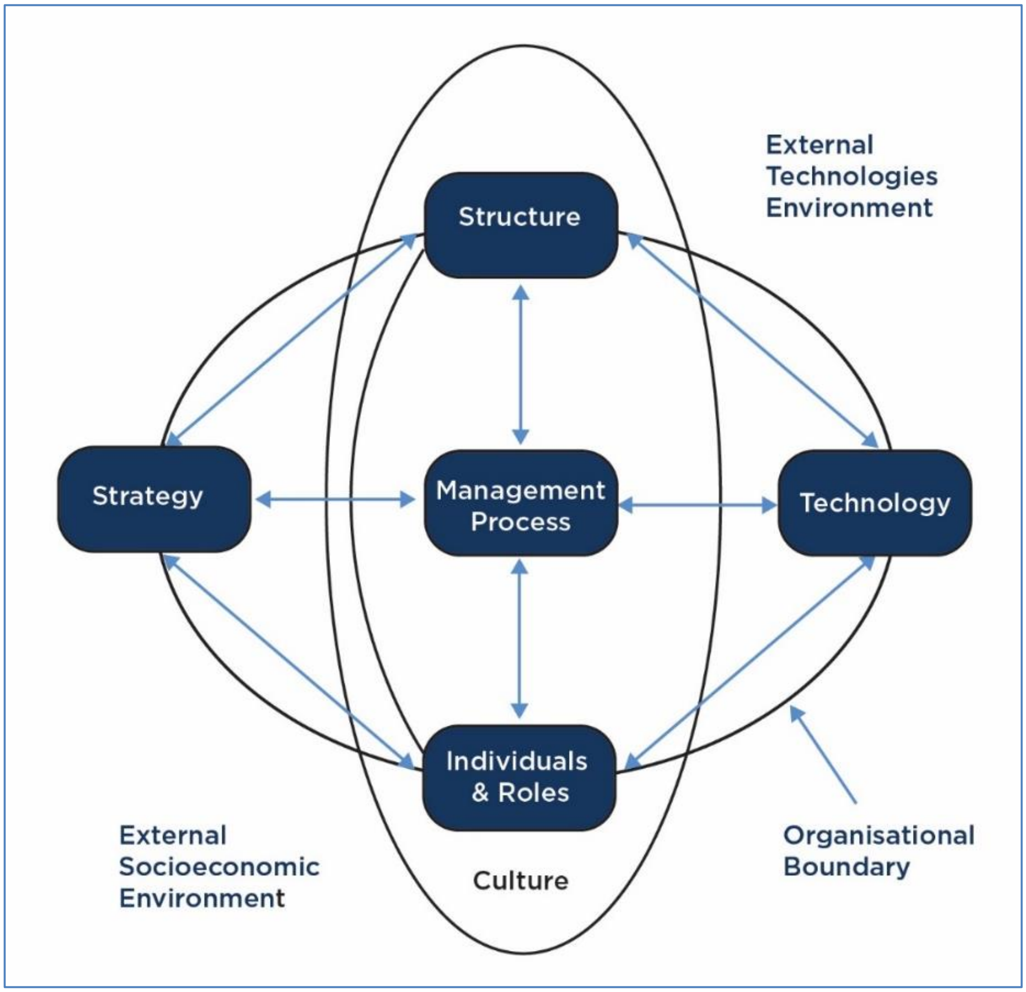


Figure 14: Michael Scott Morton's "MIT90" Framework

(Adapted from [63])

While some academics and practitioners believe that Lewin's work is powerful and foundational, some even claiming all Change Management theories are reducible to his work [73] [74], others believe that his approach was too linear and static to be appropriate for modern organisations and the complexities they face [75] [76]. Some argue that while Lewin's model is rational and makes sense in theory, its disregard for human feelings and their effects will have negative impacts if implemented in an over-simplified way. They believe that strong feelings about the change, positive or negative, can affect the outcome of the change itself. If for example a stakeholder is either overly cautious, or not cautious enough, it can negatively affect the change and lead to a failed implementation [77].

Figure 15: Kurt Lewin's Changing as Three Steps (CATS) model
(Adapted from [78])

In the CATS model, Lewin argued that the first step in any change process is to ‘Unfreeze’ the status quo. There is considered to be equilibrium and ‘Unfreezing’ is required to overcome change resistance. The second step of CATS is the ‘Change’ itself. Here the aim is to shift the paradigm to a new state of equilibrium, to a new normal, before the final step of ‘Refreezing’. This final step, the stabilisation of the new normal, is necessary to avoid regression to the previous state [79].

Arguably one of the most popular contemporary models, Kotter’s “8-Steps for Leading Change” (Figure 16) contends that to best overcome the known resistance to change and in order to effectively lead change, one should start by creating a sense of urgency around an idea or opportunity and then build a powerful guiding coalition, in terms of titles, information, relations and expertise. Next one needs to create a vision of the change and remove obstacles to the change process, be they individuals, systems or processes. One should then plan for and create short-term ‘wins’ to demonstrate the benefits of the change. The final steps are to consolidate the improvements and sustain the movement before cementing the change and the process of change as an organisational culture. Kotter argues that by effectively leading change one can overcome the inherent resistance thereto [80].

It can easily be argued that Kotter’s eight steps are an expansion of Lewin’s three, with the strong overlap evident in Table 5. Table 6 further demonstrates how various models can be linked back to Lewin’s pioneering work. This does not diminish the contribution of Kotter or his peers, as each has its own nuance and area of application. The approach of this study is not to create a wholly new field, but rather to take best practice elements from the many existing models and frameworks and develop a construct that is practically applicable to automotive production lines.

Figure 16: Kotter's 8-step Change Model

(Adapted from [80]**)**

Table 5: Lewin's three steps compared to Kotter's eight

Kurt Lewin	John Kotter
Unfreeze	1. Establish a Sense of Urgency 2. Create the Guiding Coalition 3. Develop a Vision and Strategy 4. Communicate the Change Vision
Change	5. Empower Broad-Based Action 6. Generate Short Term Wins 7. Consolidate Gains & Make More Change
Refreeze	8. Anchor New Approaches in the Culture

(Adapted from [81])

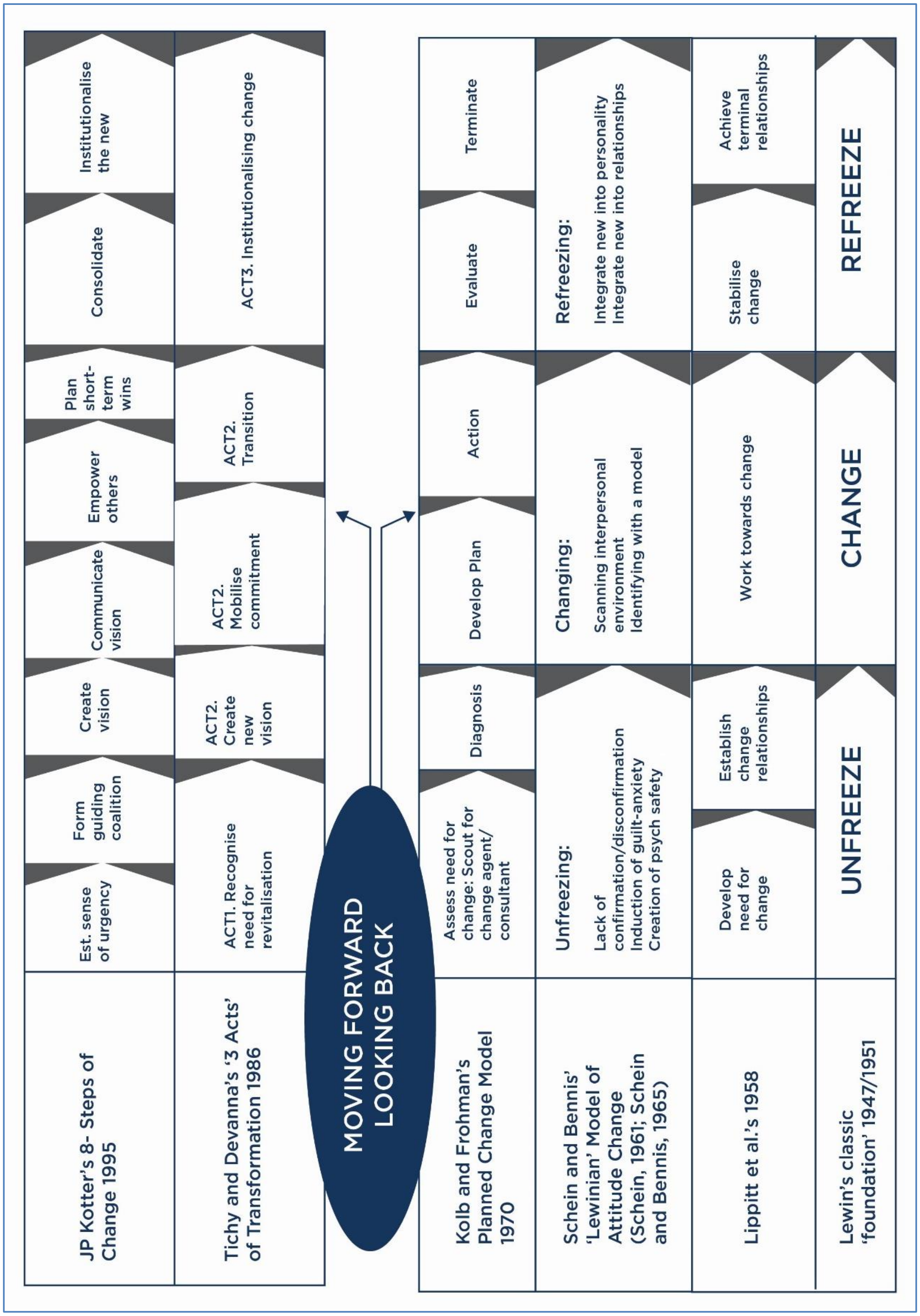


Table 6: Alignment across change models

(Adapted from [69])

4.4 Systematic review of Change Management methodologies

A systematic review makes use of pre-specified criteria to collect, evaluate and summarise the collected empirical evidence and research to answer a well-defined research question. The focus of this systematic review was to discover the different frameworks, models and methodologies that have been developed and applied in the field of Change Management.

The literature review covers full papers from January 1990 to March 2018. The articles were primarily from four application areas: academic, business, community and medical applications. Academic applications included articles that only researched the theories, but have not applied them to real-world problems or challenges. It also included the development of new change management models, reviews and comparisons of existing models, the evaluation of models, the theoretical application of models to events or situations to derive more information (for example human behaviour and change), etc. Business applications included applications in organisations, including leadership development in a business context, clients or product users' reactions, employee behaviour, communication improvements, business culture applications, strategic change, business change frameworks, safety in the business environment, etc. Community applications included the development of community leaders as well as educational applications in the community. It also included applications in families, individuals from the community and community workers e.g. law enforcement. Medical applications comprised applications in the medical sector, including clinical health care.

A narrative review of each construct was also used for exploratory understanding and further substantiation. The references to both the Systematic and Narrative literature reviews are shown in Table 7.

Table 7: Literature Review on Change Management

Model/Framework	Systematic Literature reference	Narrative Literature reference
Accelerating Implementation Methodology	[82]	[83]
ADKAR Model	[84] [85] [86] [87] [88] [89] [90] [91] [92] [93] [94] [95] [96] [97]	[98]
Baldrige Award Framework	[99] [100] [101]	[102]
Beckhard & Harris Change Process	[99] [103] [104] [105]	[106]
Bilal & Wang model	[107]	[108]
Bridges Transition model	[84] [95] [109]	[110]
Burke-Litwin model	[99] [100] [101] [104] [107] [109] [111] [112] [113] [114] [115] [116] [117] [118] [119] [120]	[121]
Conner's Stages of Commitment	[109] [122] [123]	[124]
Change Leader's Roadmap	[125]	[126]
Craine's change model	[95]	[127]
Cultural indicator tree model	[97]	[128]
Galbraith Star model	[118]	[129]
GE's Change Acceleration Process	[130] [131] [132]	[133]
Gleicher's formula	[97]	[134]
Intelligent Quality Management Process model	[84]	[135]
Kegan's subject/object schema of cognitive development	[109]	[136]
Kotter's 8 step Model for Change	[84] [86] [88] [91] [95] [97] [109] [137] [119]	[80]

Model/Framework	Systematic Literature reference	Narrative Literature reference
Kubler-Ross Change Curve	[97] [109] [137] [138] [139] [140]	[141]
LaMarsh Managed Change	[142]	[143]
Leavitt's Contingency Model	[103] [107] [117]	[144]
Lewin's Three Stage Change Model	[88] [91] [93] [97] [99] [100] [103] [104] [109] [111] [139]	[78]
McKinsey 7s Framework	[95] [99] [107] [118]	[145]
MAP-IT Framework	[97]	[146]
Nadler Tushman Congruence Model	[99] [103] [107] [109] [115] [118]	[147]
Nudge Theory	[148] [149] [150]	[151]
PROSCI Project Change Triangle Model	[91]	[152]
RACI model	[89]	[153]
Rogers' Diffusion of Innovation Model	[154] [155] [156] [157] [158]	[159]
Satir Change Model	[160] [161] [162] [163] [164]	[165]
Structural inertia model	[97]	[166]
Tichy's Technical, Political, Cultural framework	[99] [103] [115]	[167]
Weisbord 6 Box Model	[99] [107] [121] [168] [169] [170] [171] [172]	[173]

The following models and frameworks were found in the Narrative Literature Review, but did not have the necessary academic references to be included in the Systematic: Boston Consulting Group Change Delta [174], People Centered Implementation Model [175], Prosci Change Management Levers [176], Prosci Enterprise Change Management [177] and the Viral Change Roadmap Model [178] .

The models and frameworks can largely be divided into four categories:

- Change update concepts
- Psychological change experience models
- Organisational change capability models
- Linear change methodologies

Each of these categories provide a unique insight into change management and have elements required when formulating the conceptual framework to meet the research aim. Each of the categories, with examples of applicable models, will be investigated in the following sections and key characteristics for the conceptual framework highlighted. The various constructs found through the literature review (as shown in Table 7) are allocated to the applicable categories in Table 8 before being expanded upon.

Table 8: The four categories used to develop the IFAT

Category	**Model / Framework**
Change uptake concepts (4.4.1)	• ADKAR Model • Kegan's subject/object schema of cognitive development • PWC Change Curve • Rogers' Diffusion of Innovation Model
Psychological change experience models (4.4.2)	• Bridges Transition Model • Craine's change model • Kubler-Ross Change Curve • Nudge Theory • Satir Change Model
Organisational change capability models (4.4.3)	• Baldrige Award Framework • Bilal & Wang model • Boston Consulting Group Change Delta • Burke-Litwin model • Cultural indicator tree model • Galbraith STAR model

Category	Model / Framework
	• Gleicher's formula • Leavitt's Contingency Model • McKinsey 7s Framework • Nadler Tushman Congruence Model • People Centered Implementation Model • Prosci Change Management Levers • Prosci Enterprise Change Management • Prosci Project Change Triangle Model • RACI model • Structural inertia model • Tichy's Technical, Political, Cultural Framework Weisbord 6 Box Model
Linear change methodologies (4.4.4)	• Accelerating Implementation Methodology • Beckhard & Harris Change Process • Conner's Stages of Commitment • Change Leader's Roadmap • GE's Change Acceleration Process • Intelligent Quality Management Process (IQMP) model • Kotter's 8 step Model for Change • Lewin's Three Stage Change Model • LaMarsh Managed Change • Macro process model • Mobilize, assess, plan, implement track (MAPIT) • Prosci Enterprise Change Management • Viral Change Roadmap Model

4.4.1 Change uptake concepts (i)

It has been shown that not everyone accepts change at the same pace. In 1962, Prof. Everett Rogers set forth his "Diffusion of Innovation" model (Figure 17), depicting change acceptance as a norm distribution and dividing it into five different groups. The "Innovators", "Early Adopters", the "Early Majority" and "Late Majority" as well as the "Laggards" all have unique characteristics that are to be understood if they are to be managed effectively (Figure 18). "Diffusion of Innovation" is a theory that seeks to explain how, why, and at what rate new ideas and technology spread through cultures" [179]. Rogers proposed four main elements that affect how new ideas are spread, namely the innovation itself, communication channels, the time and the dominant social system. It is important to understand that the adoption curve is always in play, whether wanted or unwanted. An astute Implementation Team can use it to their advantage, instead of trying to push people from their natural groups to different ones. Not everyone will accept a change in an early stage, no matter how convincing the 'pitch' may be, but the strengths and weaknesses of the five groups together can give the Implementation Team the necessary tools for a successful introduction.

Innovators can be used to shape the vision of the change and explore the possible benefits, while the Early Adopters can be used to bridge the gap to the Majority. The Early Majority requires something practical and tangible before they adopt the innovation and the Early Adopters can provide this. This is the critical stage that has been described by Geoffrey Moore as "The Chasm" (Figure 19) [180]. Moore argues that there exists a chasm between the Early Adopters and the Early Majority. He sees the Early Adopters as "technology enthusiasts and visionaries", while the Early Majority is more pragmatic. Moore further says that the visionaries and pragmatists have vastly different expectations and he suggests an approach to successfully bridge this chasm. He believes that one should pitch a 'whole product concept', showing a holistic view of the implementation and its benefits and then target a 'beachhead', a specific target market inside the Early Majority. In the case of an Implementation Team, once the Early Adopters are on-board they need to quickly and thoroughly convince a segment of the more pragmatic Early Majority with a holistic pitch and keep the momentum by bringing more and more of this segment on board with a holistic understanding and proven early results.

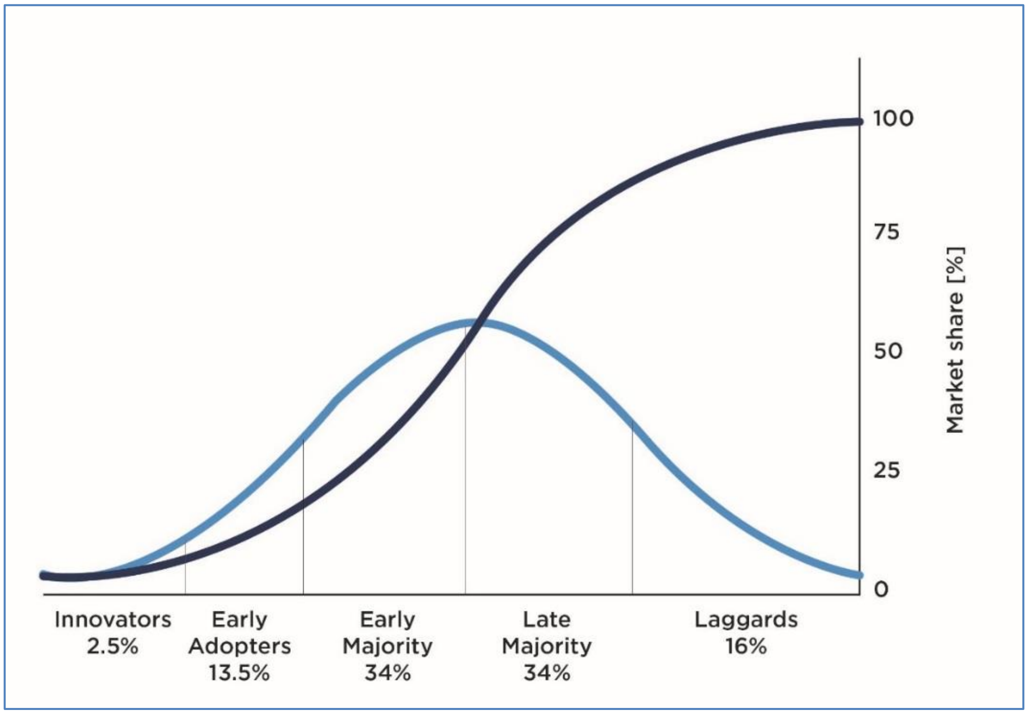


Figure 17: Rogers' diffusion of innovation

(Adapted from [159])

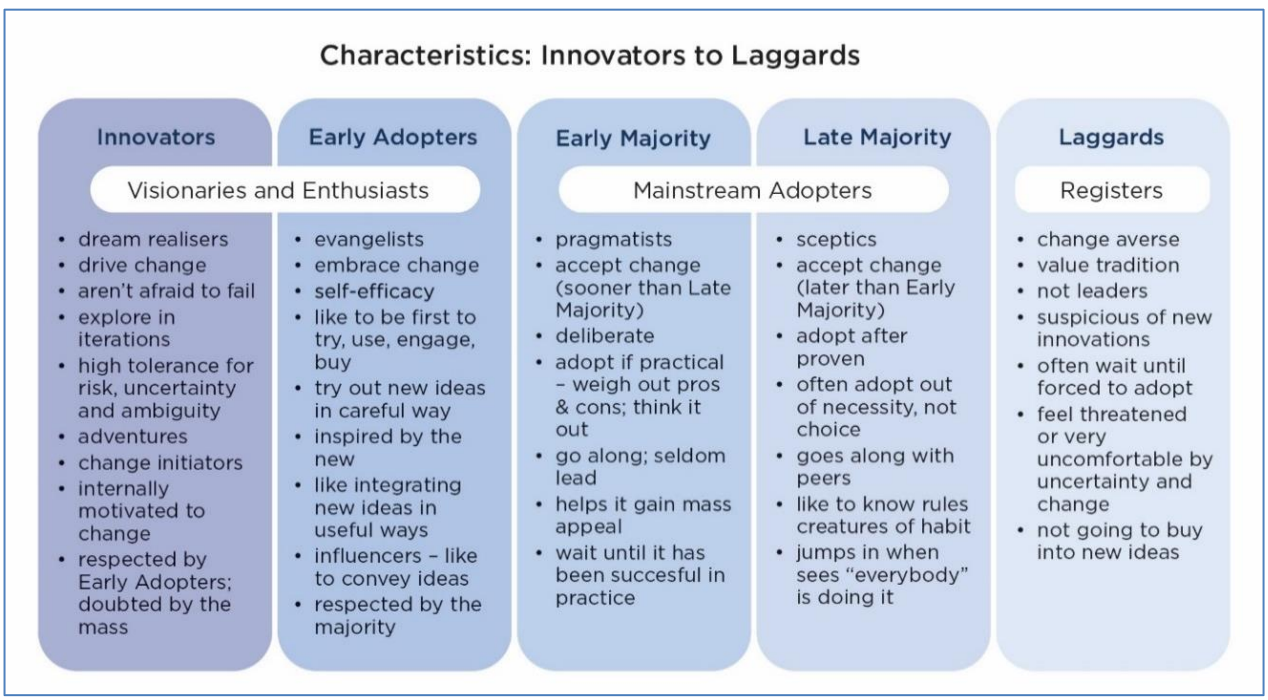


Figure 18: Characteristics of Diffusion types

(Adapted from [179])

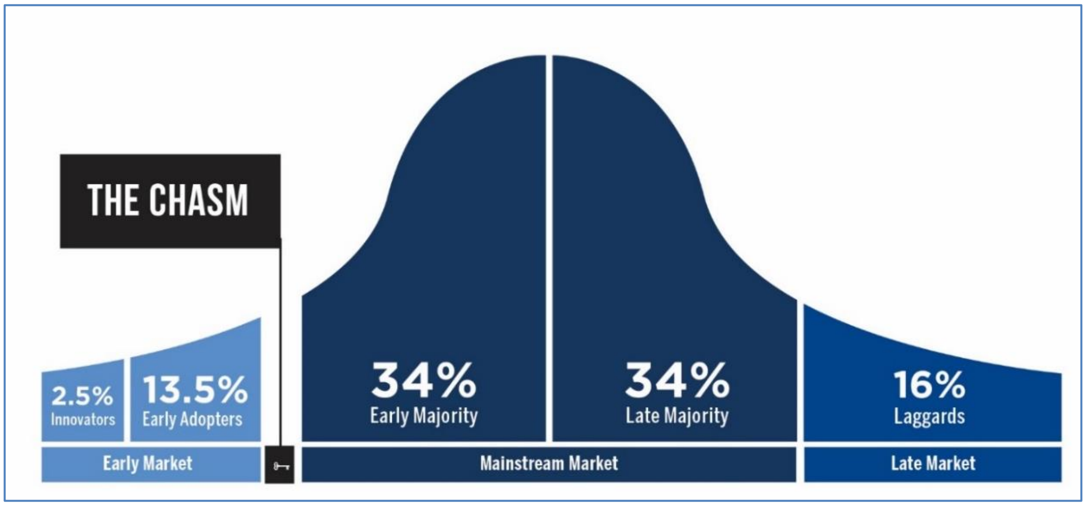


Figure 19: The Chasm between Early Adopters and the Early Majority (Adapted from [181])

Once the 'Chasm' is crossed, the results from the Early Majority will convince the Late Majority, who in their own rights will then provide order and structure in a way that the earlier segments cannot. They will ensure system compatibility and the necessary process alignments to eventually convince the Laggards. These will only come on-board when left little other choice. That said, the Laggards are still very important, as their concerns should be what the Implementation Team uses at the start of the project to 'beta-test' the innovation and to iron out all problems when only the Visionaries are involved. Visionaries will accept early imperfections, but the pragmatic Early Majority requires a thoroughly constructed and proven innovation before they will cross the chasm. In that, the Laggards can almost contradictorily be seen as the most important group as without their change-averse nature the innovation may never cross the chasm to full diffusion.

4.4.2 Psychological change experience models (ii)

Kubler-Ross theorises that for most individuals the experience of 'Change' runs through a number of stages, comparable to the well-known "5 stages of grief" [141]. As every organisation at some point needs to bring about change, whether in structures, policies or technologies, the organisation must understand that its people must adapt to these changes for it to be successful. Only once the people integrate themselves into the new way of doing things will there be true benefit to the organisation at large.

To reap benefit from a change the organisation must support its employees in the transition process and through the various stages of the 'Change Curve' (Figure 20). Some changes can be traumatic and can involve issues of perceived power or prestige. The easier the organisation makes the transition for its people, the quicker it can get to the end of the curve and starting enjoying the benefits of the change. The Change Curve therefore is a useful model that can help organisations understand change resistance and acceptance to better support its staff in change processes.

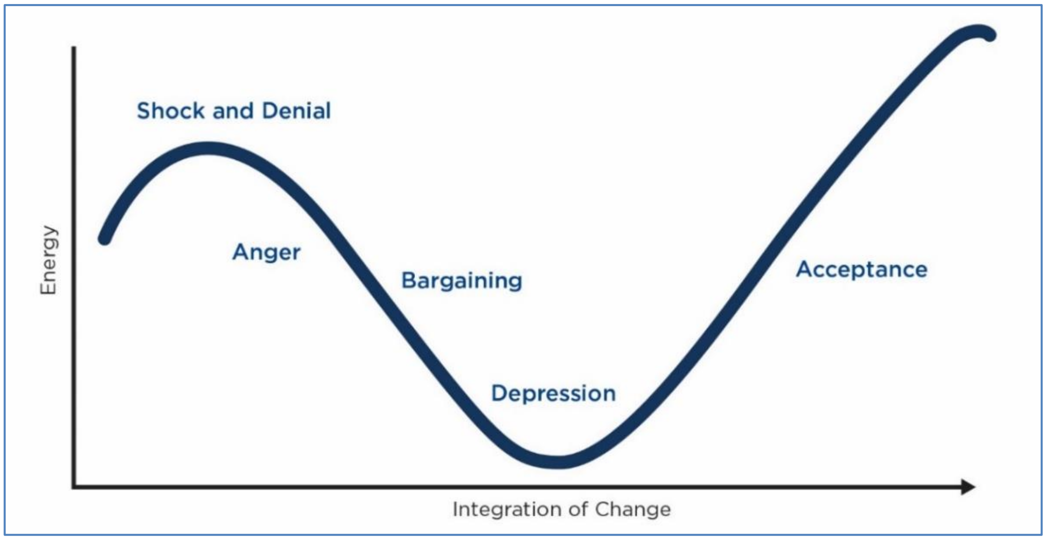


Figure 20: The Kubler-Ross Change Curve
(Adapted from [182])

It is important to understand that the transition between the stages does not always present in a linear direction. Not everyone takes a systematic approach along the path and not every stage takes an equal amount of time. People can get stuck in certain stages and may need prompting or support to move further along the path. The "five stages of grief" that can be compared to the stages of change acceptance are:

Shock and Denial: This is the first stage of the model and for most people it is the shortest. During this phase, the organisation's employees could put up temporary 'defence mechanisms' and may need time to process the disruptive news. They may not initially believe that the change will truly take place and this initial hesitation can delay or even derail the progress of the change if it is allowed to continue for too long. For an effective change, the project manager or Implementation

Team should support the employees to understand why the change is being introduced and how it will benefit the organisation. Open communication and dialogue are needed during this stage to ensure the employees understand the need for the change and the foreseen benefits. The Implementation Team should try to move the employees through this phase quickly by providing the information readily when needed and focussing on the positive aspects of the change.

Anger: When the employees finally realise that the change is decided and inevitable, they begin to think of the full implications and often become frustrated or even angry. If enough information is provided during the first stage the frustration or anger may be limited, but a lack of understanding can significantly aggravate this stage. Some people may look for someone to blame. They may take it out on the company or on their colleagues. This must be managed very sensitively, because disgruntled employees could breed a larger culture of discontent. The key tool again is communication. The organisation must create a platform where concerns can be raised and where even harsh questions are answered. Those responsible for the implementation must acknowledge the frustration and even the weaknesses of the proposed change, as this offers room for improvements. They must also understand that this is a natural ‘stage’ of change acceptance and should not take the frustrations personally, nor believe it reflects negatively on the change itself, but rather address and learn from the negativity raised.

Bargaining: When the anger or frustration eventually subsides, employees often resort to trying to find a compromise or a way to delay the change. They understand that the change will come, but try to find a winning position for their personal situation. The Implementation Team should take special care during this stage not to miss opportunities, as suggestions are not always compromises and could actually provide sustainable win-win solutions. The key is to not think of this stage as a “Zero Sum Game”, but to critically look at suggestions that could add value, while not entertaining compromises that jeopardise the planned change. This stage should not be rushed as it can greatly negate negativity and aid in the general acceptance of the change, particularly if further improvements can be found.

Depression: Before finally accepting the change, there is usually another surge of negative emotions including sadness over what is lost, fear over what is to come, guilt over not being able to do something about it, regret and others. This stage is categorised by low energy and low levels of motivation. Employees may feel that nothing they do will make a difference and that the change will be forced on them no matter what. They often feel powerless and can show signs of indifference or even reclusiveness, resulting in a lack of productivity for the company. During this stage, the Implementation Team should again tread carefully, providing uplifting support and training. This stage can be mitigated, though hardly ever entirely avoided, by focussing on the positives of the change and the added benefits to individuals. The Implementation Team must take care to look for those individuals that are taking the change the hardest and support them during this stage especially.

Acceptance: When the employees realise that the change is definitely going ahead and that there are indeed positive aspects to it, they eventually (sometimes begrudgingly) accept it. Even though they may not be happy with the change, they stop resisting it and start looking for ways to move along with it. Slowly but surely the benefits of the change will convince those that were as yet still sceptical. The Implementation Team should celebrate here, highlighting to all the success achieved and the brighter future secured through the change. This will help cement the change as a part of the organisation.

It is important for an Implementation Team to understand that feelings of shock, denial, frustration and even forms of anger and depressions are normal to some extent when dealing with change management and that they, as custodians of the process, must deal with these negative feelings appropriately to avoid disruption of the implementation. They must offer the necessary support to assist the employees along the Change Curve and effectively communicate at all times. The focus should be on reiterating what is being done, how and why it is being done and what roles the individuals play in the whole. This will aid the individuals through the negative stages and support them in finding Acceptance.

Another very interesting model describing the stages that individuals progress through during a change is the ADKAR Model (Figure 21) [98]. This model also suggests five stages, the first letter of each forming the acronym ADKAR. This model describes the dynamics of the change to the individual and expands on it to frame the change for the organisation (Figure 22).

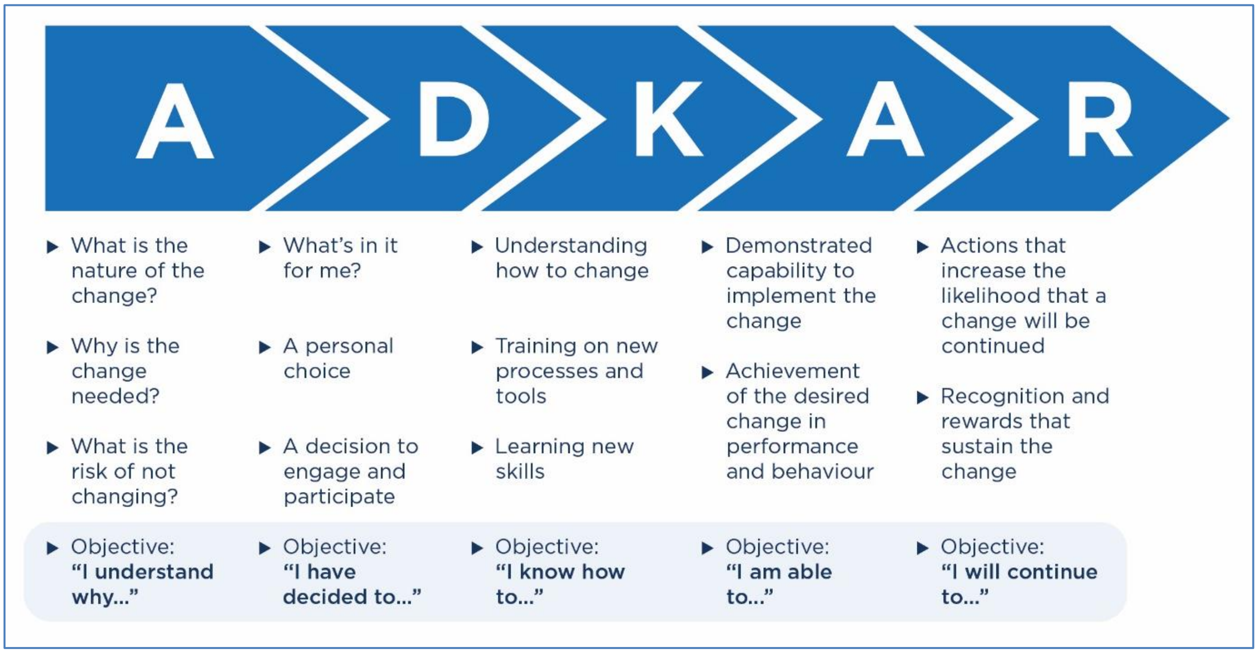


Figure 21: The ADKAR Model

(Adapted from [183])

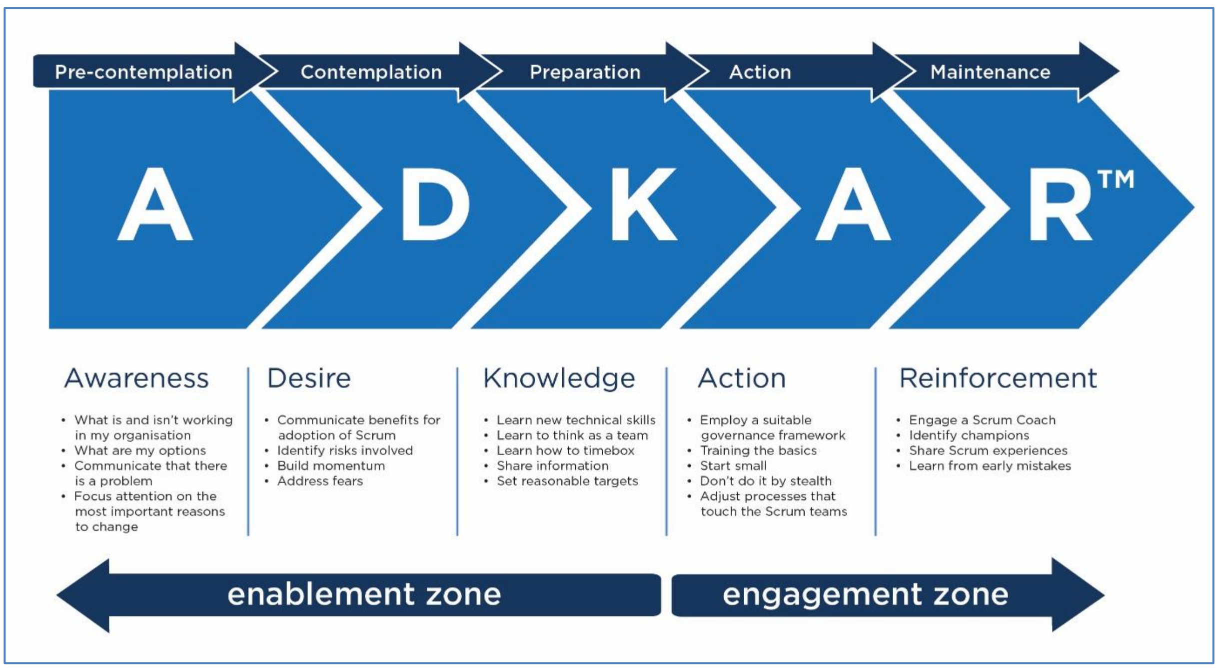


Figure 22: ADKAR Objectives

(Adapted from [184])

The acronym ADKAR represents five elements: *Awareness*, *Desire*, *Knowledge*, *Ability* and *Reinforcement*.

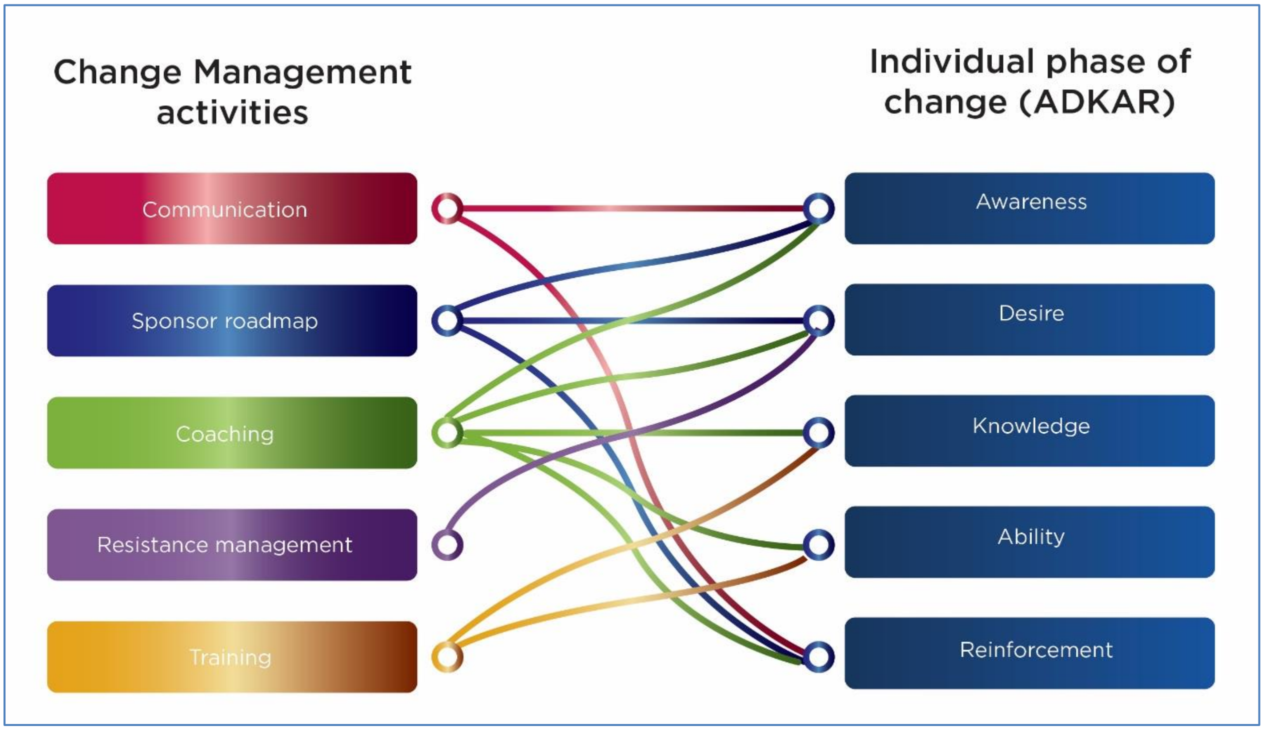


Figure 23: Change Capability and Change Experience model significant overlap (Adapted from [185])

4.4.3 Organisational change capability models (iii)

Organisation change capability models provide insight into factors that influence an organisation's ability to implement change. Many such models and frameworks exist, with varying and often overlapping concepts of what influences and determines success. The People Centered Implementation Model proposes six 'Critical Success Factors', while the PROSCI model theorises five 'Change Management Levers'. These are believed to influence an organisation's capability to successfully bring about change, like the introduction of disruptive new technologies. There again is a significant overlap in the constructs (Table 9).

The activities of communication, sponsorship, coaching and training, as well as resistance management, can be viewed as organisational change capability levers. These are not activities to be done in isolation, but are tools that an Implementation Team can use to effectively drive change in an organisation.

Table 9: PROSCI and PCI models for organisational change capability

PROSCI change lever	**PCI Critical Success Factor**
Communications lever	Shared Change Purpose
Sponsor roadmap lever	Effective Change Leadership
Coaching lever	Powerful Engagement Processes
Resistance management lever	Committed Local Sponsors
Training lever	Strong Personal Connection
	Sustained Personal Performance

(Adapted from [175]), [176])

Communication: Communication is possibly the most crucial component of change management. It forms a large part of the Sponsorship activity, but also goes further than that. Communication lies at the heart of transformational efforts and is entrenched is almost all other activities. Giving the right information to the right group of people at the right time is vitally important to successful change management and effectively doing this can greatly contribute to mitigating negativity. Examples of this lever are tailored messages for individuals or smaller groups, creating platforms for difficult questions, or simply repeatedly communicating the reason for the change and its benefits. A core theme of effective communication plans is to always clarify the reason for the change and the "What's in it for me?" to the individuals.

Sponsorship: It has been shown that effective sponsorship can greatly influence the success of a change in an organisation. Effective sponsors are at the heart of change projects and they champion the change from the start of the project to the end. They build awareness of the change, foster buy-in from otherwise reluctant individuals or areas and create the desire among people to effect the change. They create momentum and bolster the Implementation Team during difficult times. Senior leaders can convey strategic messages and concepts in a way that others cannot and can so unify the people behind a shared goal. Effective sponsorship requires active and visible participation by a coalition of sponsors, preferably senior executives, in constant communication with the people affected by the change and those that need to implement the change.

Coaching: Managers are the key players of the Coaching lever. Managers cover a wide spectrum of activities, from creating awareness to providing the required support and eventually recognition and reinforcement. The managers of the affected areas are the best positioned to clarify the benefit for the teams and to lead by example in embracing the change. Managers can be seen as both agents of the change and recipients thereof, so special care must be taken to ensure all the affected managers are on board with the change, as they will often be the ones disseminating it further down the hierarchy. The senior managers provide the sponsorship, but it is the middle and sometimes lower management that cascades the change into the organisation. Their role is critical and should not be underestimated. Coaching is largely based on trust and the Implementation Team cannot substitute management in this regard. Their role as coaches and change agents must be levered to ensure success.

Training: A solid training plan is of vital importance during periods of change to bridge the knowledge gap, particularly when disruptive new technologies are introduced. An effective training plan will answer many questions and alleviate many fears that staff have about the planned change, as well as clarify its impact on them. The Implementation Team should liaise with management to identify the gaps in understanding or skill and jointly develop this plan. Training should address not only the ‘how’ of the change, but also the ‘why’, in order to be truly effective.

Resistance Management: Resistance to change is well known and researched, but the effective management of change resistance is less so. Resistance can occur at any point of an introduction, but is especially prevalent at the start and should be proactively managed to give the introduction the greatest chance of success.

When trying to manage change effectively, it is also important to understand an organisation’s culture. It can be simplified as “the way we do things around here”, the unwritten rules of conduct in that particular environment. The Cultural Tree Indicator Model (Figure 24) provides insight into this, showing at the roots are the organisations core beliefs and commonly held assumptions [186].

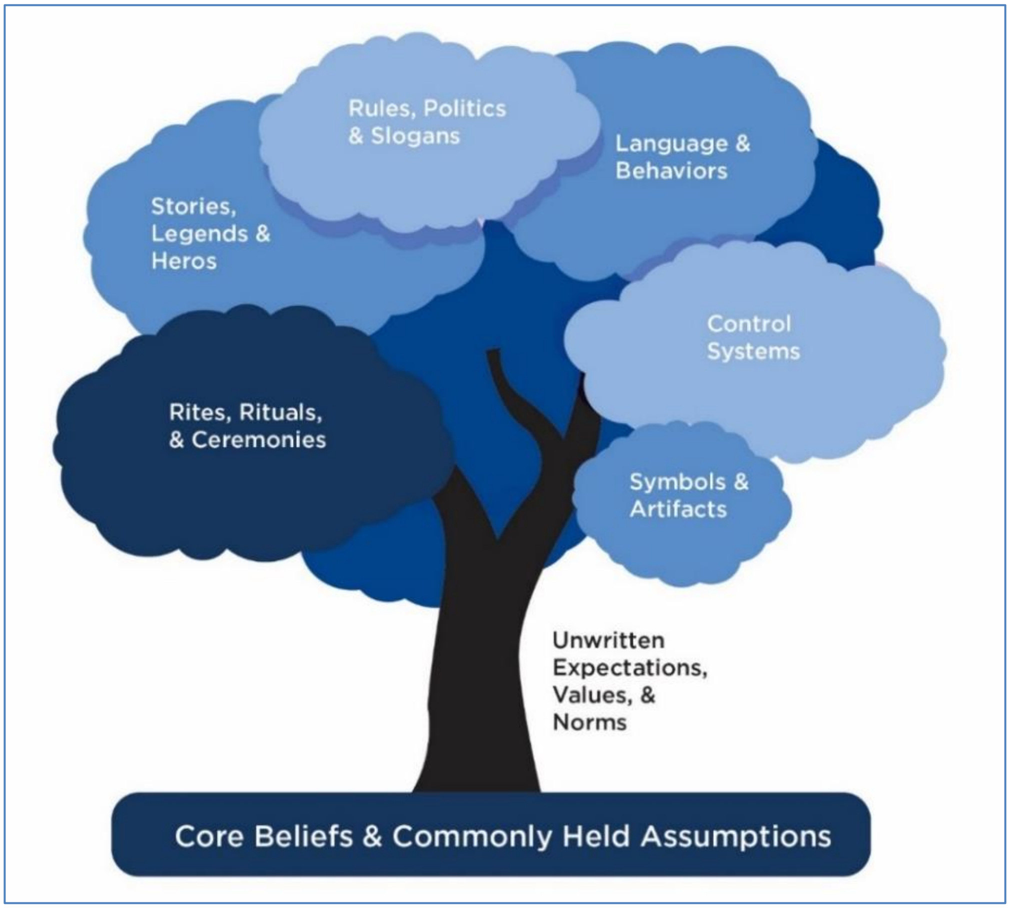


Figure 24: The Cultural Tree Indicator Model

(Adapted from [186])

4.4.4 Linear Change Methodologies (iv)

The Aachen Innovation Model or W-Model, proposes seven steps (Figure 25) compared to Kotter's eight (Figure 16) and the Change Leader's Roadmap's nine (Figure 26). These methodologies all provide an ordered, step-by-step, practical approach to change management.

1. Goal Setting – defining the strategic direction and innovation objectives of the initiative based on the enterprise's overall objectives and strategy.
2. Future Analysis – identifying and analysing different innovation opportunities that could potentially lead to new product development activities.

3. Idea Generation – generating specific product ideas based on the opportunities identified in the previous phase. Ideas are systematically and consistently organised based on the information required to plan for and evaluate them.

4. Idea Evaluation – identifying those product ideas with the greatest potential to fulfil the innovation objectives (set out during Goal Setting). Ideas are assessed for their organisational, market, competition and technological (or technical) feasibility.

5. Detailing Ideas – developing detailed product concepts for the feasible product ideas.

6. Concept Evaluation – quantitatively evaluating the product concepts using the criteria of the Idea Evaluation phase and the verified information of the Detailing Ideas phase. Concepts are selected that are technically and economically feasible and aligned with enterprise strategy.
7. Implementation Planning – assimilating the activities of the pervious phases by providing a systematic guide for implementing the selected product concepts – referred to as an Innovation Roadmap.

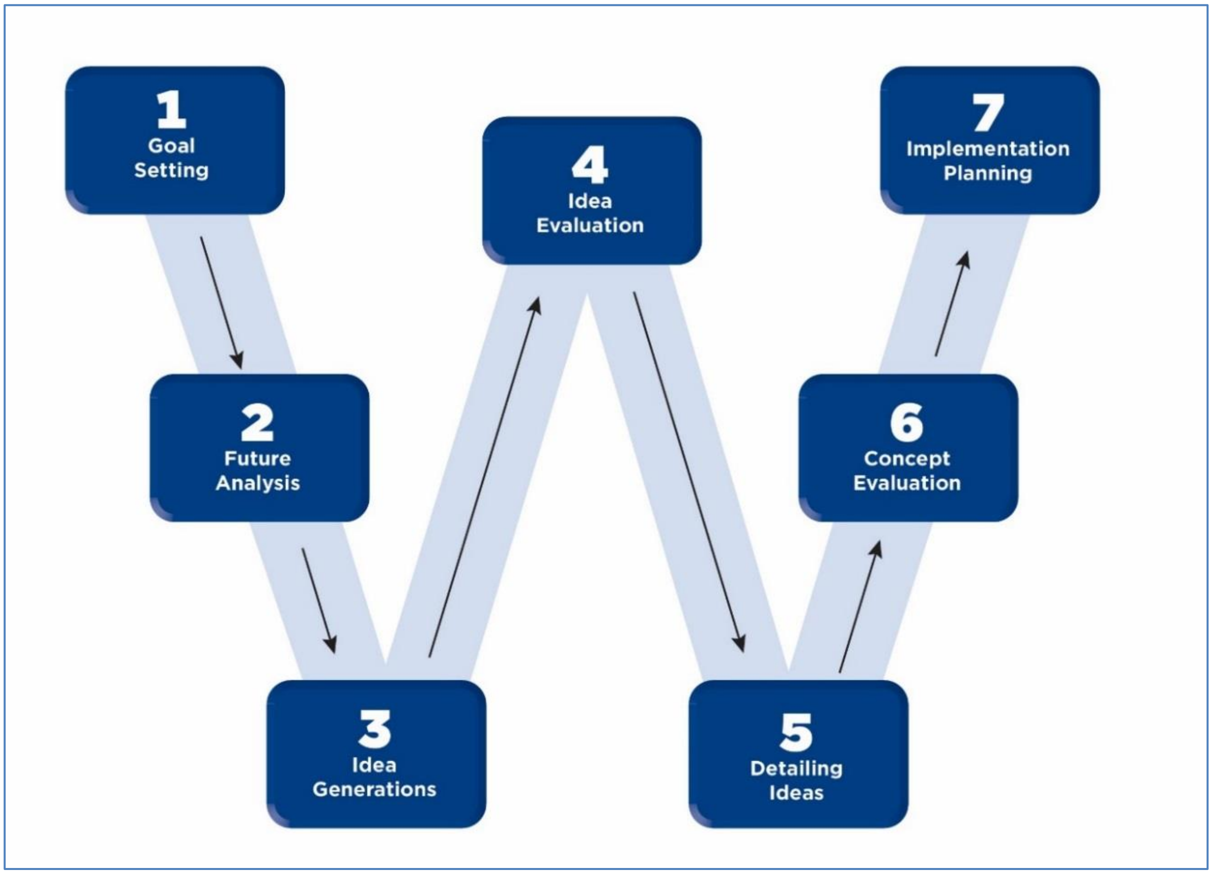


Figure 25: The Aachen Innovation or “W-Model”

(Adapted from [187])

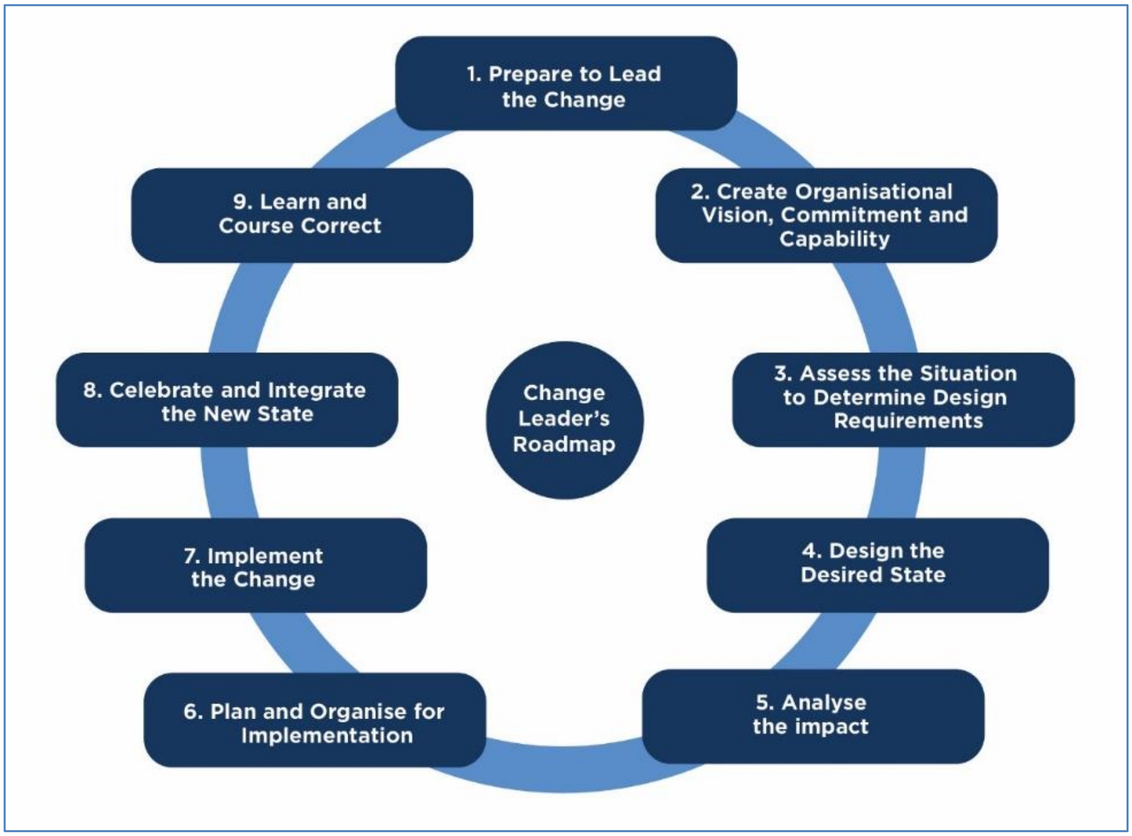


Figure 26: The 9 phases of the Change Leader's Roadmap
(Adapted from [188])

It is interesting to note that in these respected models, the actual implementation step is very loosely defined. Kotter's first step is to create a sense of urgency, yet only at step six does one see anything implemented and then only a pilot. The W-Model waits until the very last step to do "Implementation Planning" and does not directly address the implementation itself. What is Implementation then?

> "Implementation is the constellation of processes intended to get an intervention into use within an organisation: it is the means by which an intervention is assimilated into an organisation. Implementation is the critical gateway between an organisational decision to adopt an intervention and the routine use of that intervention; the transition period during which targeted stakeholders become increasingly skilful, consistent, and committed in their use of an intervention. Implementation, by its very nature, is a social process that is intertwined with the context in which it takes place" [26].

4.4.5 Change Management concepts for framework development

The conceptual framework proposed in this study should address the implications of change uptake concepts, in that it acknowledges and leverages the differences between groups of people to best serve the implementation decision. Each of the groups first identified by Rogers has strengths and weakness and each can be used to further the project, if utilised correctly. If the framework was to ignore these concepts, the weakness of one or more of the groups could put the project at risk, so it is imperative that change uptake as a concept not be ignored. Some elements of the change uptake concept should therefore be incorporated into the conceptual framework if it is to fully meet the research objectives.

While it is important for the Project Leader and Implementation Team to understand the implications of psychological change experience models, their effects can largely be seen in other constructs. The different speeds with which and extents to which people experience the impacts of a change affects to a certain extent into which of the Diffusion of Innovation categories they fall. ADKAR, though it is a change experience model also has significant overlap with other constructs, including PROSCI’s Change Levers, which is a Change Capability Model (Figure 23). The conceptual framework should take cognisance of psychological change experience models, but they need not form an integral part of the meta-theoretical construct, as their implications can also be seen through other models. For the purposes of meeting the research objectives it would be sufficient that the Project Leader or Implementation Team are aware of these concepts, they need not necessarily be highlighted or specifically catered for in the conceptual framework.

To meet the research requirements, the conceptual framework will need to effectively manage change and a detailed view of critical success factors is required to support the Project Leader and Implementation Team with the project. Aspects critical to successful implementation will need to be incorporated into the conceptual framework proposed by this study, to enable Implementation Teams to safely, effectively and efficiently introduce technological change to automotive production lines.

Linear Change Methodologies provide a step-by-step approach to Change Management. It is clear that there is significant overlap between the W-Model's 7 stages, Kotter's 8 steps and the 9 phases of the Change Leader's Roadmap (Figure 26) [126]. To meet the research aim and objectives, a practical step-by-step approach is required and linear change concepts provide this practical methodology. A linear approach will thus form the core of the IFAT.

4.5 Complexity Management

4.5.1 The rise in complexity

Researchers from many different fields, manufacturing engineering among them, have been studying the unique supply network structure of Japanese automotive manufacturers for decades. Their 'keiretsu', the long-term relationships between the OEMs, their suppliers and sub-suppliers, has piqued interest since the 1980's [189]. Thought it is often criticised for creating high entry barriers for new and/or foreign companies, the 'keiretsu' has been praised for giving Japanese OEMs and their suppliers a competitive advantage on the world stage [190].

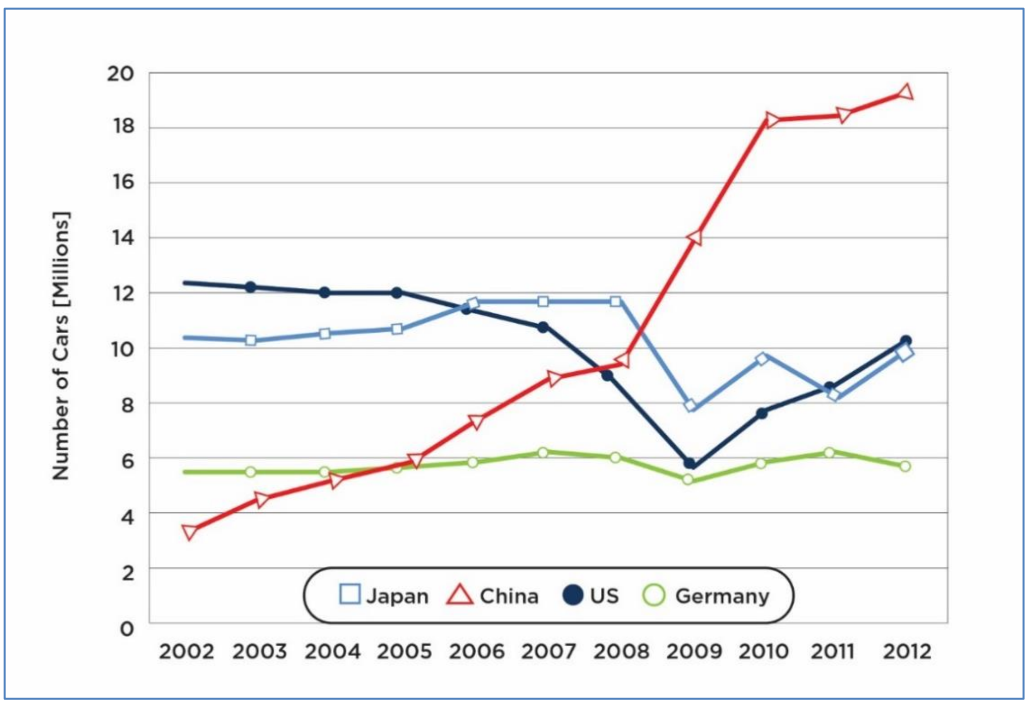


Figure 27: Vehicle production volumes from 2002 to 2012

(Adapted from [189])

Since the early 2000s though, the situation in Japan has changed significantly. The automotive industry of Japan, along with European and American counterparts was negatively impacted by the Financial Crisis of 2008, as well as the rapid growth of China and its automotive OEMs. Japanese manufacturers were pushed in the direction of global procurement strategies, damaging the long-standing ‘keiretsu’ system [191].

Automotive OEMs around the world compete in an extremely competitive industry (Figure 27), with market and customer demands constantly changing and regulations constantly being strengthened. Change is being driven among other by the increasing cost of labour in developing countries where many of their manufacturing plants are located and by the ever-present need to cut costs and improve customer satisfaction [9] [192]. These pressures mean that the landscape of manufacturing is now more complex than ever [193]. While product and process variety is seen as a way of improving the customers’ value-perception [194], they also create complexity for the organisation and companies are looking at ways of addressing this to mitigate a related increase in manufacturing costs [195].

The word ‘complexity’ is generally used in daily life to describe characteristics that are not yet fully quantifiable. Complexity comes at a cost. Motorola waged a well-documented “War on Complexity”. On a portfolio level the company defined the problem as having too many products, too many high-complexity products and too many low-volume products. At a detail level, Motorola defined the problem as having not enough component re-use, having too many non-standard components, having too many parts in general and too complex sub-assemblies. The “War on Complexity” resulted in a $1.4 billion decrease in carried stock and a $2.6 billion cut in supply chain costs [196]! It is reported that the food conglomerate Kraft created a $400million annual saving ‘simply’ by removing complexity from the manufacturing and supply operations of the Toblerone chocolate [197] [198]. Complexity in systems, specifically production systems, is of significant concern to companies and their management, as it has been shown that lowering complexity can be linked to increased performance of the manufacturing network. Complexity should therefore be treated as a cost criterion that companies should strive to minimise [199] [200].

Some companies produce relatively simple products with complex production processes (e.g. injection moulding of common plastic parts), while others produce complex products through relatively simple processes, but for the most part there is a positive correlation between product and process complexity (Figure 28).

Mass production was traditionally based on assembly lines that were dedicated to producing one model in large quantities. By leveraging economies of scale and by dividing work between different assembly stations, these lines achieved very high levels of efficiency and productivity [201]. Dedicated assembly lines are under threat by the modern paradigm of mass customisation, as customers demand higher levels of product variety, yet are not willing to compromise on cost or lead-times [202] [203].

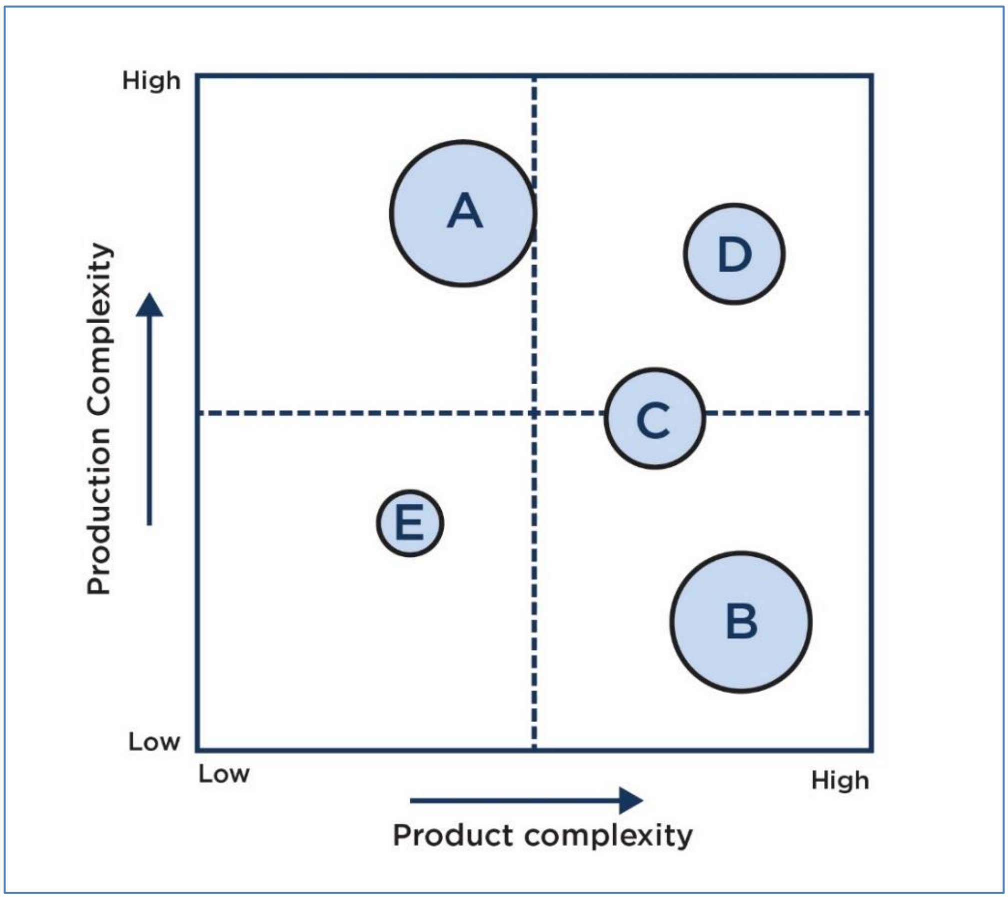


Figure 28: Portfolio of Complexity of Manufacturing Firms
(Adapted from [199])

The Mass Customisation paradigm promises customised products at mass manufacturing prices and because of this shift traditional, dedicated production lines needed to adapt. It has been proven though, both empirically and by simulation, that increases in product variety have a significant negative correlation on performance, specifically on quality and productivity. Mixed-model assembly lines (MMALs) (Figure 29) are recognised as a key enabler to handing the increased variety of products demanded by end customers [204]. MMALs not only save on investment costs, but also ease the managing of demand fluctuations, as a manufacturer can relatively seamlessly switch from building one product to another, or in most cases less of one and more of the other.

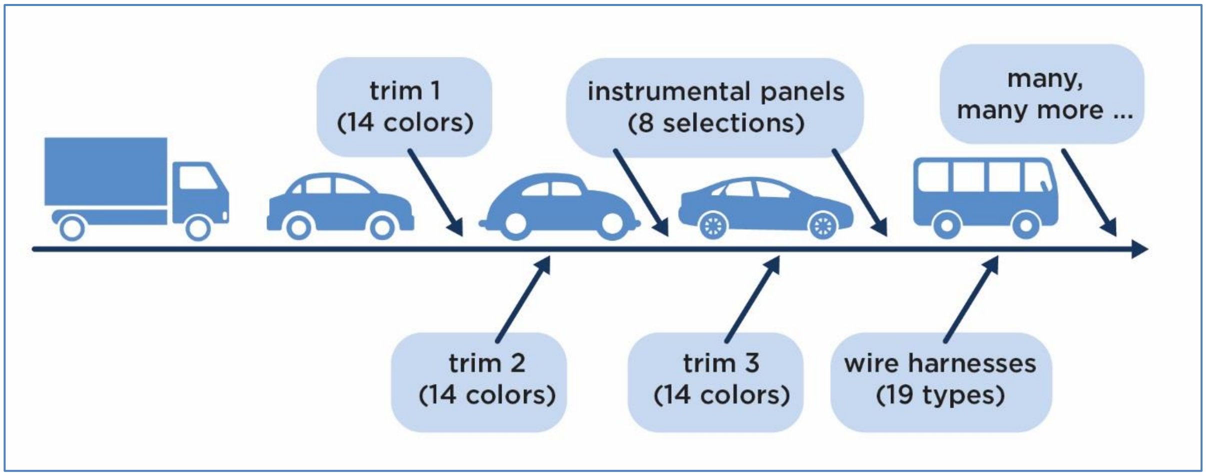


Figure 29: Illustration of an automotive mixed-model assembly line (MMAL)
(Adapted from [205])

4.5.2 Sources and the mitigation of complexity

Many diverse measures have been suggested within various scientific disciplines to define complexity and there are many drivers influencing complexity (Figure 30). Measures of complexity are invariably multi-dimensional. Thirty-two types of complexity have been defined across twelve disciplines including structural, computational, technical, project and operational complexity [206].

In automotive manufacturing the number of parts, their size and geometry, their variety and their manufacturability are all indicators of complexity, as is the level of standardisation or lack thereof. Part handling and insertion attributes contribute to the time required to assemble and test. The volume and speed of manufacturing or assembly contributes to complexity, as does the number of suppliers and sub-suppliers, the number and locations of competitors, the level of market turbulence or certainty and any number of other sources. When automotive manufacturing is considered, the relevant domains of complexity can essentially be clustered into three sub-categories, namely: product complexity, production/process (manufacturing system) complexity and organisational complexity [207].

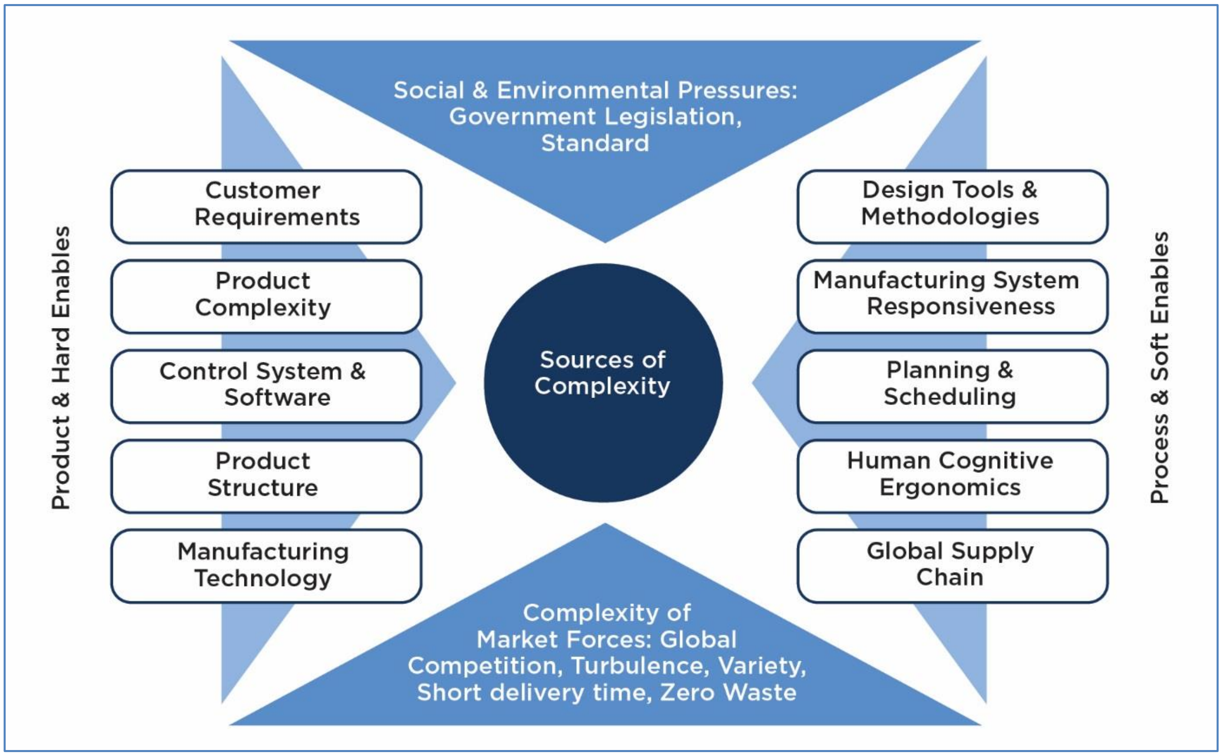


Figure 30: Drivers of manufacturing complexity

(Adapted from [207] [208])

4.5.3 Product complexity

4.5.3.1 Introduction

Based on data from the International Motor Vehicle Program of MIT, seventy manufacturing plants around the world were studied and a "significant negative correlation" was found between product complexity and manufacturing performance [209].

Part complexity has to do with the variances of parts and their combinations e.g. different colour parts, different sizes of engines, different speed gearboxes, etc. Option complexity relates to the number of configuration options on the products and across the model ranges on the line e.g. Full Roof, Sunroof or Panoramic Roof possibilities or the various different options with regard to radios, head units, rim sizes, etc. Model mix complexity is the variety of different models built on the same assembly line. It could mean different body variants of one platform or even completely different platforms being accommodated on the same production line [209]. Daimler for example, has been growing its model portfolio significantly in recent years (Figure 31), with many models often built in the same production facility, increasing the model mix complexity of many locations e.g. C Class sedans assembled on the same lines as GLC SUVs in Bremen, Germany.

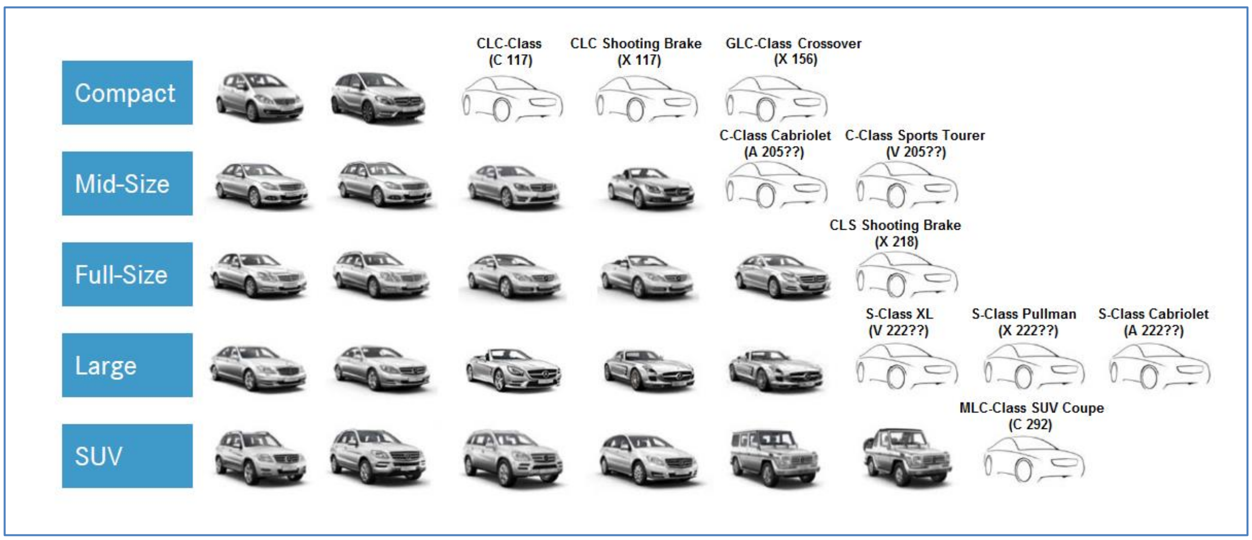


Figure 31: Rapid increase in an OEM model mix from 2012 to 2015

(Adapted from [210])

Few people understand the complexity of modern vehicles at a component or sub-component level. Even when one looks at relative old cars like the MK2 Golf, it surprises many people how many components it was made from (Figure 32). Both simulations and empirical data show that an increase in product variety in automotive production leads to a significant negative impact on performance, both in terms of quality and productivity [205]. During the period from 1975 to 1990, the number of part-numbers in German companies increased by approximately 400% [199]. MBSA, a German subsidiary, states that they had to change over 3500 parts for the 2018 C Class

Facelift project and that this number represents only unique purchase parts, not counting subcomponents [211]. Contemporary vehicles comprise thousands upon thousands of parts and the complexity is increased by the fact that not only mechanical and electrical parts are assembled, but also complex software and machine-human interfaces (Figure 33) [207].

Figure 32: Exploded view of the 1983 Volkswagen Golf MK2
(Adapted from [212])

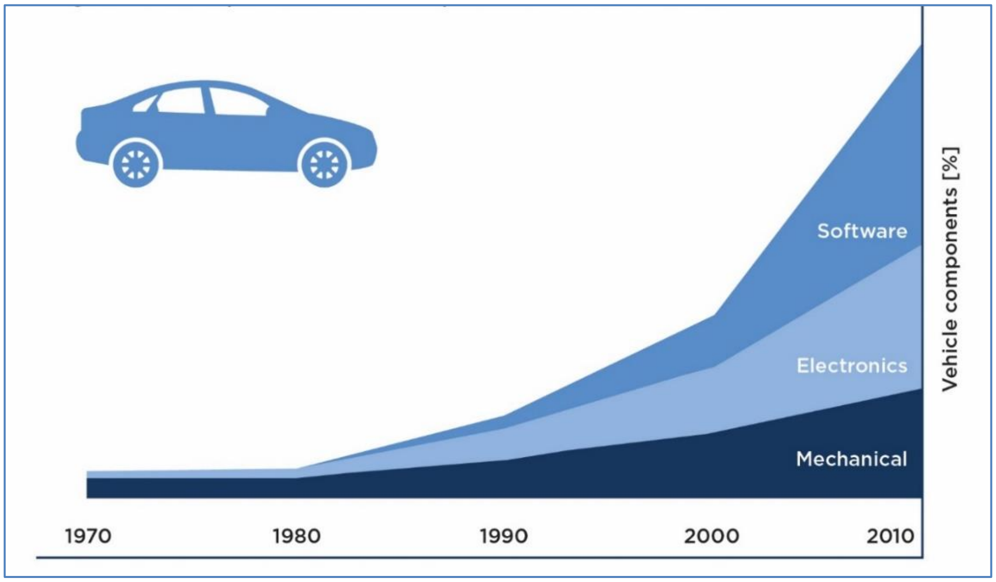


Figure 33: The exponential increase in parts since the 1970's
(Adapted from [213])

In automotive production lines, variants of different components are selected and assembled sequentially as a unit proceeds down the assembly line. Figure 34 shows the ‘product family architecture’ of a product made from two different components, A and B, with each having a few variants (A_1, A_2, A_3, B_1 and B_2). In this example, different suppliers provide components A and B to the OEM.

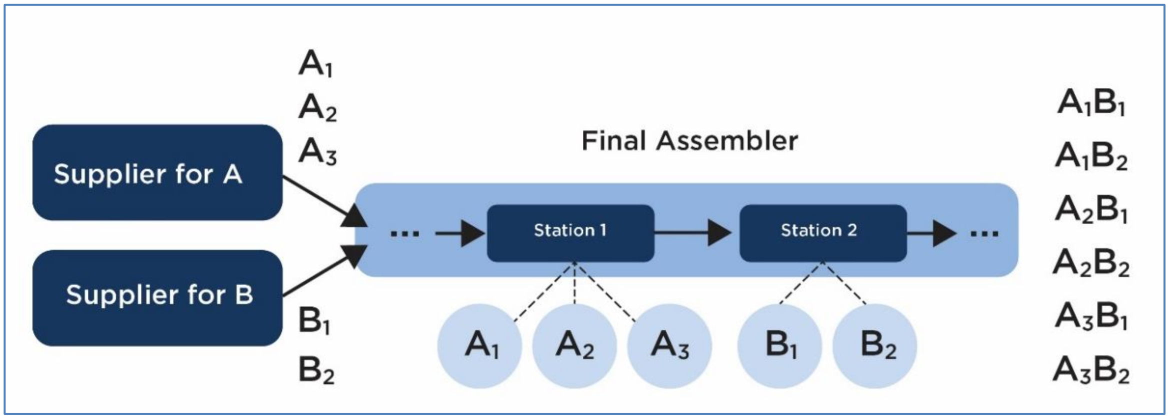


Figure 34: A mixed-model assembly line and its supply chain
(Adapted from [205])

While each supplier only produces or delivers two or three variants, the effect on the final assembly is compound and the OEM as final assembler has six different variants of the end product. The maximum end combinations are calculated by the mathematical product of the variants of the subcomponents. In this over-simplified example, it is 6 (3x2), but when one takes into account that a typical vehicle comprises thousands of parts from hundreds of suppliers, each with its own internal variants, the complexity of automotive manufacturing starts to become apparent.

Not only parts are increasing, but so is the amount of models and model variants OEMs are producing. BMW claims that every vehicle that rolls off the belt is unique and the number of possible variations in the BMW 7 Series alone could reach 10^{17} [201], or stated another way, there are one hundred quadrillion potentially different variants of this model. By the mid-1990’s already 50% of assembly variants in automotive manufacturing were used in less than 5% of the units produced [199]. This creates massive complexity for OEMs, with arguably little benefit other than perceived value.

4.5.3.2 Managing Product complexity

A modular supply chain can greatly reduce complexity in production plants. A modular configuration means that the final assembler (the OEM) buys product modules from sub-assemblers rather than assembling the components on its own. An example of this would be a Tier 1 supplier purchasing hundreds of parts from various Tier 2 suppliers, assembling them and delivering fully assembled cockpits to the production line of an OEM. The final assembler, the OEM in this example, reduced the complexity of handling hundreds of parts (and their associated variants) in-house and instead only procures the fully assembled cockpit from the Tier 1. In Figure 35, the OEM reduces its interfaces by two thirds by following a modular approach. This is a simplified example, but serves to illustrate the significant mitigating effect of modularity.

Standardising components and reducing the size of the portfolio are further mitigating strategies, but these are often not practically possible for manufacturing plants, who typically build according to the design intent and instruction of centralised Research and Development divisions.

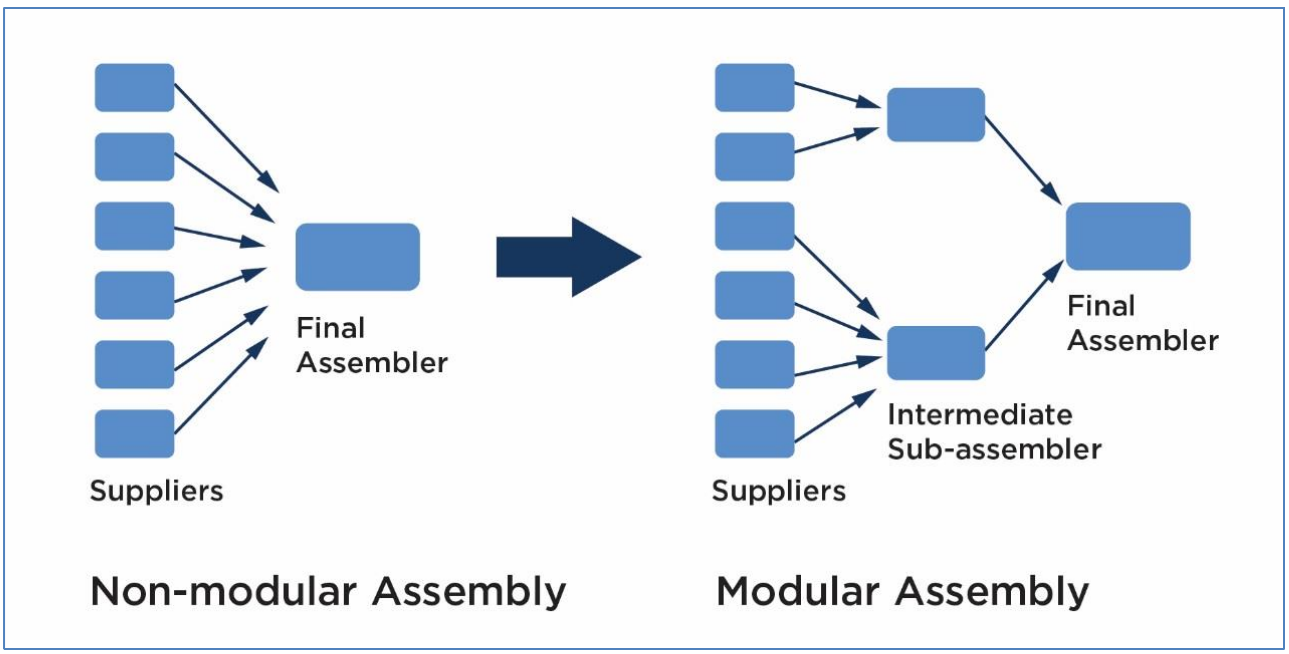


Figure 35: Non-modular vs Modular Assembly
(Adapted from [205])

Another way of mitigating product complexity that is gaining traction in manufacturing and other organisations is that of ‘Warenkorb’ or ‘Shopping Cart’. This concept seeks to simplify assembly operator tasks, by placing the responsibility for picking the correct parts for a vehicle in the supply chain. Under this concept, a ‘Shopping Cart’ is filled with the parts for a specific vehicle only, so the assembly operator does not need to decide on applicable parts; he or she simply fits the parts that are in the basket or on the trolley. The trolley accompanies the vehicle along a particular production line and the operators fits the appropriate parts as found on the trolley. This reduces waste by eliminating walking and significantly frees up line-side space, by removing racking for components. By eliminating the need for the assembly operator to decide on the applicable part, a large portion of the product complexity is mitigated. Figure 36 demonstrates the application of the ‘Warenkorb’ technique at MBSA, showing the trolleys travelling with the vehicles on their ‘Trim3’ line in the Assembly shop. The introduction improved efficiency on the line significantly and resulted in a 6% improvement in ‘Engineered Hours per Vehicle’, a key automotive KPI.

Figure 36: Shopping cart concept at MBSA

4.5.4 Production and Process complexity

4.5.4.1 Introduction

It has been noted that the layout of the various components in a system and the connectivity among them also affects complexity [207]. The physical and logical layout of a manufacturing system dictates material flow planning, particularly the movement of parts and tools to and from warehouses and on the shop floor. This complexity has a direct correlation not only to transportation costs, but to overall resource efficiency.

Operators at various stations along an assembly line often manually select and assemble components. They must select the right parts and the correct tools to assemble the order as per the customers' requirements. Complexity is manifested in the added worker's efforts to recognise, grasp, orient, insert and assemble the parts, in recognising and using the correct tools, as well as in using it in the correct process. This process of continuously selecting precisely the correct combination is often repeated hundreds of times a day to produce the vehicles to specification. As the variety of parts and tools increase, the operators are faced with growing complexity and the need for quick decision making in a 'takt'-based environment. This influences overall system performance as even one incorrect selection can mean that the vehicle is not built correctly the first time and needs to be sent for rework, an expensive non-value adding process. Higher complexity is therefore linked to longer assembly time in the case of manual assembly. In any given station, aside from part choices, an operator could be required to make many additional decisions related to the assembly processes of that station. The operator may have to select tools, fixtures, the best-suited assembly process, etc., all of which adding to overall complexity for the given operator. In automatic assembly, complexity translates into additional equipment required to complete the assembly process. Here higher complexity usually directly translates to higher equipment costs.

4.5.4.2 Managing Production and Process complexity

A production or manufacturing system should not be seen as a fixed object, but rather one that is subject to adaption and emergence [214]. Well-designed systems often have features that allow for adaption and reconfiguration, including modular design (both physically and in logic), cellular workstations, buffers and physical de-couplers. Reconfigurable systems that are able to produce a high variety of different products often include technological enablers like functional changeability, scalability and modularity [9]. It has been shown that as product variety increases, the optimal supply chain configuration moves from non-modular to modular assembly [205]. Modularity therefore can be seen as a way of mitigating an increase in production complexity.

Introducing commonality, for example common fixtures or tools for multiple variants, is another way of reducing complexity. The measurement of a product's production complexity supports manufacturing orientated product design, aids designers in reducing assembly complexity and allows for better decision making on parts, sequences, tools and layouts. Alternative suppliers and shipping routes must be investigated as well as alternative packaging to further reduce complexity [215]. Importing technology from foreign suppliers can have several drawbacks, including creating a power imbalance between customer and supplier [216], but with new technologies companies may be limited in their ability to find suitable suppliers in their country.

Volume-flexible assembly lines capable of adapting configurations to different demand requirements were analysed and methods have been proposed to cope with re-configuration of resources for capacity planning, but these to date only provide a scientific foundation, not yet concrete formalised tools or methods [217] [218] [219]. Nonetheless, 'scalability' is an option to consider when attempting to reduce complexity, specifically with regard to market fluctuation. Mixed-model assembly lines is another way of coping with fluctuating demand on individual products. An important aspect of assembly system design is sequence planning, as robust assembly planning can reduce complexity. As upstream tasks or stations have an influence on those downstream, the most effective sequence is the one to minimise total complexity (C_{ij} does not equal C_{ji}) (Figure 37).

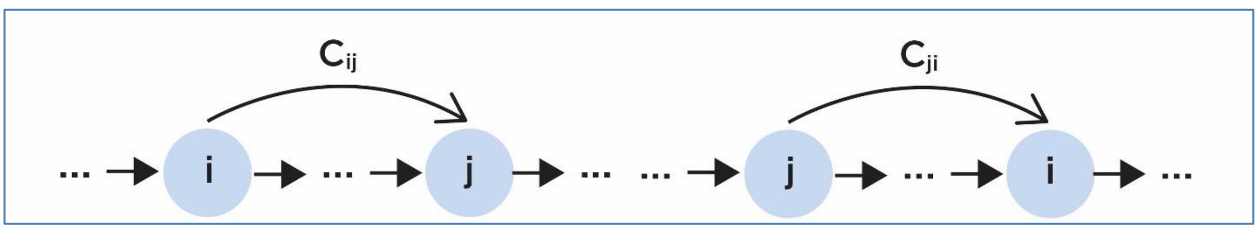


Figure 37: Differences in transfer complexity values of assembly sequences (Adapted from [205])

4.5.5 Organisational complexity

4.5.5.1 Introduction

Not only the products produced by companies, or the manner in which they produce them are affected by complexity, but so are the organisational structures. Effective and resource efficient work requires different and increasing levels or different combinations of discretion complexity [220]. Complex network science is an interdisciplinary field, inspired by real-world complex networks such as human interactions, the Internet and others. Many metrics for networks have been developed and many models successfully applied in a range of scientific fields. It is increasingly being applied to fields of management, including Supply Chain Management, as there is significant evidence proving that an organisation's network structure has a correlation to its efficiency, competitiveness and overall performance [221] [222] [223].

Flexible processes, enlarged product portfolios and varying market demands require that companies embrace new strategies and concepts of organisational design and structure. Organisations have to adapt to fast-paced disruption, or they risk following the path of Nokia. The supply network of OEMs and their suppliers can be measured by both the in-degree and out-degree (the number of incoming and outgoing links) of the 'nodes'. Every link adds complexity to the overall system. Globalisation, including global suppliers and a global customer base has exponentially increased the interconnectivity of activities and vastly increased complexity [189].

4.5.5.2 Managing Organisational complexity

When considering supply chain design, vertically integrated supply chains is also a way of handling the increase in variety demanded by the mass customisation paradigm at an organisational level. Vertical integration or disintegration in this context is an extension of the same modularity concept that can be used to reduce product complexity and while it is effective in that, it also has an effect on mitigating organisational complexity. Figure 38 shows that the same group of organisations can be structured in many different configurations.

A suggested method of finding the optimal supply chain network is a three-step approach, to first generate a list of all possible configurations of the supply chain, next to calculate the complexity of each of the variations and then to determine and install the optimal configuration.

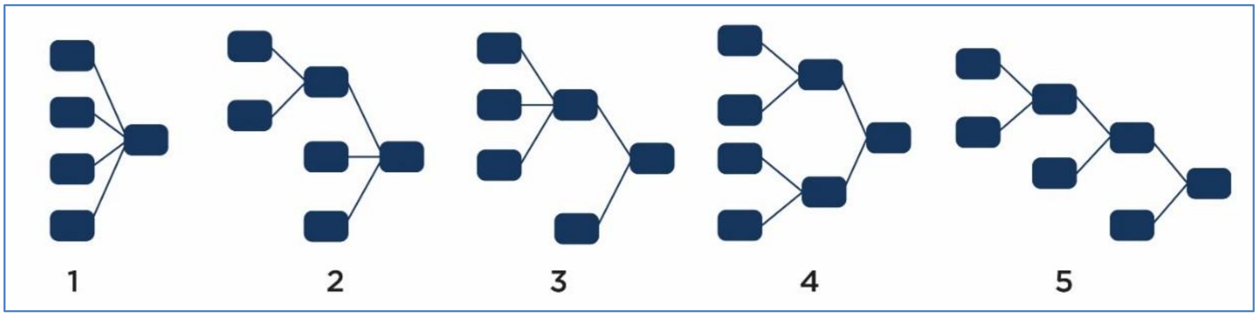


Figure 38: Possible configurations of a supply network with four suppliers (Adapted from [205])

A strong mechanism in managing organisational complexity is by leveraging the various managerial levels in the organisation effectively and efficiently – what Elliott Jaques named Stratified Systems Theory (SST) [224]. Jaques argues that executives should plan in years and decades, not months or days, allowing organisations to be better prepared for market and other changes. Companies that adapt well to change are typically vested in and well positioned for "the long game" [225] [226].

SST proposed that work could be divided into seven levels, or 'Strata' (Table 10), with increasing levels of complexity. As the levels increase, so does the complexity and each level therefore poses new challenges to the decision-makers, becoming increasingly conceptual or 'fuzzy' the higher the Strata. Jacques showed how organisational structure directly impacts effectiveness. Strategic Intent and Development is typically formulated at the 4th and 5th Strata and disseminated from there to more operational levels (Figure 39). This ideal structure allows lower strata to deal with the lower complexity operational tasks needed for an Implementation project.

Table 10: Elliott Jaques' Stratified Systems Theory

Stratum	Time Span	Work Complexity	Cognitive Mechanism	Position
VII	20 years	Construct complex systems; construct versus predict future	Linear extrapolation; develop new theories	Board Chairman Corporate CEO
VI	10 years	Oversee complex systems; group of business units; plan long-term strategy	Reflective articulation between systems; higher conceptual approaches	COO Executive VP Group Executive VP
V	5 years	Command one complex system; connections to environment	Shape, reshape whole systems, boundaries; utilize theory	President VP Top Specialist
IV	2 years	Oversee operating subsystems; design new methods, policies	Develop alternative systems; abstract from data; parallel processing	General Manager Division Manager Chief Specialist
III	1 year	Direct one operating subsystem; predict needs 12-18 months out	Linear extrapolation; alternate pathways	Unit Manager Department Manager Director
II	3 months	Direct an aggregate of tasks; diagnose problems	Reflective articulation; formulate new ideas; handle ambiguity	First-line Manager Supervisor
I	1 day	Carry out one task at a time; daily, weekly, monthly quotas	Concrete shaping; concrete thinking; linear pathways	Operators and clerks Day workers

(Adapted from [224], [227])

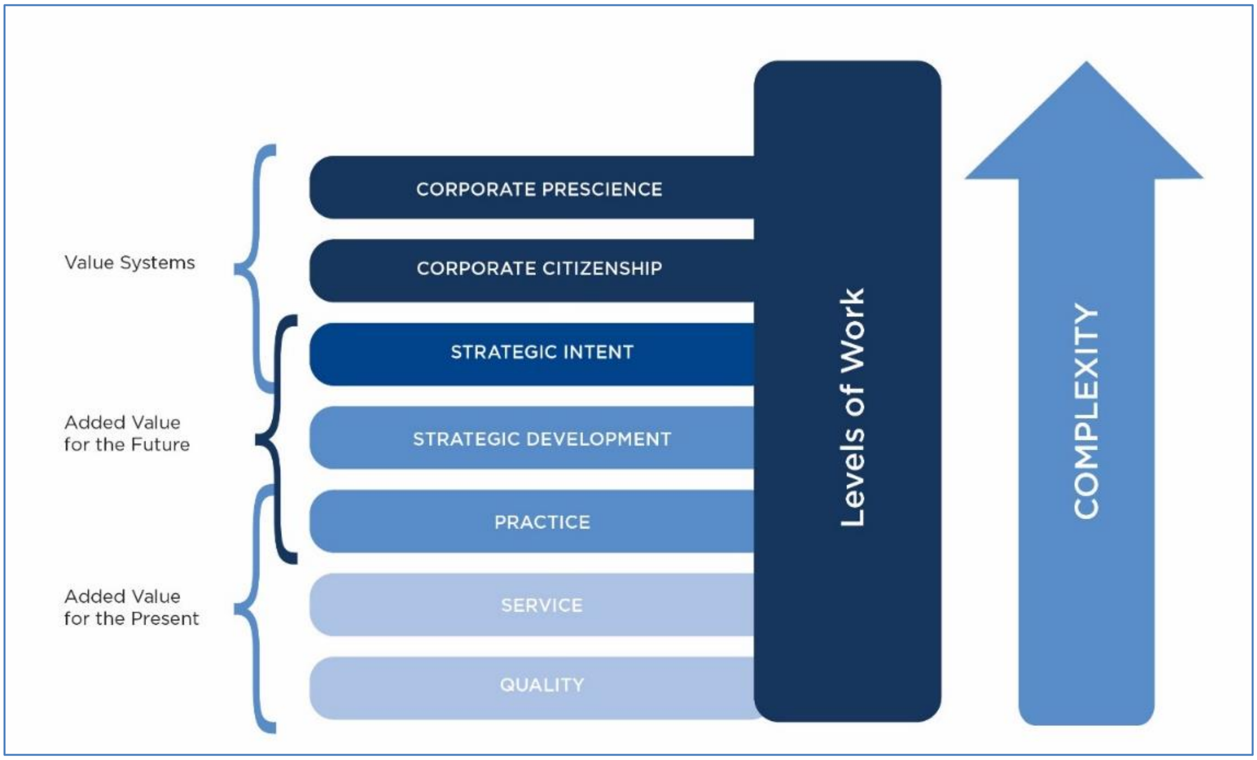


Figure 39: Levels of Work increasing in complexity
(Adapted from [228])

4.6 Implementation and continuous improvement theory

One of the most frequently used tools to plan projects is a Gantt chart. It allows for a holistic view of all required activities, while simultaneously providing insight into the required timespans. It can also be used to highlight interdependencies and stop-start relations.

It has been found that the "frequent introduction of new and innovative products is a necessary precondition for maintaining long-term competitiveness" and that effectively and efficiently managing product introductions are important success factors for mass customising companies. It has also been noted that the introductory phase can pose extraordinary challenges for manufacturers, as the additional costs, quality defects and the resultant order delays can negatively impact the overall introduction [229]. There are several approaches that can be taken when implementing a new system or technology. Countless variations and adaptations are possible, but four main approaches can be clustered as shown in Figure 40.

The manner of introduction may differ depending on the organisation, the specific situation, as well as the technology. The norm in automotive is akin to Pilot Running, where trail vehicles of the new model are built in iterative maturity loops, while the old model continues production until the new is fully phased in.

To determine the effectiveness and efficiency of the Implementation and to learn from it, it is necessary that it be evaluated. For a ‘hard’ introduction, this evaluation can only be done after the fact. For a phased introduction, an evaluation can be done after each phase and for a gradual introduction, the Implementation Team can decide on suitable intervals for evaluation. The method of evaluation must be robust enough to allow a critical view of the Implementation and in the case of phased or gradual introductions, there should be an opportunity to correct or improve aspects related to the evaluation prior to the next phase or before the implementation is finalised.

Many methods have been put forward with regard to implementation and continuous improvement. It can easily be argued that none have captured the imagination quite to the extent of the Plan-Do-Check-Act (PDCA) Cycle introduced by Dewing in 1950 (Figure 41) [230]. The Cycle follows a simple, four-step iterative logic:

- **Plan**: Understanding of the problem, defining the scope and target, developing alternative solutions and selecting one for implementation
- **Do**: Implementing the selected solution, training the staff on the new standard and ensuring that the standard is followed
- **Check**: Verifying if the implementation had the desired effect and that the problem is resolved
- **Act**: Defining what needs to be done if the desired state is not (fully) reached (yet).

By understanding existing implementation approaches and the continuous improvement abilities of each, it is possible to design a framework that will function in the highly competitive automotive sector and improve the rate of success of implementation projects.

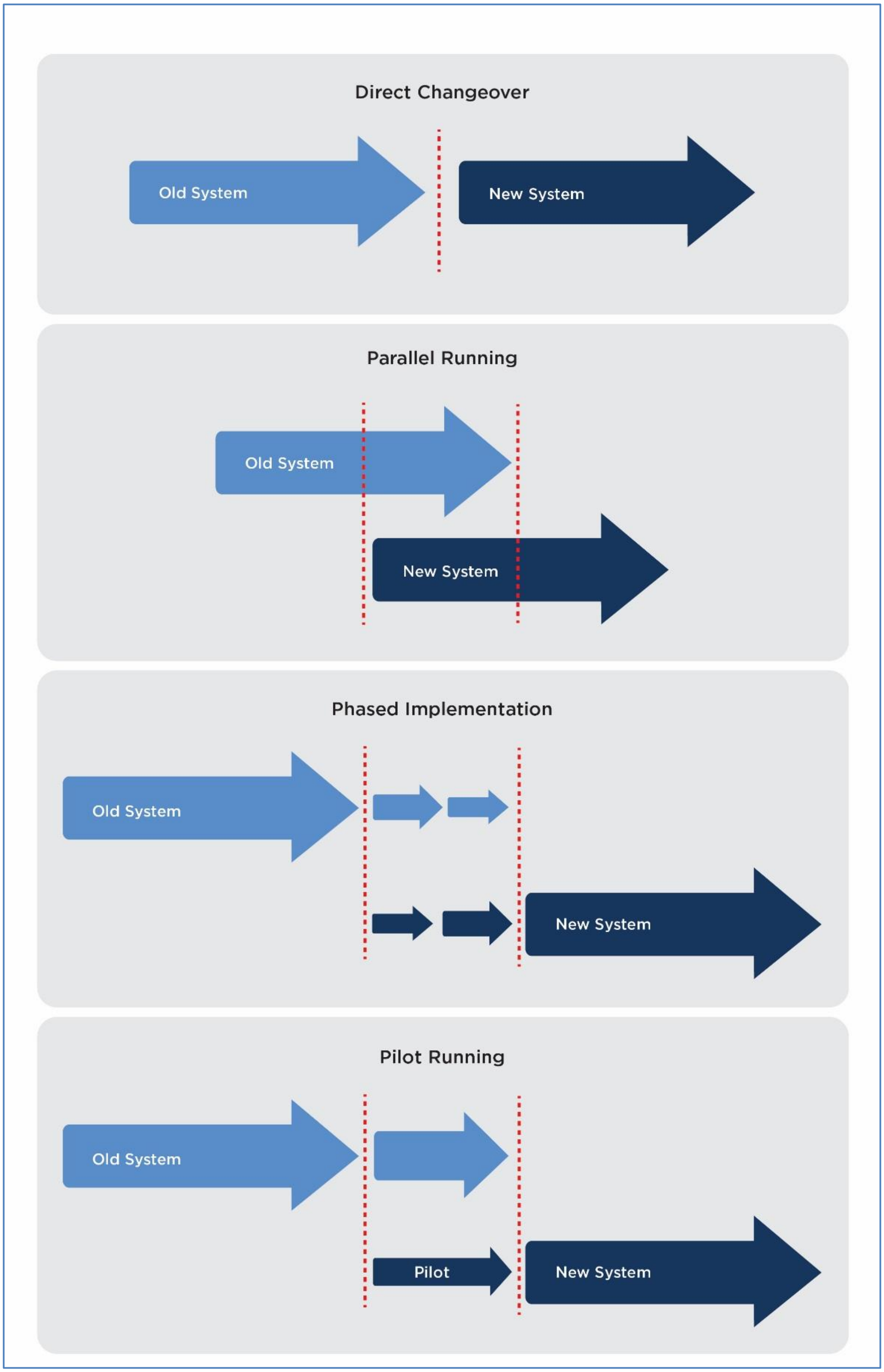


Figure 40: Approaches to implementation

(Adapted from [231])

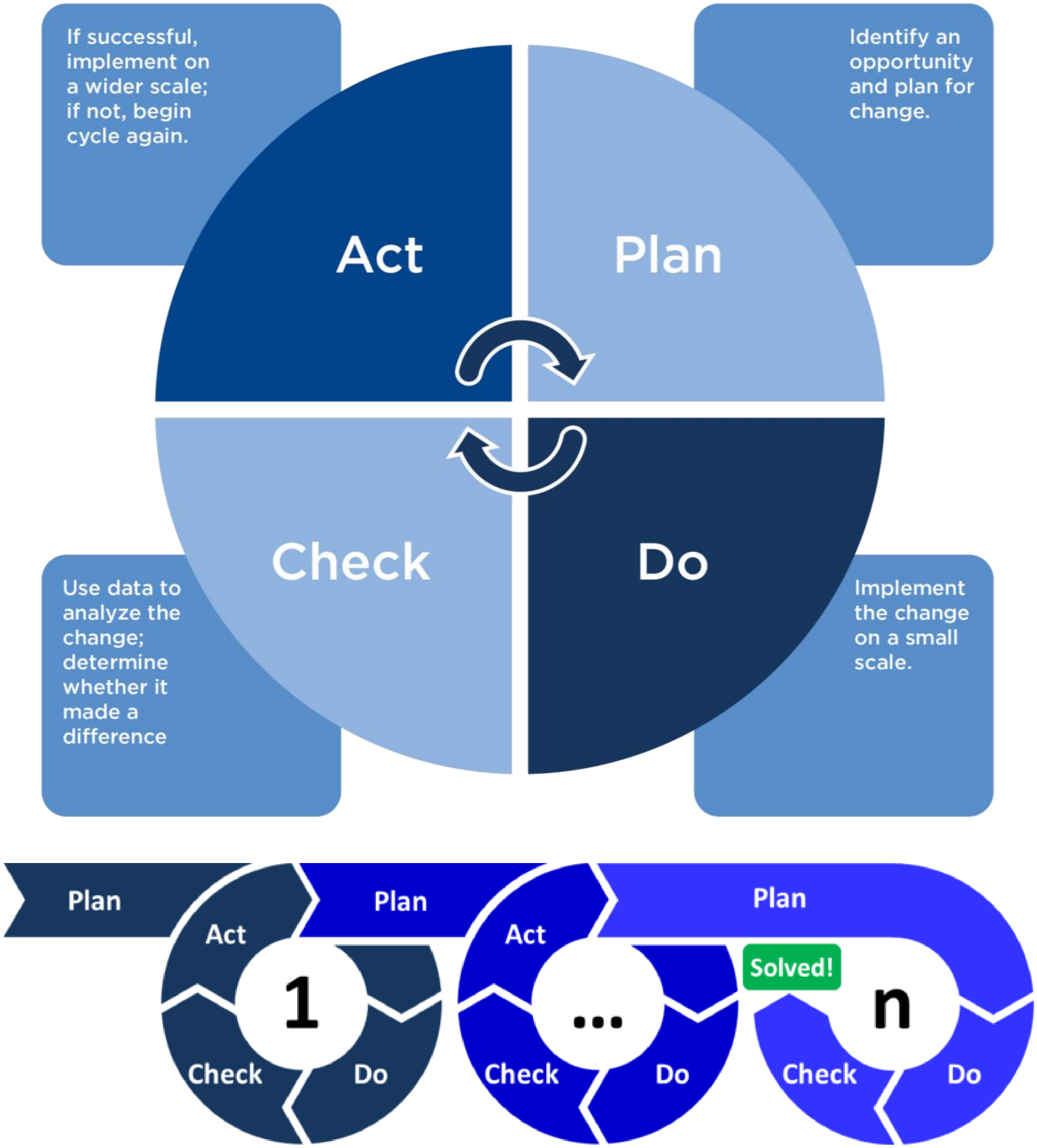


Figure 41: The PDCA cycle and its iterative application (Adapted from [230], [232])

4.7 High Voltage technology

4.7.1 Hybrid and Electric Vehicles

By definition, Hybrid vehicles need two or more power sources. They can be classified according to their level of 'hybridisation', with micro hybrids having start-stop functionality, starting-off aids and some recuperation ability. Mild hybrids have a complete secondary power source, but use it only to support the primary drivetrain, while full hybrids have two complete drivetrains that can operate independently. The most significant advantage that these vehicles have is that they have both an internal combustion engine and energy storing batteries, enabling them to realise the fuel savings of an Electric Vehicle when using the batteries, while having another form of power when the batteries are depleted. Plug-in hybrids are a form of full hybrid, with the added feature that the batteries can be charged from an external source e.g. from the power grid.

Hybrid vehicles are fundamentally different from standard vehicles that are almost exclusively powered by internal combustion engines (ICEs). For the purposes of this study, the term Hybrid vehicle refers to a vehicle with a conventional ICE, as well as a battery. Although there is some research being done into 'ultra-capacitors', the norm currently is Lithium-ion batteries [233]. A Petrol/Electric combination is used in the C350e of the case study, but Diesel/Electric hybrids have generally the same electric components and could be introduced in the same manner. For the purposes of this study, the term Hybrid vehicle excludes Micro Hybrids, as they do not require High Voltage components and are not 'true' hybrids in the sense of having multiple power sources for driving. While Fuel Cell Electric Vehicles (FCEVs) have commonality with Hybrids and Electric Vehicles (EVs), they are a unique type of vehicle with significantly different manufacturing requirements. The IFAT is not primarily designed for this type of vehicle.

EVs typically have only an electric motor, or multiple electric motors to propel the vehicle. The power required by the motors is stored in batteries, with no on board conversion of fuel into electricity as is the case with FCEVs and no combustion of fuel to create motion, as is the case with ICE vehicles. EV batteries can be recharged at charging stations in cities or at home through an electricity socket.

A battery swopping concept, where a depleted battery can be exchanged for a charged one at a swopping station has also been developed, but has not found a lot of traction in the industry. EVs have a limited range before they need to be recharged, as conventional vehicles have a limited range before they need to be refuelled. According to the US Department of Energy, recharging currently still takes considerably longer than refuelling and this is seen as one of the main drawbacks with EV technology [234].

The immense weight of the batteries is another significant drawback. The SLS AMG E-Cell (Figure 42) has 12 battery modules with 72 Lithium-ion cells each. This battery pack produces 552kW and 1000Nm torque, propelling the vehicle from zero to 100km/h in 3.9 seconds. Although it can produce enormous power, it weighs over 500kg and has a major impact on the vehicle's electric range [23].

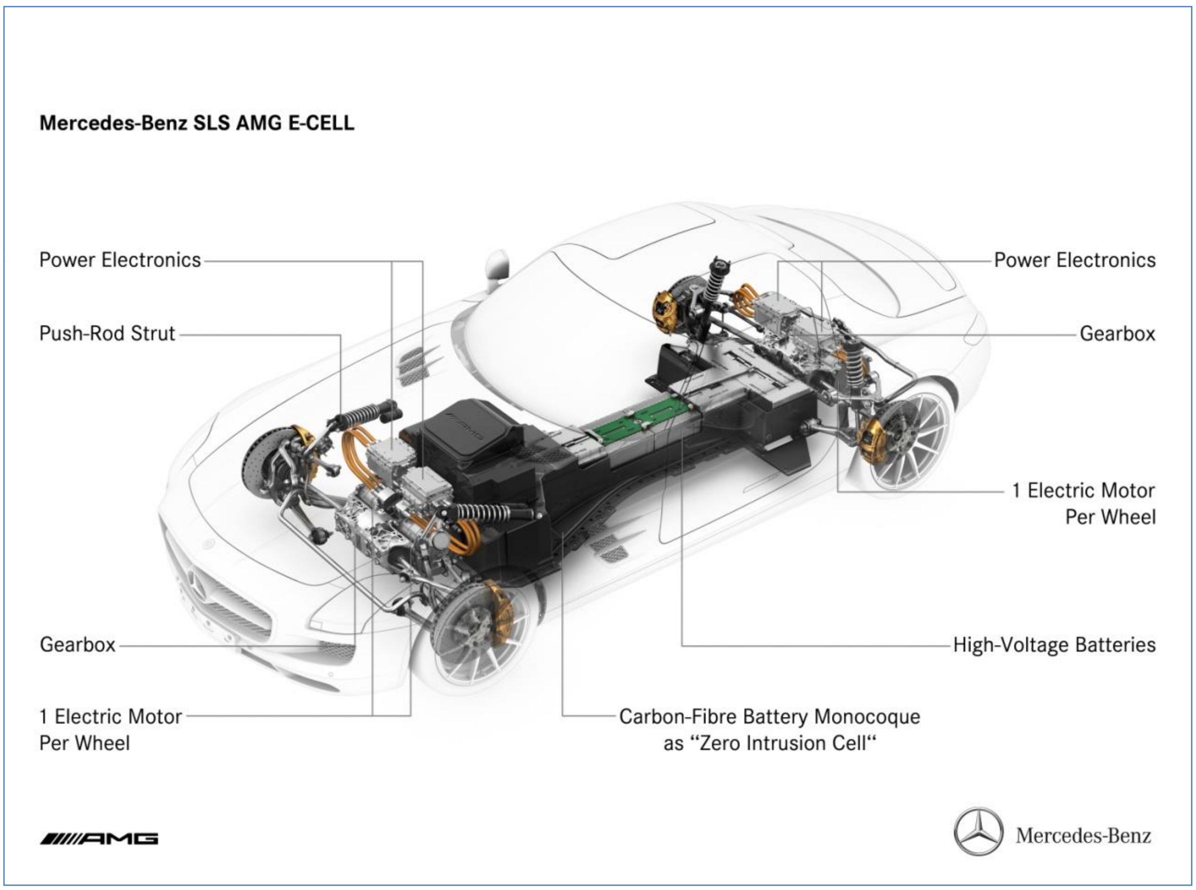


Figure 42: The inner workings of an SLS AMG E-Cell

(Adapted from [235])

Electric motors (Figure 43) are usually coupled with a gearless or one-gear transmission and as the power is derived from electricity it can be utilised fully from the start, providing very fast acceleration. An EV's propulsion is generated by its batteries, electric motors and motor controllers. The controller(s) take the electricity from the batteries and provides power to the motors. These controllers use potentiometers with variable resistors to determine how much power to deliver. EVs can utilise either DC or AC current. With a DC current, the controller delivers either full power if the accelerator is fully depressed, or zero power if it is lifted. If the pedal is only partially depressed, the controller 'cuts' the voltage continuously to create an "average voltage". With AC current, the controller produces 3-phase power by converting the DC current of the batteries with six transistor sets. One set is needed per phase to 'pulse the voltage', while another set per phase is required to reverse the polarity multiple times per second (Figure 44).

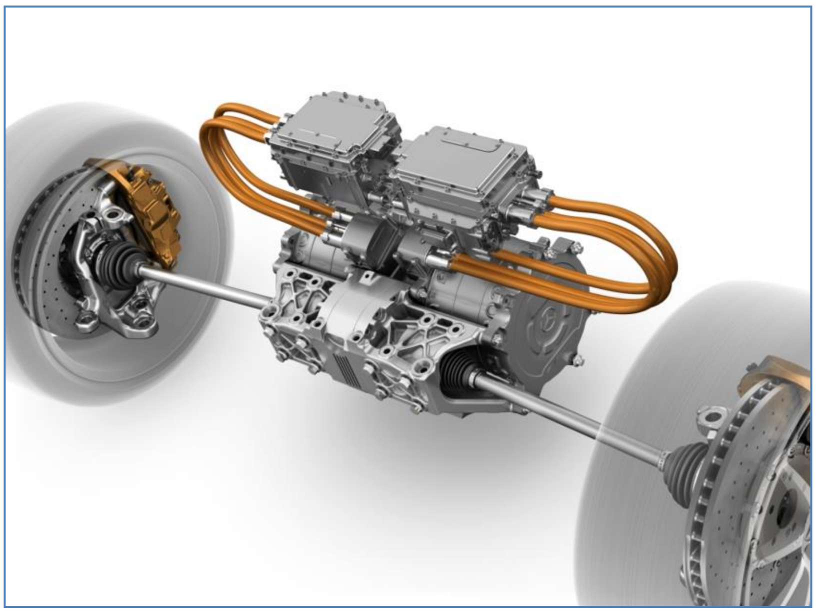


Figure 43: The Electric motors powering the SLS
(Adapted from [236])

Electricity is stored in the vehicle's batteries and used as needed, but the innovative design means that the batteries are not only charged once the car is "plugged-in", but also when braking. Some of the energy used when braking the car is recaptured and again stored in the batteries to be used later – this is known as "regenerative braking", or KERS (Kinetic Energy Recovery System) (Figure 44) [237].

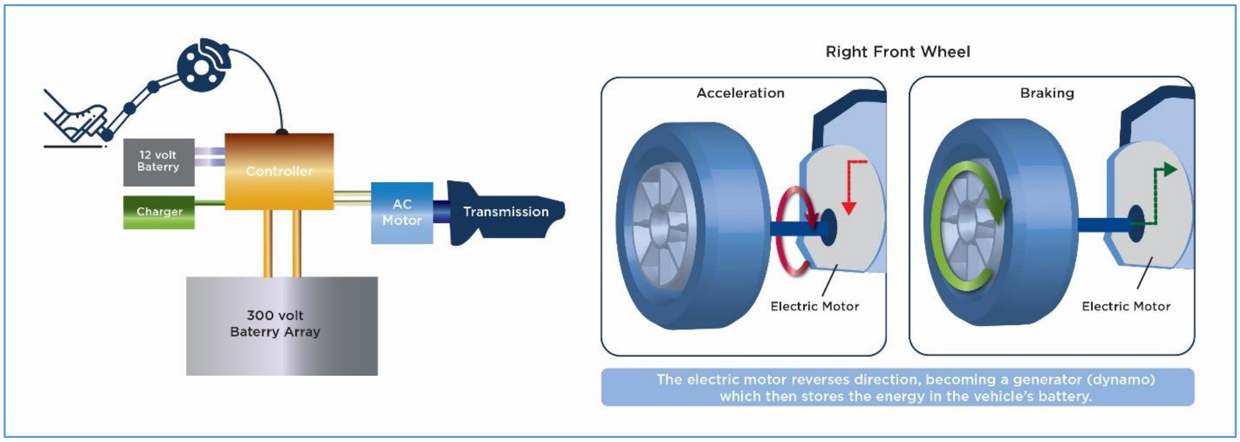


Figure 44: Hybrid and Kinetic Energy Recovery Systems
(Adapted from [238])

4.7.2 Sourcing and reverse logistics of components and equipment

HV component manufacturing is specialised and largely concentrated in only a handful of countries. Few, if any, HV components are manufactured locally in South Africa for example and the majority have to be imported. The import specifically of HV batteries is very strict, with stringent packaging and shipping regulations. The return or discarding of damaged or non-conforming High Voltage batteries and other components is also a critical topic, as possibilities to safely ship damaged HV batteries back to their import-suppliers or to safely discard them is often limited [239].

Importing technology from foreign suppliers can have several drawbacks, including creating a power imbalance between customer and supplier [216]. Buying equipment from international suppliers can be prohibitively expensive, though when a technology is new to a country, the local equipment manufacturers may not have the expertise to build the equipment. Maintenance and spare parts availability for the new technology is also a concern that needs to be looked at.

4.7.3 Safety and other legislation

Hybrid vehicles have batteries with significantly higher voltages than conventional vehicles, due to the need to drive in an electric mode i.e. without using a combustion engine. The German VDE (Verband der elektrotechnik elektronik informationstechnik e.V) specifies in VDE 0100 Part 410 that humans are endangered starting at 50V alternating current (AC) or 120V direct current (DC). The Economic Commission for Europe (ECE) stipulates in ECE Regulation 100 that maximum contact voltages in the automotive industry are 30V alternating current (AC) or 60V direct current (DC). It should be noted that it is not the Voltage alone that is dangerous, but rather the current. For the purposes of this dissertation, 'High Voltage' is referred to for ease of reference, as this is the commonly used terminology that most people are familiar with.

There are often initial safety concerns with the introduction of new technologies. While new technologies can have many benefits, they can also introduce new risks and introducing them can be a sensitive process [240]. A distinction must be drawn between conceptually and contextually new technologies. As many automotive manufacturing plants are subsidiaries of large global OEMs, one can assume that technologies that are being introduced on their production lines will mostly only be contextually new, rather than conceptually new. In other words, it would be a technology new to the specific environment, rather than a conceptually new technology, i.e. a newly invented or developed technology. The new technologies are typically invented or designed by centralised Research and Development (R&D) departments, before they are rolled out to the manufacturing plants. The risk profile should theoretically be known by the mother company, rather than be completely unknown as with a newly invented technology. That said, there could still be mitigating or aggravating local circumstances e.g. local labour conditions, local equipment and even local weather conditions that need to be accounted for. An analysis of these per project is therefore prudent.

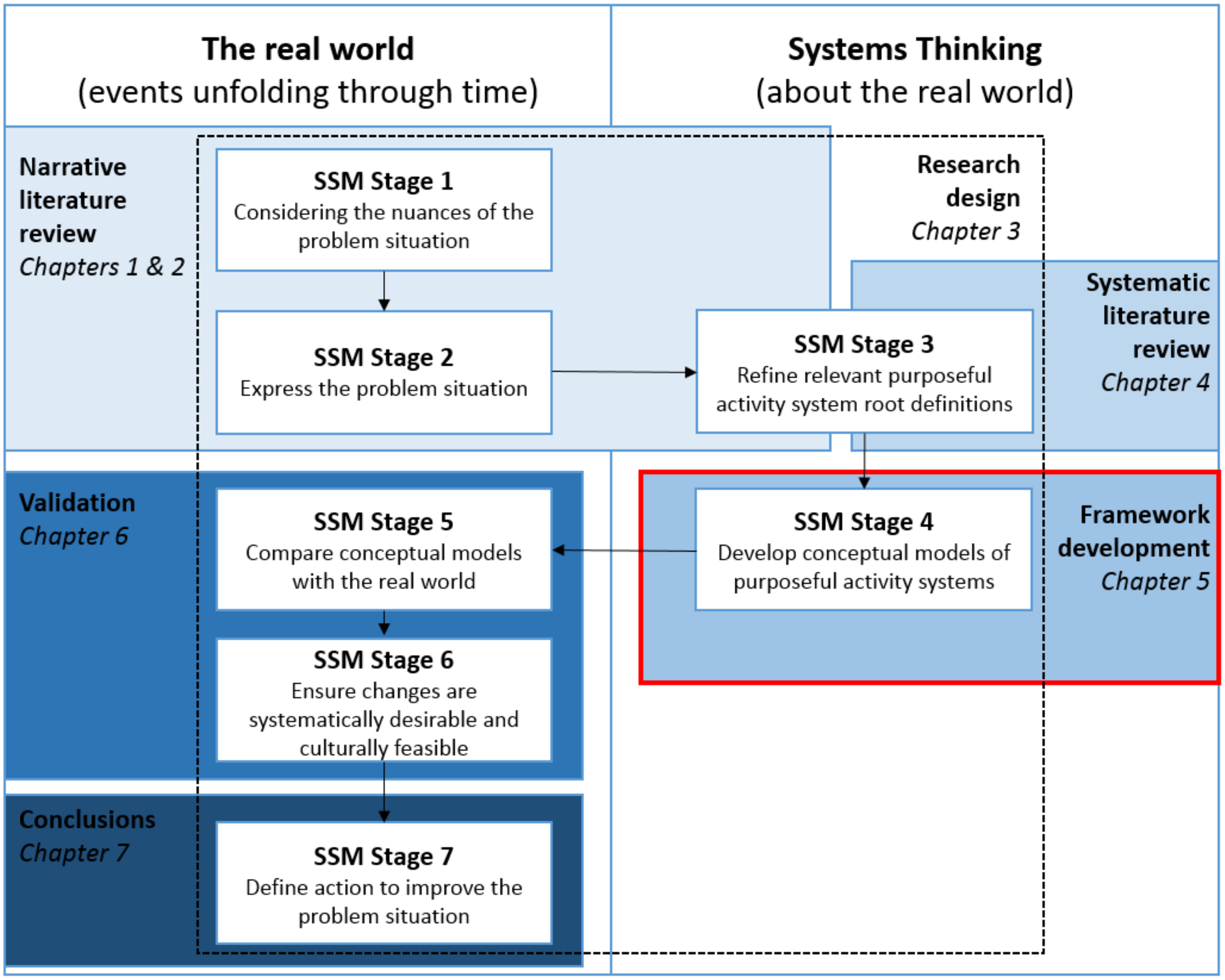
Legislation around the world also differs. South African legislation for example defines Machinery as an "article (particular object or item) or combination of articles assembled arranged or connected and which is used or intended to be used for converting any form of energy to performing work or which is used or intended to be used whether incidental thereto or not for developing receiving storing containing confining transforming transmitting transferring or controlled any form of energy" (Appendix C - Occupational Health and Safety Act of 1993). The South African "Electrical Machinery Regulations 1988" applies to "designers, manufacturers, installers, sellers, users, employers and suppliers who design manufacture install sell generate or use electrical machinery." Though it is 'only' a component and forms part of the vehicle, under the definition of the Occupational Health and Safety Act in South Africa, a High Voltage battery can be defined as "Machinery", which in turn means that the Electrical Machinery Regulations would be applicable to any OEM using HV batteries in the country [21]. There is however no legislation specifically aimed at HV technology and automotive OEMs in South Africa are not bound to e.g. the VDE or ECE regulations. This is potentially also the case in many other developing countries, where automotive OEMs are increasingly placing their manufacturing plants. The relevant legislation would need to be scrutinised for each implementation project, to ensure full compliance with local regulations.

Where there is no specific legislation, there is also likely to be no accredited safety training providers, which could be a hurdle for introduction in these countries. Companies that wish to introduce HV technology under these circumstances may need to use international trainers, but would be recommended to make provision for local training, as new employees entering the workforce will create a sustained demand.

4.7.4 Conclusion

The unique components in Hybrid vehicles are the reason why the production of these vehicles is so specialised and needs special focus. Suppliers, shipping routes and methods, as well as alternative packaging concepts must be addressed when introducing HV technology [215]. Special attention needs to be paid to safety training and legislative topics, to ensure the introduction of the technology does not endanger any staff or contractors and does not contravene any legislative or regulatory requirements. It is clear that the introduction of HV technology is not something that should be underestimated. The need for a robust framework as discussed in the Research Aim is undeniable.

5. CONCEPTUAL FRAMEWORK



5.1 Developing the Framework

While Change Management is very useful in a theoretical approach, the fact that in large multinational companies like automotive OEMs the decision-making team, the technology development team and the implementation team might all reside on different continents, effectively rules out certain steps from many models, or alters them significantly from the initial intent. Most Change Management theories or frameworks are abstract and do not give concrete, practical guidance that can be followed by Implementation Teams in these situations. From the perspective of automotive OEMs' manufacturing plants, what was missing in the literature was a hands-on practical and measurable framework for the implementation of technological change in their production lines. Manufacturing plants needed something that an Implementation Team could practically use to safely, effectively and efficiently introduce High Voltage technology to their production lines and manage or mitigate the associated rise in complexity. The research objective was to create this framework. The requirements that have to be considered to conceptualise this framework will now be discussed.

5.2 Research requirements

To conceptualise an expedient framework it is important to understand the requirements thereof. The research requirements for the framework are built around the Research Objectives listed in Chapter 2.3. Van Aken, et al. [241] categorised five different kinds of requirements: Functional requirements, User requirements, Design restrictions, Attention points and Boundary conditions. These are further explained in Table 11.

Table 11: Van Aken's Research Requirement types

Req. designation	**Requirement type**	**Requirement description**
F	Functional requirements	The core requirements and specifications of the framework, usually in the form of performance requirements or result demands. This essentially comprises what the framework is designed to do.
U	User requirements	Requirements from the viewpoint of the end-user. These explain the constraints and how the user will use the framework. As there is some overlap in terminology, this can be described as 'how' the framework will be used, rather than 'what' it is intended to do.
R	Design restrictions	Requirements that pertain to the preferred solution space, specifically limits and exclusions, as well as elements of the design.
A	Attention points	These requirements relate to the design of the framework, but are not strictly design restrictions. They need not necessarily be met if not practical, but are to be attended to if feasible.
B	Boundary conditions	Unconditional requirements that can't be altered and have to be met unreservedly e.g. legislation, codes of conduct and ethical matters.

Though the assignment of requirements to one of the five categories is potentially subjective, each identified requirement is necessary for the development of the framework. Regardless of whether a specific requirement is categorised as a Functional or a User requirement, it would still be duly considered and addressed. As each is given due consideration, the effects of the categorisation are limited. The categorisation serves primarily to stimulate thought around a specific viewpoint and to aid requirement definition. There may therefore be some overlap in requirements due to the categorisation.

In addition to those derived from the objectives, some research requirements have also been derived from the literature study of the areas of change management, complexity management, implementation theory and high voltage technology. The relevant section, whether research objective or learnings from literature, will be detailed in each of the applicable tables for ease of reference.

5.2.1 Functional requirements (F):

These are the core of specifying the framework's requirements and take the form of performance or output demands around which the framework should be designed. Practically that means, "what the framework is designed to do". These requirements are not mere desirables, but essential functions of the framework and all must be verified and validated to ensure the framework conceptually and practically meet the research requirements. It should be noted that some constructs describe these as 'User' requirements i.e. "what the user needs the framework to do". Under Van Aken's nomenclature 'User' requirements are based largely on the needs of the Project Leader or Implementation Team i.e. the end-users.

Table 12: Functional requirements

ID	Requirement	Motivation	Source & Reference
F1	The framework must be able to facilitate the introduction of HV technology into automotive manufacturing plants.	The efficacy of the framework must be provable within the context of automotive manufacturing facilities around the world.	Research Aim (2.2)
F2	The framework must specifically address Change Resistance in the context of HV implementation projects.	Change Resistance is one of the main reasons that projects fail and the risk associated to the introduction of HV technology is significant. Change Resistance in the case of a dangerous technology can easily derail a project and the management of this resistance must be addressed unequivocally in the Framework in order for the implementation to be successful.	Literature – Change Management (4.3)

ID	Requirement	Motivation	Source & Reference
F3	The framework must address HV safety and suggest ways of safeguarding staff and on-site contractors.	HV technology can be lethal or cause injuries. There is no specifically applicable automotive relevant HV legislation in many countries and automotive OEMs introducing this technology need practical instruction in safe usage within the intent of the legal frameworks where available and according to international best practice. The implementation must thus not only be lawful within the legislative framework of the given country, but where feasible should also encourage best practices that exceed legal requirements, especially in countries where the legal frameworks do not yet exist or are weak.	Literature – High Voltage (4.7.3)
F4	The framework must address required HV facilities and equipment.	As the technology is relatively new, there is likely a shortage or complete lack of competence in the field in many countries and equipment will likely need to be imported from the handful of leading countries. Power imbalance and long-term strategy should be considered in this regard.	Literature – High Voltage (4.7.2)

ID	Requirement	Motivation	Source & Reference
F5	The framework must address HV training requirements.	Training to reach and support the necessary level of operator competence may be limited in many countries and international trainers may need to be used for the initial stages. Care should be taken not to create a long-term dependency.	Literature – High Voltage (4.7.3)
F6	The framework must address HV production process and resource efficiency, offering complexity-mitigating approaches.	Relatively low production volumes of Hybrid or Electric Vehicles will likely disproportionately affect efficiency in manufacturing locations and the increase in production complexity should be mitigated if possible. Modularity, optimal assembly sequences and other approaches should be specifically considered.	Literature – Complexity Management (4.5.4.2)
F7	The framework must address HV component supply chains, their limitations and how product complexity can be mitigated.	The majority of HV components will likely have to be imported in many countries and this could strain the supply chain, as well as increase costs unless mitigated. Increases in components and their variants could be offset by concepts like modularity, 'Warenkorb', etc. These need to be critically examined for feasibility.	Literature – High Voltage (4.7.2)

ID	Requirement	Motivation	Source & Reference
F8	The framework must define ways how to measure efficiency and its impact on production performance indicators, when HV technology is introduced on the line.	The impacts to applicable Key Performance Indicators (e.g. Time, Cost and Quality) must be measurable and evaluated in the framework as the implementation does not occur in a vacuum, but rather in existing production lines.	Research Aim (2.2)
F9	The framework must provide/suggest tools that can be used to identify all areas affected by the HV technology introduction, as this knowledge may not necessarily pre-exist in the country of application, or may be substantially different from previous implementations.	The user(s) must be given suggested tools that will support reaching the objective of implementing the technology. This does not need to be exhaustive or overly prescriptive, but sufficient to achieve the desired outcome. A tool is needed to identify root definitions to determine all affected areas or aspects of the introduction i.e. a 'deep-dive' into the implementation.	Research Design - (3.3.2)
F10	The framework must provide/suggest tools that can evaluate the criticality of the various factors or activities necessary for HV introduction and assess their influence.	A tool to assess the criticality of various topics is vital, as the Implementation Team must be able to focus its limited resources on the most critical topics. For this, it is first necessary to identify the issues and then assess them for risk and impact.	Research Design - (3.3.2)

ID	Requirement	Motivation	Source & Reference
F11	The framework must provide for iterative maturity loops of trial vehicles builds.	Iterative improvement loops are a norm in automotive manufacturing. OEMs typically go through a number of trials before a product is approved for customer use. These can include digital trials, ramp-up factory trials and on-line trials in the designated manufacturing plants. Each iteration should serve as a maturity loop and continuously improve the next iteration.	Implementation Theory – (4.6)
F12	The framework should leverage the differences of rates at which people adopt new technologies.	The framework must take cognisance of differences in the rate at which people accept technology and utilise these different diffusion rates to support the implementation.	Literature – Change Management (4.4.1)
F13	Differences in organisational change capabilities should be acknowledged and the levers be used appropriately to support HV implementation.	Organisational change capability levers offer significant potential for implementation projects and should be leveraged appropriately.	Literature – Change Management (4.4.3)
F14	The framework must become part of standard procedure, so that it can be used repeatedly for future product introductions.	The framework is not intended to be used only for one implementation, or by only one OEM, so it must allow for repeated use e.g. introduction of Hybrid Vehicles, followed by the introduction of Electric Vehicles or repeated by more OEMs.	Research Aim (2.2)

5.2.2 User requirements (U):

These are requirements from the viewpoint of the end-user of the framework, including requirements of how the framework will be used. The intended users of the framework developed in this research are automotive OEMs. Different parts of the organisation can use different parts of the framework, but it is focussed primarily on application in manufacturing plants. The primary users in the plants will likely be the Project Leader and Implementation Team. The requirements in Table 13 are conceptual and do not provide specific steps or stages for the design of the framework, but the framework must be verified against all of these to ensure that it fulfils the requirements of the research.

Table 13: User requirements

ID	Requirement	Motivation	Source & Reference
U1	The framework should consider the special context of automotive manufacturing plants, specifically regarding OEM constraints e.g. a plant's ability to influence product design or construction decisions.	Most manufacturing plants operate to some extent independently from typically centralised R&D divisions e.g. all automotive OEMs in South Africa are foreign-owned and as such are limited in the extent of decisions that can be taken locally. Manufacturing plants outside their home countries are often awarded models and instructed what to build, with little to no input into vehicle design or which components to use i.e. contract manufacturing.	Literature – Complexity Management (4.5.3.2)

ID	Requirement	Motivation	Source & Reference
U2	The framework must provide a clear step-by-step approach or roadmap that an Implementation Team can use to introduce a new technology.	Existing change management frameworks are too abstract for the rapid implementation projects often needed by automotive manufacturing plants.	Research Aim (2.2)
U3	The framework must clarify for the users the context, pre-requisites and timing of each step, as well as detail the main resources and activities.	It is necessary for the Project Leader and Implementation Team to understand the milieu within which they are operating, in order to be effective and ensure all required aspects are considered. This is to avoid one of the most common reasons that projects fail i.e. miscommunication.	Research Aim (2.2)
U4	The framework should suggest roles and responsibilities for all steps and activities.	Clear roles and responsibilities are necessary to implement technology effectively and to mitigate increases in organisational complexity. This also reduces the likelihood of miscommunication failures.	Literature – Complexity Management (4.5.5.2)

ID	Requirement	Motivation	Source & Reference
U5	The framework should be robust enough to be used by manufacturing plants in developing countries, physically far removed from the OEMs home country and the responsible R&D centre.	Companies (or division of companies) that develop technologies often hand them off to user organisations before they are fully ready for implementation. The team that invented or designed the technology often does not even reside on the same continent as the team that needs to implement it. The framework should function also in these scenarios.	Research Aim (2.2)
U6	The use of the framework should allow sufficient flexibility to apply discretion and effectively leverage prior knowledge.	The framework should not be so rigid as to reduce applicability. Customisation should be catered for, as should use of prior knowledge.	Research Aim (2.2)
U7	The framework should be user-friendly.	The framework should be practical and usable within the reasonable time and capacity constraints of automotive OEMs.	Literature – Complexity Management (4.5.5.1)

5.2.3 Design restrictions (R):

These requirements pertain to the space within which the framework will operate and places limits and exclusions on applicability.

Table 14: Design restrictions

ID	Requirement	Motivation	Source & Reference
R1	The framework must be presented practically as a linear, step-by-step construct that an Implementation Team can follow to introduce HV technological change.	Change management frameworks/models are predominantly conceptual in nature and do not give concrete instructions that an organisation can practically follow for effective technology implementations.	Research Aim (2.2)
R2	The framework should facilitate implementation in existing automotive production lines.	Most OEMs have running production lines and the majority of implementations would need to be made in existing facilities, rather than greenfield sites. Greenfields are not the focus of this study, though application is not expressly excluded.	Research Aim (2.2)
R3	The framework must not be too prescriptive and should allow user flexibility in the selection of tools.	No framework can offer all solutions for all situations or implementations. If the approach is too broad, the framework risks being clumsy and not practically useful. This framework is specific to high voltage implementation in an automotive context and needs only provide sufficient tools to facilitate such an implementation.	Research Aim (2.2)

ID	Requirement	Motivation	Source & Reference
R4	The framework is intended for automotive high voltage technology, though it could also be used for other implementations.	The focus of the framework is to offer a way to introduce HV technology to existing automotive production lines. Use in other industries is possible, though not the intention or focus. These uses need to be verified before any application.	Research Aim (2.2)
R5	The framework itself is not a legislative document and can't prescribe specific legal requirements, as these will differ depending on the country of application.	Though the framework considers legislative aspects (e.g. high voltage safety), it is not legally binding and specialist input should still be obtained for these matters for all implementation projects.	Literature – High Voltage (4.7.3)

5.2.4 Attention points (A):

These requirements are relevant to the design and deemed as desirable, but not essential to be met. They are not design restrictions that limit the framework, but are there to be noted and considered.

Table 15: Attention points

ID	Requirement	Motivation	Source & Reference
A1	The framework may contain discretionary items due to inherent factors pertaining to the implementation.	While the framework is intended for automotive manufacturing plants to use, there is still significant variability between the different organisations (e.g. mother company nationality, size, location, etc.) that can potentially play a role. The prevalent organisation culture also should be considered in any implementation project.	Research Aim (2.2) Literature – Change Management (4.4.3)
A2	The framework should be seen in the context of an evolving field of knowledge.	There were no practical frameworks for this type of HV implementation. The purpose of this study was not to provide a definitive best practice, but to offer a first practical, useable foundation that can be built on by academia and industry and allows for the extension of the framework as new and better practices become known.	Research Aim (2.2)

ID	Requirement	Motivation	Source & Reference
A3	The framework should be designed to achieve its objective of implementing high voltage technology in an automotive context.	While the framework could be used for other purposes, it is not specifically intended or designed to cater to anything other than the stated purpose.	Research Aim (2.2)

5.2.5 Boundary conditions (B):

These requirements must be met unconditionally and must be seen as rules that cannot be bent or broken (e.g. legislative requirements, ethical matters, etc.)

Table 16: Boundary conditions

ID	Requirement	Motivation	Source & Reference
B1	The framework must not break any laws or legal regulations.	The author cannot control or restrict the use of the framework once conceptualised, so it is important to note that it implies and expects reasonable boundaries of application.	Ethical implications (3.4)
B2	The framework must not be used to put any individuals at undue risk.	When dealing with high voltage, safety is paramount and the use of a framework should not supplant the primary responsibility of organisations towards the health and safety of their employees.	Ethical implications (3.4)

5.3 Developing the Implementation Framework for Automotive Technology

Having reviewed the literature of change uptake concepts, psychological change experience models, organisational change capability models and linear change methodologies, one can evaluate the strengths and weaknesses of the different constructs. The linear models lack depth with regard to aspects of successful implementation. The non-linear models provide insight into these success factors, but lack a practical step-by-step approach. To create a holistic meta-theoretical construct that addresses all the research requirements, the strengths of all these change management categories are required.

To create a conceptual framework the strengths of these different types of Change Management models and methodologies had to be combined with the applicable aspects of Complexity Management, specifically those related to the mitigation of product, process and organisational complexity. A thorough understanding of different types of introduction and their application also had to be combined with a detailed understanding of HV technology, if the framework was to be effective at introducing this type of technology. These four bodies of knowledge were routed through the five different requirement types identified in 5.2 to ensure that all were met. Lastly the developed framework had to be formatted into a linear style to provide the practical step-by-step approach required by the Research Aim. Figure 45 graphically represents this approach as followed by the author.

A 5-step linear approach forms the foundation of the IFAT. The linear approach is fundamental to satisfying the Research Aim. Non-linear constructs are arguably more complex and likely more difficult to practically use in the rapid implementation projects that automotive manufacturing companies face. An analogy can be drawn between the linear change methodology proposed in the conceptual framework and an automotive production line, where a vehicle moves from one station to the next as it is being assembled (Figure 46). The 5 linear steps of the IFAT that will be detailed in the following section are “Vision”, “Method”, “Pilot”, “Implementation” and “Improve”.

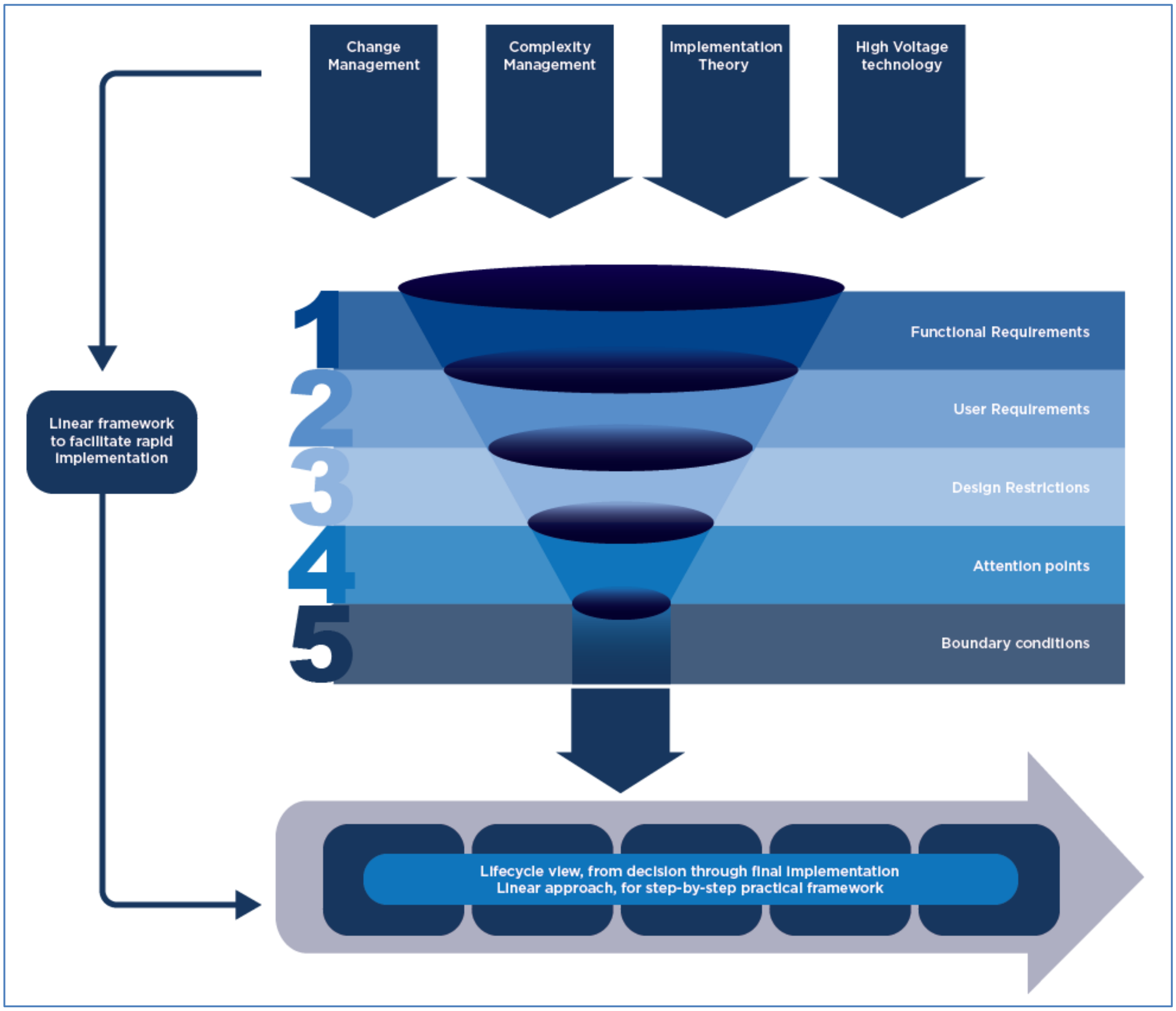


Figure 45: Creating the IFAT

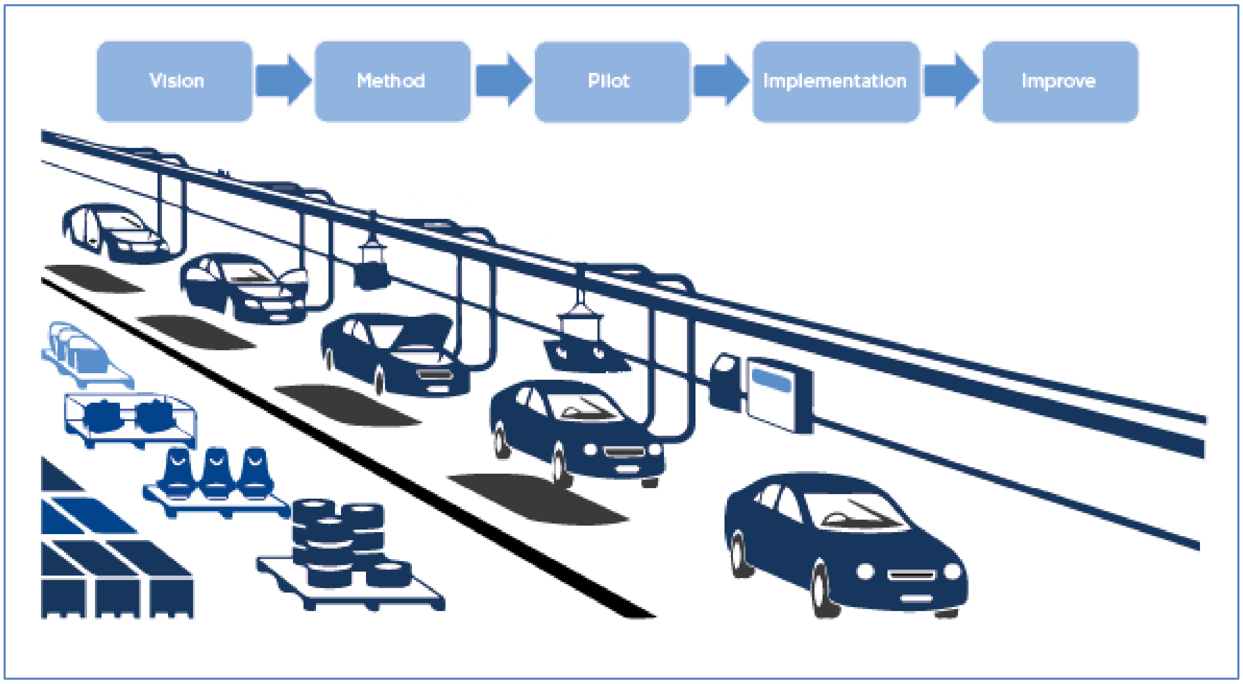


Figure 46: An assembly line analogy for a linear change management (Adapted from [242])

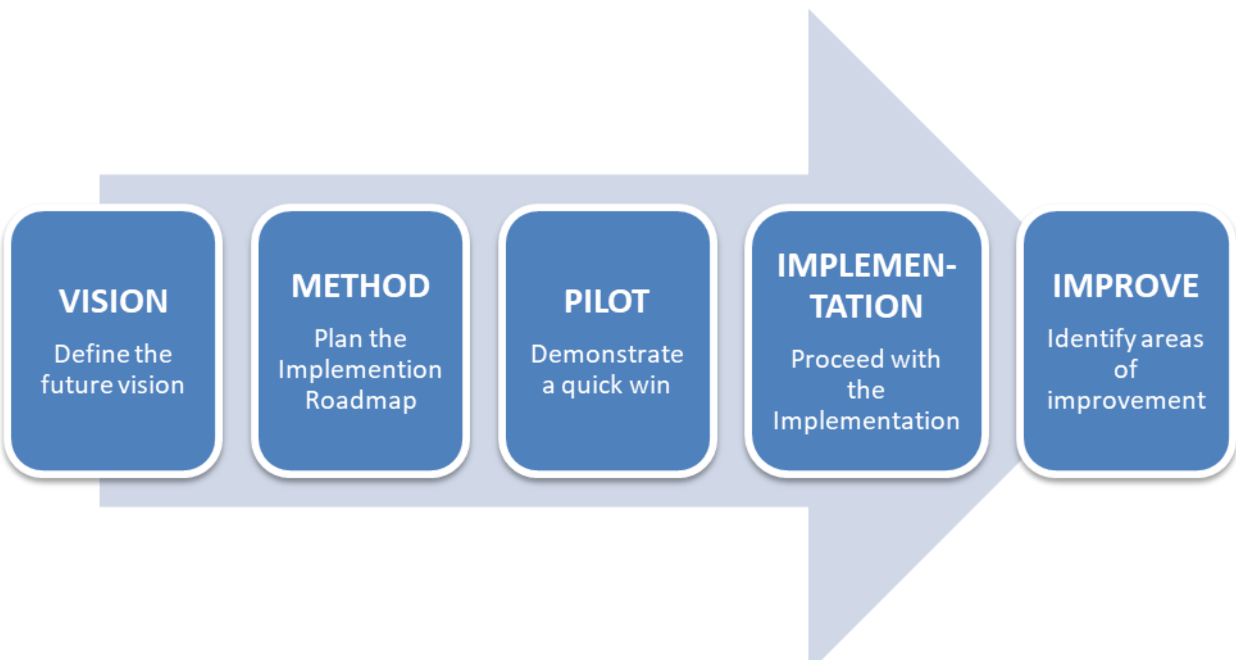


Figure 47: The five foundational linear steps of the IFAT

The 5 Steps of the IFAT will now be further detailed. After each section the detail of the discussions will be presented in a summative graph as per the template of Figure 48. Each section will provide further information on the Step's:

- **Purpose, context and timing**: Describing what the Step is trying to achieve, in which environment this is being done and within which timeframe.
- **Main resources and activities**: Detailing the main resources, whether people or other, as well as the actions that need to be completed in the Step.
- **High Voltage focus points**: Providing clarity on the HV aspects largely applicable to all implementation projects of this technology, namely safety and training, facilities and equipment, processes and resource efficiency, as well as components and supply chains.
- **Output requirements**: Specifying the required output that the Step should deliver.

Each sub-process is given a unique reference number in the summative graph, which is used later when verifying and validating the framework.

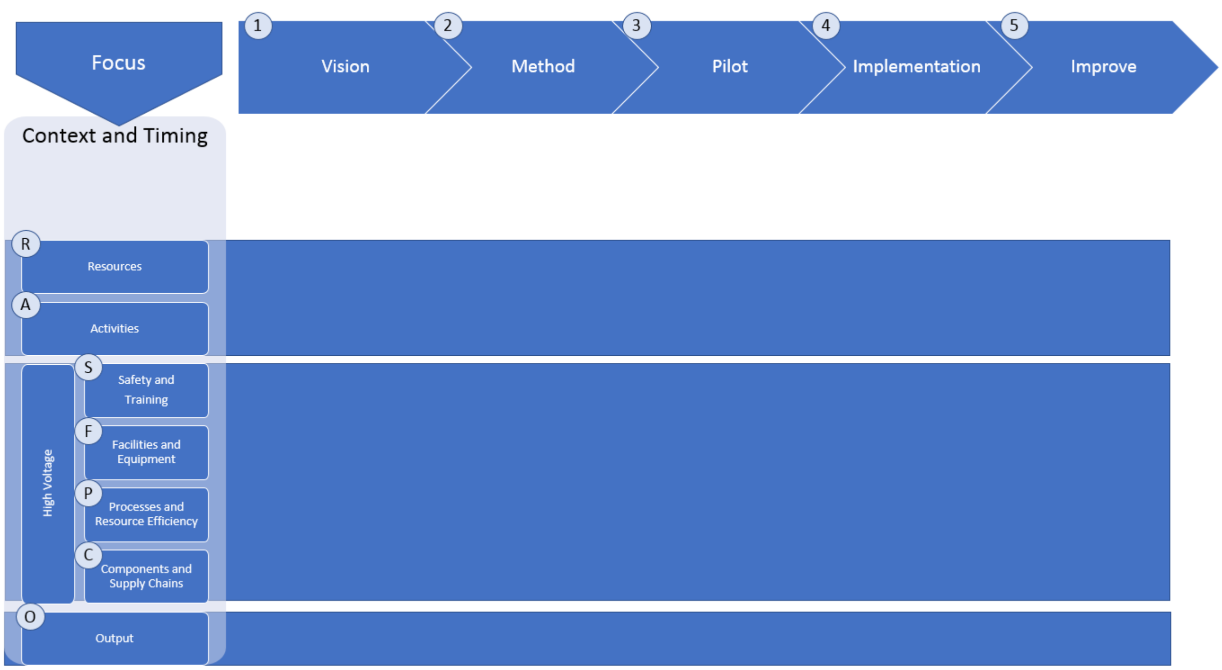


Figure 48: Summary template for the IFAT Steps

5.4 IFAT Step 1: Vision

Purpose, Context and Timing: The first step of the Implementation Framework for Automotive Technology is the 'Vision'. The key objective in this step is to define the Vision of the future state. This must be completed before the Method Step can be started. It is important that the Implementation Team is clear on what the goal and strategy of the Project is, if they are to successfully implement it. It is known that the size of the organisation, the resources available to it and the support of its management has an impact on the adoption of new technologies [16]. It is also known that once an adoption decision has been made, the attitude of management plays a large role in the implementation success. Generally, the higher the level of the managers that define the problem or the need for implementation, the greater the probability that the organisation will implement it. These leaders operate at a higher SST stratum than the Implementation Team and should support with providing clear strategic intent. A summary of Step 1 is shown in Figure 49.

Main resources and activities: The targeted demographic in this Step is the Innovators and the key change lever is the Sponsors. While "Opinion Leaders" can sway general sentiment, it is known that strong Sponsorship creates upfront buy-in and significantly reduces resistance to the change. Strong sponsors must be obtained in the Vision step and be kept on board for the duration of the project. In the case of automotive manufacturing plants, where the decision-making team is frequently international and the Implementation Team is local, it is best that the sponsors be a coalition of local and international leaders. In this Step, the Implementation Team and the Sponsors should clearly show the Vision of the future, clarify the reason for implementation and highlight the benefits thereof. They should also ensure this is done in line with the prevalent organisational culture and within the acceptable norms for that location, to reduce initial resistance. The targeted group during this Step is the Innovators, as they typically move through the change experience curve faster than other groups and have disproportionately short negative periods. Care must still be taken to allow them the necessary time to process the new information though, to ensure that in their eagerness for the new technology they do not place the broader project at risk. The negative aspects and potential dangers of the new technology must be highlighted to the group to ensure this.

High Voltage focus: A critical focus point during this Step must be on establishing a strategic concept with regard to High Voltage safety. It is necessary that at the Vision stage there is a clear understanding and agreement how the risk posed by HV technology will be addressed throughout the project. The risk to employees and contractors is potentially lethal and any implementation project will be met with substantial change resistance if the safety of the workers is not addressed upfront. The project is unlikely to get off the ground if the desire to implement this dangerous technology is communicated to the broader organisation without a clear understanding of how HV safety will be assured, specifically in countries without applicable legislation. The Vision does not have to be detailed to the extent where facilities and equipment, processes and resource efficiency or components and supply chains are fully planned, but each needs to be understood to the level where they will not impact the broader strategy and timeline.

Output: The main output of this Step is a clear Vision, with Sponsor involvement. Several metrics exist to measure Sponsor involvement, but defining 'hard' metrics for the clarity of a Vision is not always practical in rapid implementation projects. A qualitative approach may be used for this step where deemed appropriate. It is of critical importance that the Sponsors, typically higher-level management, effectively convey the Vision and make known their support of the Implementation and the High Voltage safety concept. An official Project Charter or similar type document would serve this purpose, depending on the time available. Retrospective reviews of the Vision step, including the role and commitment of the Sponsors, should be encouraged to facilitate continuous improvement for future projects.

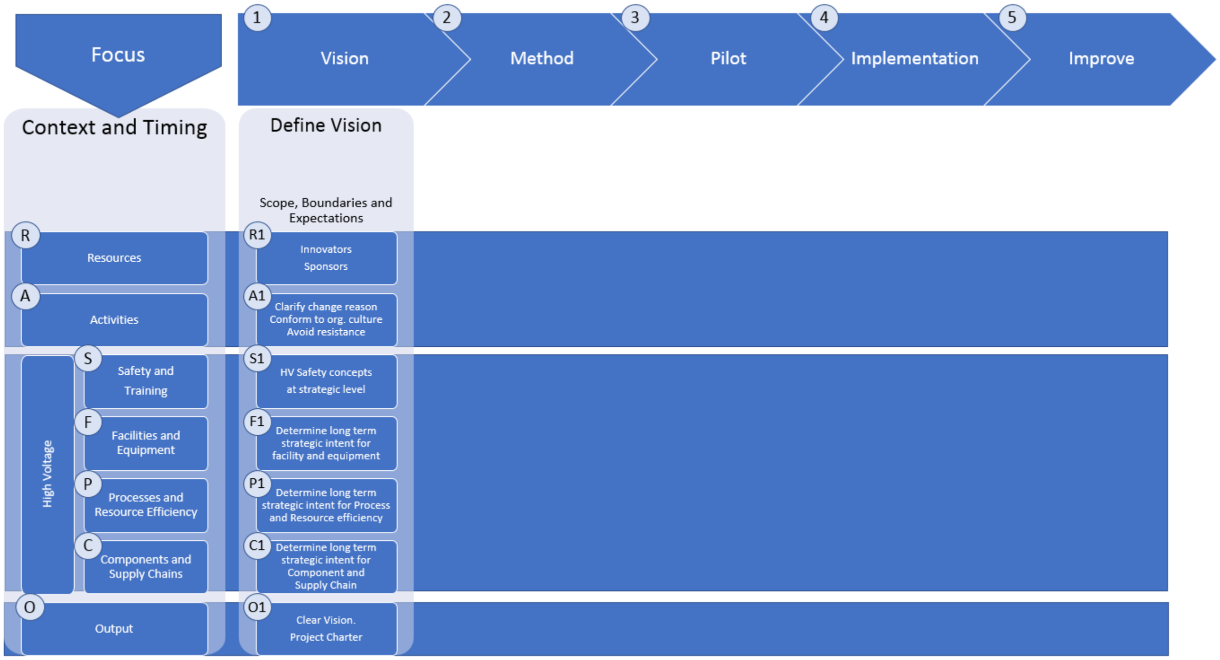


Figure 49: Summary of the IFAT at Step 1

5.5 IFAT Step 2: Method

Purpose, Context and Timing: The second step of the Implementation Framework for Automotive Technology is the 'Method'. The key objective in this step is to plan the change's Implementation Roadmap. This step of the IFAT must be completed between the 'Vision' step and the 'Pilot'. Once the Vision is clearly communicated, the Implementation Roadmap must be planned. It must detail all the activities necessary prior to and through the actual implementation of the new technology as well as detail who should perform these functions. While there are generic activities that all implementations would share, an individual Roadmap per project is required. Though existing institutional and continuous improvement knowledge should be leveraged, care should be taken to not purely rely on existing knowledge or checklists, as many of these may need to be adapted to cater for the nuances of HV technology (Appendix E - Standard existing checklists). It is also in this Step that mitigation for increases in product, process and organisational complexity should be considered. A summary of Step 2 can be seen in Figure 50.

Main resources and activities: The targeted group of this Step is the Early Adopters and the key change lever is 'Coaching'. By engaging the Early Adopters in this process, the Project Leader and Implementation Team can get multi-disciplinary inputs, while concurrently stimulating the Early Adopters' interest in the project through early involvement. Early Adopters are generally slightly more pragmatic than Innovators, yet still positive enough to not hamper the project with significant change resistance. Coaching of affected managers is also important at this stage. While they do not necessarily require detailed training on the use of the technology, they should be made to feel included in the process, as they are the ones that will disseminate the technology to the largest group of stakeholders. These managers must be fully briefed on the reason for the change and the benefits thereof, as well as sensitised to the risks and potential implementation barriers. This is particularly true when the implementation is safety relevant and can put employees at risk, as is true for all HV implementation projects.

A CATWOE analysis (Figure 51) is very useful to determine all root definitions necessary for a comprehensive Change Implementation Roadmap. Depending on the project, the Project Leader may decide to do a CATWOE or similar analysis (e.g. TWOCAGES) only with the Implementation Team, or may decide to do a series of interviews with specialists from each of the affected areas. The CATWOE should not be done unilaterally by the Project Leader, as the purpose is to find all the affected root elements and this is best found through a varied approach. Results from previous projects may be used as a base, but care should be taken to look for new or altered root definitions, as each project is unique. All identified elements and risks to the implementation need to be thoroughly reviewed by the Implementation Team once the CATWOE analysis is completed.

The steps necessary to manage these risks will be the basis of the Change Implementation Roadmap. The process can vary from team to team and project to project, but it is essential that all root definitions be reviewed and preferably rated with regard to the project's readiness and the impact of the element if not in place before units are built. Questionnaires or Focus Groups with representatives from the affected areas may be used to evaluate the elements. A Risk Assessment Template and a Risk:Impact Matrix was developed for the IFAT (Figure 52), with each root definition recommended to be rated on a scale of 1 to 5. The lower the readiness or the higher the impact, the more severe the rating and required next steps. All red and yellow-rated definitions need specific counter-measured in the Roadmap in order for the project to be successful. This tool is suggested, but other fitting evaluation methods may be used for this purpose.

High Voltage focus: Several significant HV related factors would be relevant for any manufacturing plants introducing this technology and should therefore be included in the risk assessment process regardless whether they were found in the CATWOE analysis of that specific project or not. If the elements were not found however, the Project Leader should consider re-doing the exercise as critical topics were likely overlooked. It is important that each of these are addressed in the Method step and specifically planned for. Specific areas of focus should be safety and training, facilities and equipment, processes and resource efficiency, as well as components and supply chain.

- **Safety and Training**: Whereas in the Vision Step a general understanding of how the manufacturing plant will deal with the HV technology was conveyed to the workers, in the Method step the implementation needs to be planned in precise detail. With the technology being new to that particular manufacturing plant, one can assume that the workers are not trained in HV safety. If the plant is in a region where the technology is already prevalent, then this training should be relatively easy to arrange. It should be noted that in many Developed Nations there may be specific HV legislation that training should comply with. Should the manufacturing plant be in a foreign location and/or somewhere where the technology is not readily available, then the training becomes more difficult to arrange and international facilitators may need to be used. Care should be taken in this case to not create a dependency, but rather to upskill local trainers as soon as possible. Training should be completed before any units are built and where feasible should not merely conform to locally applicable legislation, but also strive to replicate existing best practice policies.
- **Facilities and equipment**: If the technology is new to a country, facilities or equipment may also have to be imported, as it is likely that companies in the country would not have the necessary expertise to fabricate these. Care should again be taken to avoid power imbalances and international dependency where possible, though manufacturing plants may not be able to avoid this entirely, specifically in countries where they have limited options. Timelines should

be closely examined, endeavouring to achieve series-conditions as early as possible, to facilitate effective maturity loops in the following Steps.

- **Processes and resource efficiency**: It is likely that a first introduction of HV technology will be on limited units, so the most resource-efficient introduction might not necessarily be to include the full work-content on the existing production lines. It may be more efficient to follow a modular approach where feasible. These calculations and decisions should be taken in the Method step, prior to actual testing or implementation. Concepts such as modularity of suppliers, vertical integration, 'Warenkorb' and other complexity mitigating approaches need to be critically considered and planned in this step.
- **Components and supply chains**: For any new introduction, it is highly probable that new supply chains will need to be created, likely with new suppliers. The levels of Vertical Integration and Localisation should be optimised within the context of the manufacturing plant's OEM constraints. Depending on the country of implementation, components may need to be imported from international suppliers. Care should be taken to understand the logistical requirements, specifically regarding the HV battery, as these have very specific regulations in many areas. HV batteries e.g. are forbidden on many commercial airlines and therefore have to travel by land or sea, limiting flexibility and short-term chances to react to stock or order fluctuations. Reverse logistics faces similar constraints, as the ability to return or discard damaged batteries may be limited in many countries.

Output: The main output of this Step is a comprehensive Change Implementation Roadmap. The Roadmap can take many forms, though it typically contains (or is) a Gantt chart. The Project Leader and Implementation Team would use this Roadmap to steer the project, detailing all the tasks and activities necessary prior to and during the next Steps. At the conclusion of this step, all role-players and stakeholders must be clear and what needs to be done, by when it needs to be done and critically, who needs to do it. It is important therefore that the Change Implementation Roadmap created must contain not only the functions and timing, but also the responsible area, or preferably the responsible person. Miscommunication and misunderstanding between project members has been proven to be one of the main contributors to projects failing, so it is important for the Implementation Team to establish clear roles and responsibilities already in the Method step, before any vehicles are built. Allocating responsibilities to the Roadmap enables the Project Leader and Implementation Team to hold the parties accountable and it makes regular monitoring or tracking of the project more effective, as they know exactly who to ask for what detail at what time. It also allows all role-players to know exactly what they are responsible for and by when, giving them the opportunity to raise time or capacity concerns early enough to not jeopardise the project in a later phase. The Change Implementation Roadmap cannot be finalised before all responsible parties have committed to it and if escalation is required, e.g. due to a lack of capacity, then it should be done at this stage, rather than later in the project.

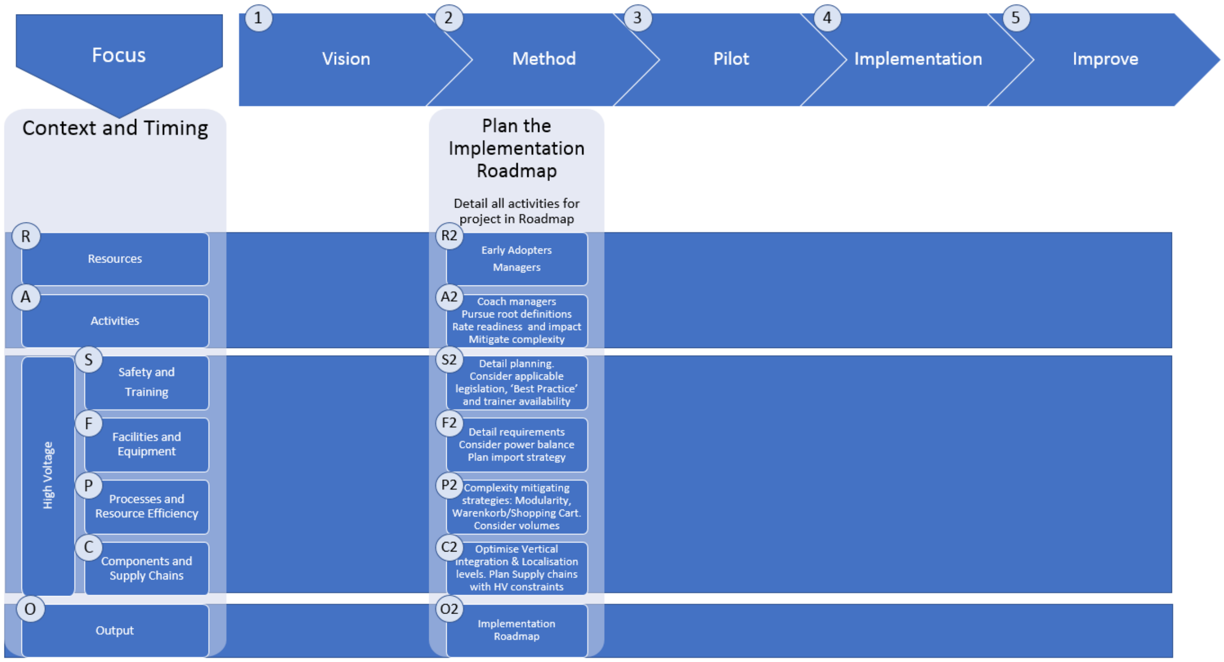


Figure 50: Summary of the IFAT at Step 2

Figure 51: CATWOE Analysis concept

Implementation Readiness Assessment

For each of the below 'Root definition elements' as defined in the CATWOE Analysis, please rate your understanding of the production plant's readiness for the technology's introduction, as well as the impact the new technology has on the factory if/when introduced.

Readiness

1 Completely unprepared, even for offline builds
2 Prepared for offline builds
3 Prepared for small-batch on-line builds with additional support
4 Prepared for large-batch on-line builds with additional support
5 Completely prepared for on-line builds as peak volume

Impact

1 No impact even if introduced at peak volume
2 Minimal impact if introduced in small volume
3 Significant impact if introduced in large volume
4 Significant impact if introduced even in small volume
5 Plant-disruptive impact, even if single unit built

Nr	Root defintion	Readiness	Impact
1	tbd - from CATWOE analysis		
2	tbd		
3	tbd		
4	tbd		
5	tbd		
6	tbd		
7	tbd		
8	tbd		
9	tbd		
10	tbd		
11	tbd		
12	tbd		
13	tbd		
14	tbd		
15	tbd		
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21	tbd		
22	tbd		
23	tbd		
24	tbd		
25	tbd		
26	tbd		
27	tbd		
28	tbd		

IMPACT						
	5	Low	Medium	High	High	High
	4	Low	Medium	High	High	High
	3	Low	Medium	Medium	High	High
	2	Low	Medium	Medium	Medium	Medium
	1	Low	Low	Low	Low	Low
		5	4	3	2	1
	READINESS					

Figure 52: The Risk Assessment template and Impact:Readiness matrix

5.6 IFAT Step 3: Pilot

Purpose, Context and Timing: The third step of the Implementation Framework for Automotive Technology is the ‘Pilot’. The key objective in this step is to demonstrate a quick win, while also testing implementation readiness and maturing the Roadmap. This Step can only be taken once the actions from the Change Implementation Roadmap are completed to the degree where a pilot introduction is possible. The ‘Pilot’ step should be taken before the full ‘Implementation’, as it both tests implementation readiness and support with ‘crossing the chasm’ between the Early Adopters and Early Majority. Typically the ‘Pilot’ step would take the form of an introduction in an isolated sub-system, or predominantly in the case of automotive production, this would be the production of a batch of test vehicles. A summary of Step 3 is shown in Figure 53.

Main resources and activities: The targeted group of this Step is the Early Majority and the key change lever is Communication. Communication, specifically regarding safety factors, is critical at this stage, as the organisation is likely not yet completely ready for the full implementation. Some measures, protocols or procedures that will ensure safety in series conditions might not yet be in place and the Pilot phase could carry a higher risk than the actual implementation. It is important that the Implementation Team ensure the risks are fully understood and communicated, as an accident in this phase can severely hamper or even halt any further implementation. The Pilot does not have to be fully representative of reality or series conditions, but it serves as a method of confirming the readiness for the further implementation. An Engineering Trial, or a similar batch of test units, can be built manually, not necessarily on the existing production lines, as the focus on this step is not to prove the series conditions or even necessarily series readiness, but rather to demonstrate the technology and its applicability. Once this Early Majority sees that the implementation is not only theoretically possible, but also practically demonstrable, they can be brought on board – a major step in the diffusion of the technology. The Implementation Team and the Sponsors must highlight the ‘quick win’ that is achieved in the Pilot phase, while also keeping the broader organisation focussed on what actions are still necessary for the full implementation.

High Voltage focus: Qualification of the workers in a safe and effective Trail build is the main focus of this Step. This tests and reinforces the safety and training aspects of HV technology, while also ensuring operators are thoroughly trained in the new assembly processes and components. This would likely be the first time that any of the general workers would be exposed to High Voltage technology, so emphasis must be placed on safety and on learning the new production processes that will be required when the vehicle is in the series production. The Step also serves as an early testing opportunity of new facilities and equipment, as well as the new supply chains. The Pilot does not have to be 100% in series processes or equipment, but the focus should be to mature the planning and Roadmap as much as possible before the full Implementation.

Output: The main output of this Step is an effective trial build. The 'quick win' is what serves to convince the Early Majority and to solidify the 'Strategic Intent'. The Pilot must be evaluated by the Implementation Team for its effectiveness (not necessarily efficiency) once complete. The review should specifically focus on which aspects are not yet ready for the full implementation and be compared with the Roadmap. If some items are not yet accurately reflected in the Implementation Roadmap, it must be updated accordingly with any 'Lessons Learnt' from the Pilot.

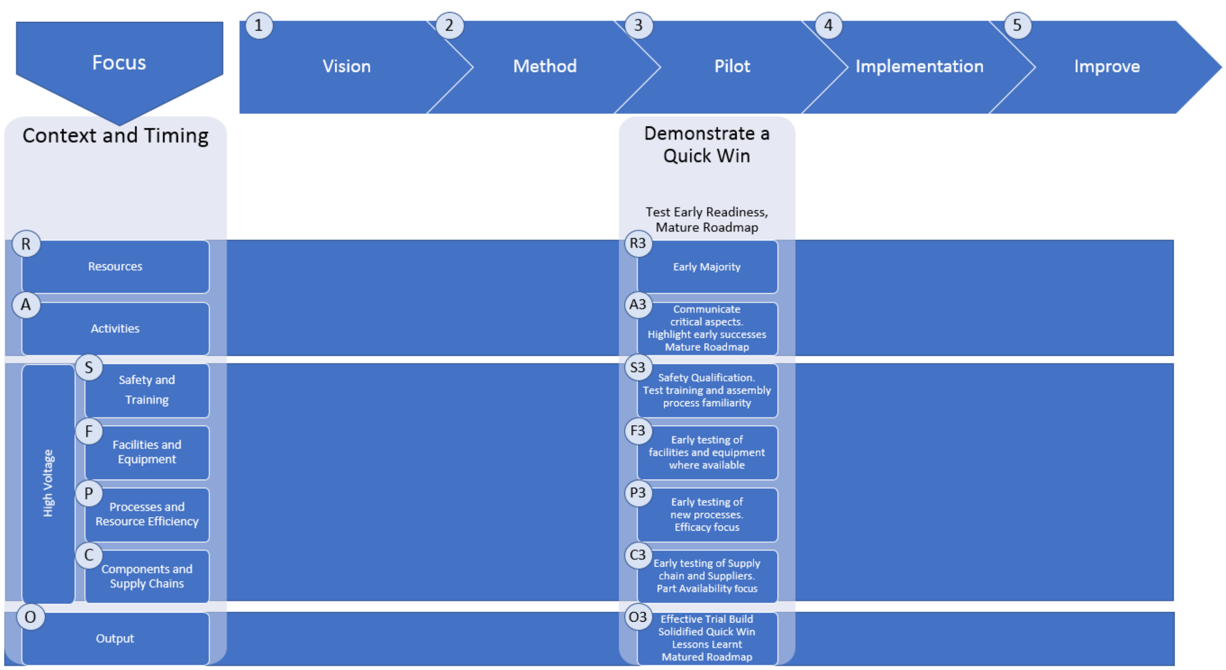


Figure 53: Summary of the IFAT at Step 3

5.7 IFAT Step 4: Implementation

Purpose, Context and Timing: The fourth step of the IFAT is the 'Implementation'. The key objective is for the full implementation of the new technology into the production lines, as planned in the Change Implementation Roadmap. Once the Roadmap is updated with the 'Lessons Learnt' from the Pilot step and the necessary activities are concluded, the new technology can be implemented in the broader context. In contrast to the Pilot, the Implementation Step is not just in an isolated sub-system, but is the full implementation of the new technology in the broader organisation. It often would still comprise an iterative approach of batches of vehicles in maturity loops before final Start of Production. A summary of Step 4 can be seen in Figure 55.

Main resources and activities: The targeted group in this Step is the Late Majority and the key change lever is Resistance Management. The literary 'chasm' has been crossed, with the innovation having diffused to the Early Majority during the Pilot phase. In the Implementation phase, the aim of the Implementation Team is to assure the Late Majority and get their buy-in to the project. The Implementation Team can use the tangible evidence from the Pilot, combined with the successes achieved during the Implementation to allay any fears and ensure the innovation is diffused. Regardless of whether the change is 'hard', phased or gradual, a successful implementation or successful implementation portions, should have sufficient evidence to sway the Late Majority. As shown in literature, the Implementation is not necessarily a 'hard' switch-over, though this is sometime required depending on the type of technology introduced. Automotive OEMs typically build batches of trial units in a 'phased introduction' approach. The iterative approach serves to mature the product, process, facilities, etc. before the final SOP. Resistance Management is critical in this step, as significant resistance during the actual Implementation can lead to project failure and if necessary, the Implementation Team must use Opinion Leaders and/or the Sponsors to ensure the project is not derailed.

High Voltage focus: During this Step, the implementation should be using live High Voltage components in as close to series conditions as possible, to test the systems and processes that will be used after the official Start of Production. Care should be taken to validate all HV safety equipment and processes, as well as focus placed on the efficiency factors related to the introduction. If the required levels of efficiency cannot be reached, more iterations might be necessary prior to the official project close. Applicable metrics of this efficiency may be time impacts (e.g. time lost due to the HV units being built) and quality impacts (e.g. customer-relevant defects on the product). Measures of efficacy (e.g. the amount of units built), safety requirements and other non-negotiables should also be looked at too. A possible evaluation matrix is proposed in Figure 54.

Output: To determine the effectiveness and efficiency of the Implementation and to learn from it, it is necessary that it be evaluated. The method of evaluation is not overly prescriptive, but must be sufficiently robust to allow a thorough review of the impacts of the implementation. For a 'hard' introduction, this evaluation can only be done retrospectively. For a gradual introduction, the Implementation Team can decide on suitable evaluation intervals and for a 'phased introduction', an evaluation can be done after each phase. In the case of phased or gradual introductions, there should be an opportunity to correct or improve aspects related to the evaluation prior to the next phase or before the implementation is finalised i.e. iterative maturity loops. This Step ends at the formal Start of Production (SOP), at which time the Implementation is considered complete.

	Effectiveness	Efficiency		Pre-requisites
	Units produced	Time (min lost)	Quality (fph)	Safety, Health & Environment
Implementation Iteration 1				
Implementation Iteration 2				
Implementation Iteration 3				

Figure 54: Possible evaluation matrix

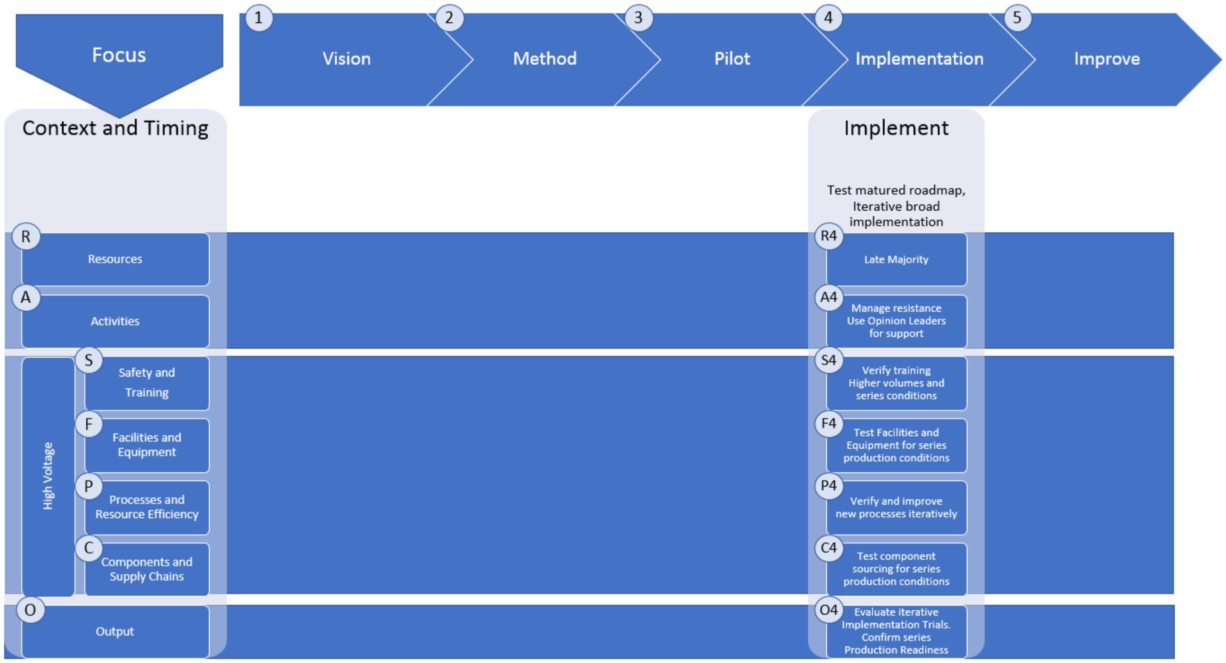


Figure 55: Summary of the IFAT at Step 4

5.8 IFAT Step 5: Improve

Purpose, Context and Timing: The last step of the IFAT is to 'Improve'. The key objective in this step is to identify areas of improvement for the future, serving to ensure Continuous Improvement. By measuring the successes and failure of the entire project and critically evaluating both, improvement ideas and concept for future projects can be generated. This ensures the organisation learns from each project and carries those learnings into future projects. Figure 56 is a summary of Step 5.

Main resources and activities: The targeted group in this Step is the Laggards and the key change lever is Sustained Performance. After the implementation, the Laggards will slowly buy into the new technology. The new technology is by now fully implemented and if done successfully many of the concerns of the Laggards will have been resolved. They will have no other choice than to accept the new status quo. When the Implementation is complete, the Implementation Team must take time to celebrate the successes of the project, while also taking time to reflect on what could have been done better. The evaluation is critical for continuous improvement, while the celebration is necessary to foster the type of organisational culture that supports new introductions and that ultimately aids all future introductions. The organisational culture cannot be stressed enough, as this is what supports future implementation projects and has long-term effects. If the culture is not open to new ideas and new technologies, it places the larger organisation at risk of business continuity. Failing to welcome new ideas and new technologies is a known risk for organisations and can lead to a very rapid downfall e.g. Nokia.

High Voltage focus: During this Step, the Implementation Team should look at factors that distinguished the HV introduction from normal projects and compile a 'Lessons Learnt' document for future use. Areas of future improvement should be suggested, specifically regarding HV technology. The document should look at, but not be limited to Vision communication and Change Resistance, HV Safety, required facilities and equipment, processes and resource efficiency, components and supply chains, trial builds, measures of efficacy and efficiency, etc. These should be evaluated and the knowledge retained for future use.

Output: A holistic critical evaluation of the implementation project is necessary and the Continuous Improvement feedback should be preserved to aid future implementations. The Method step in particular can benefit from this, when the future Implementation Team is planning a new Implementation Roadmap.

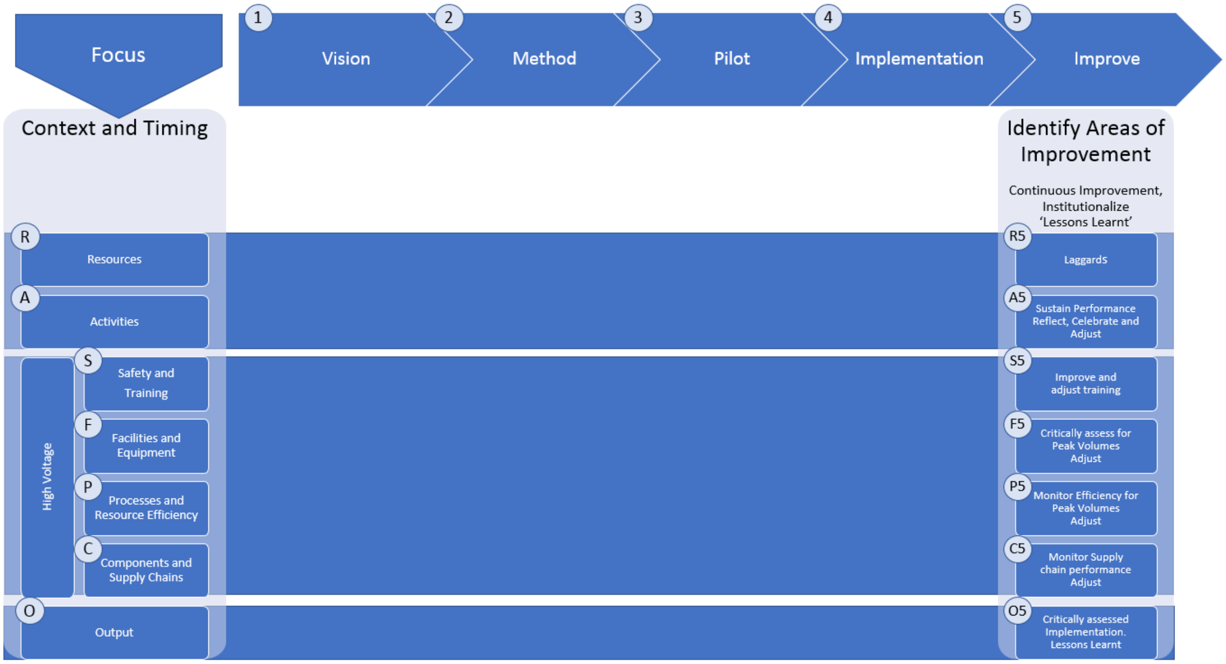


Figure 56: Summary of the IFAT at Step 5

5.9 Strata of the IFAT

Figure 57 details to which SST stratum of the organisation the different steps apply and where they should ideally be implemented for maximum effectiveness and efficiency. In organisations the size of most automotive manufacturers, there are typically defined hierarchical levels though, as shown, these can be geographically dispersed. The IFAT is developed in the context of an automotive manufacturing plant and while the instruction to introduce might come from offsite or abroad, it is the factory that needs to implement and the IFAT was developed for this need.

The Vision step is recommended to originate at the 5th Stratum, which in automotive terms would normally be the CEO of the local subsidiary, typically a President or Vice-President of the global OEM, assuming the manufacturing site is not located in the OEMs home country. This step should also be strongly supported by the 4th Stratum, usually a Senior Manager or Divisional Manager responsible for product planning or one otherwise linked to implementation projects in the local entity.

The Method step in turn is led by this Divisional Manager, supported by Departmental Managers (3rd Stratum), while the Pilot is directed by the Implementation Team (2nd Stratum). The Implementation itself should be effected by the general workforce (1st Stratum).

The Project Leader would typically perform 4th or 3rd Stratum functions depending on the size of the project, though in a matrix organisation he/she could be leading peers (the Implementation Team) at a lower organisational rank e.g. a 2nd Stratum Project Leader leading a 2nd Stratum team, or a 3rd Stratum Project Leader leading a 3rd Stratum Team. The functions need not necessarily coincide with hierarchical status, though there is often some correlation.

It is crucially important for the success of future projects that the 'Improve' Step take place across all the strata. Each level of the organisation should learn from the project and improve the future approach.

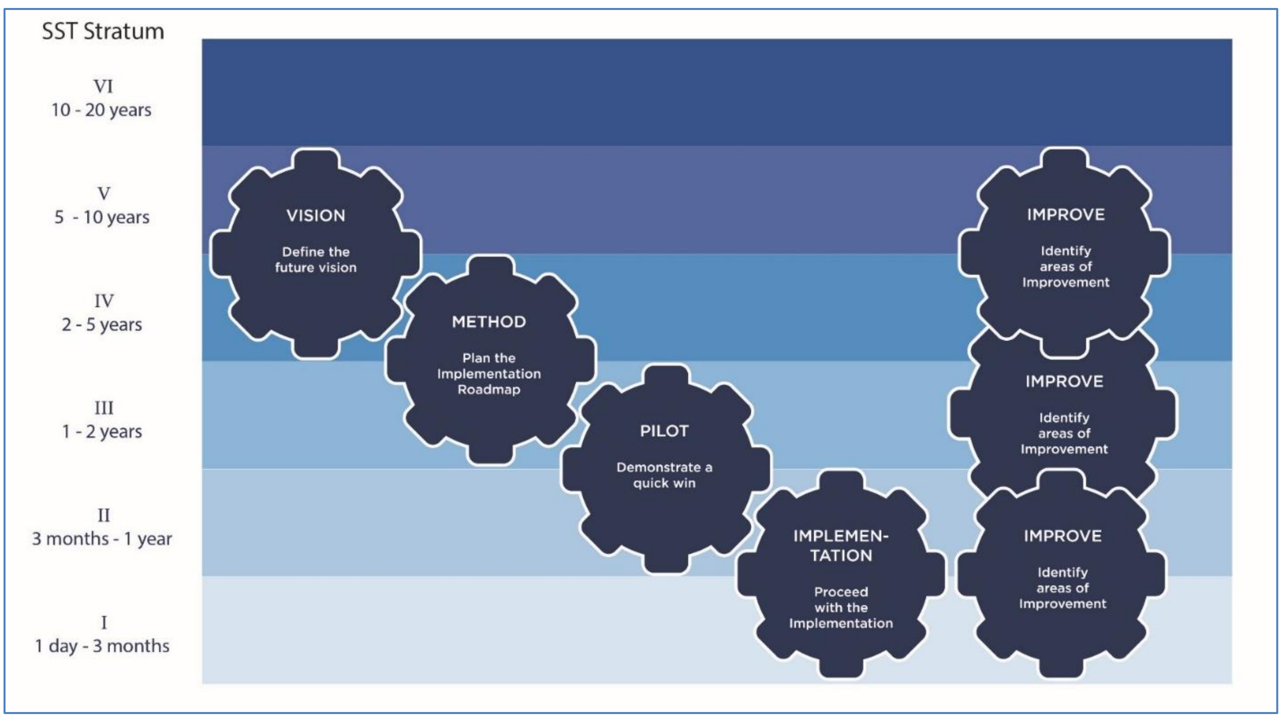


Figure 57: Conceptual framework and applicable SST Strata

5.10 Conceptual foundation and conclusion

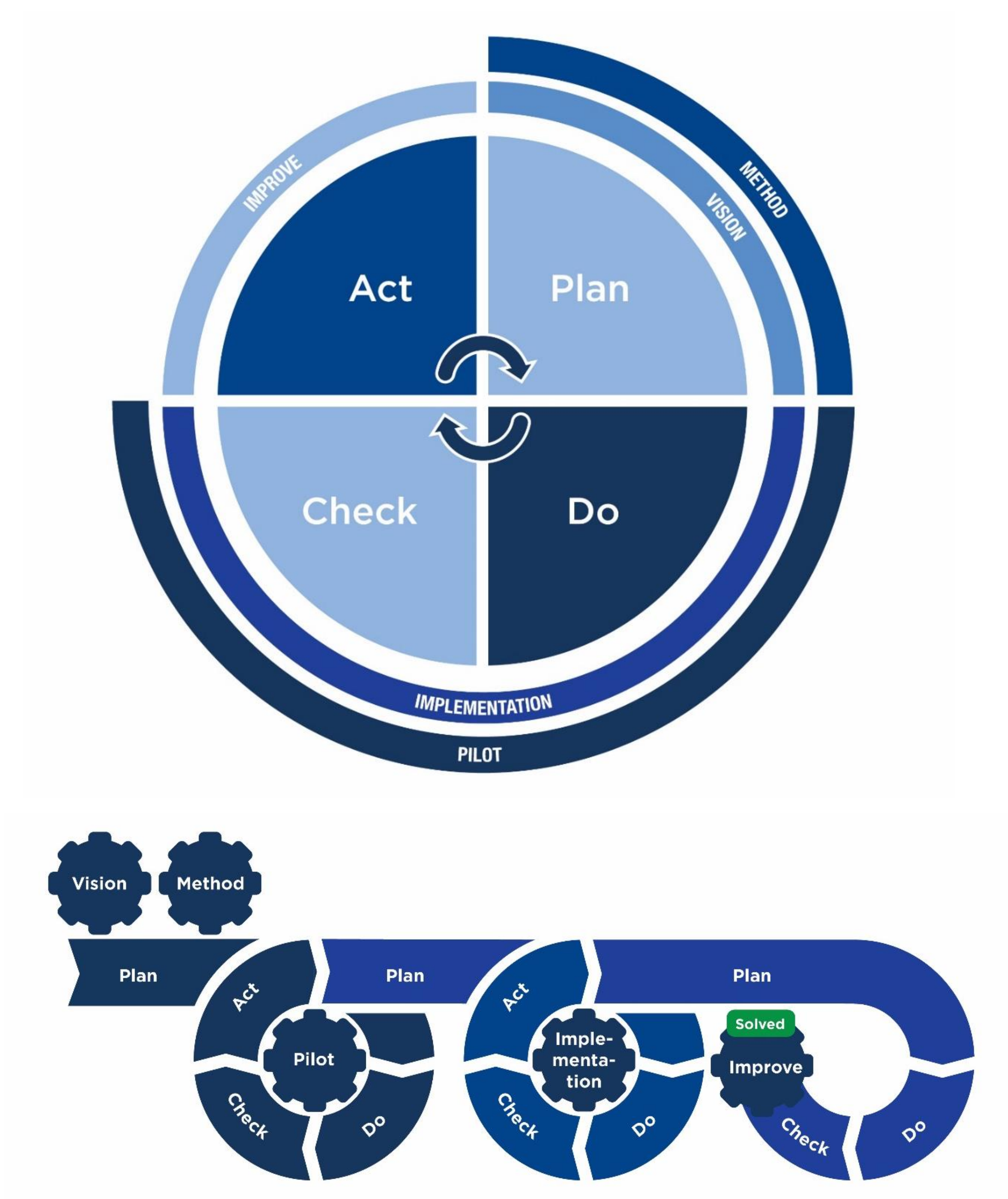


Figure 58: Conceptual framework overlap with the PDCA cycle

As discussed, while Change Management theory is very useful in a broad sense, it does not provide tangible, practical guidance for successful rapid implementations. From the perspective of an Implementation Team in an automotive manufacturing plant, what was missing in the literature was a hands-on practical and measurable framework for the implementation of technological change in automotive production lines – something that an Implementation Team could practically use to safely, effectively and efficiently introduce HV technology and manage or mitigate the associated rise in complexity.

The 5-step linear approach described in this chapter has its root in Change Management, Complexity Management, Implementation Theory and HV technology, drawing on elements of change uptake concepts, psychological change experience models, organisational change capability models and linear change methodologies, to create a meta-theoretical construct capable of meeting all the research requirements. As with the CFIR, the intention of the IFAT was not to replace, but rather embrace the best elements of existing theories and create something that is both holistic and practically applicable.

Overlap with the ubiquitous PDCA (Plan-Do-Check-Act) cycle should therefore not be surprising, but rather expected, at least conceptually. As seen in Figure 58, the Vision and Method steps of the IFAT, can be compared conceptually to the Plan component of the PDCA. The Pilot and Implementation steps overlap with both the Do and Check parts of the PDCA, as both IFAT steps contain elements of implementation and evaluation, while the Improve step overlaps with the PDCA's Act. It is also shown that this can be viewed as an iterative process, with a few PDCA cycles possible within the definition of the IFAT.

While the PDCA's concepts provide guidance to many organisations, the IFAT makes the steps more practical and specifically applies them to automotive manufacturing and HV technology. This practical and measurable framework is the unique contribution of the IFAT to the pre-existing body of knowledge and to the automotive industry specifically. The Conceptual Framework can be seen in Figure 59 and a strategic level and in Figure 60 at a detail process level.

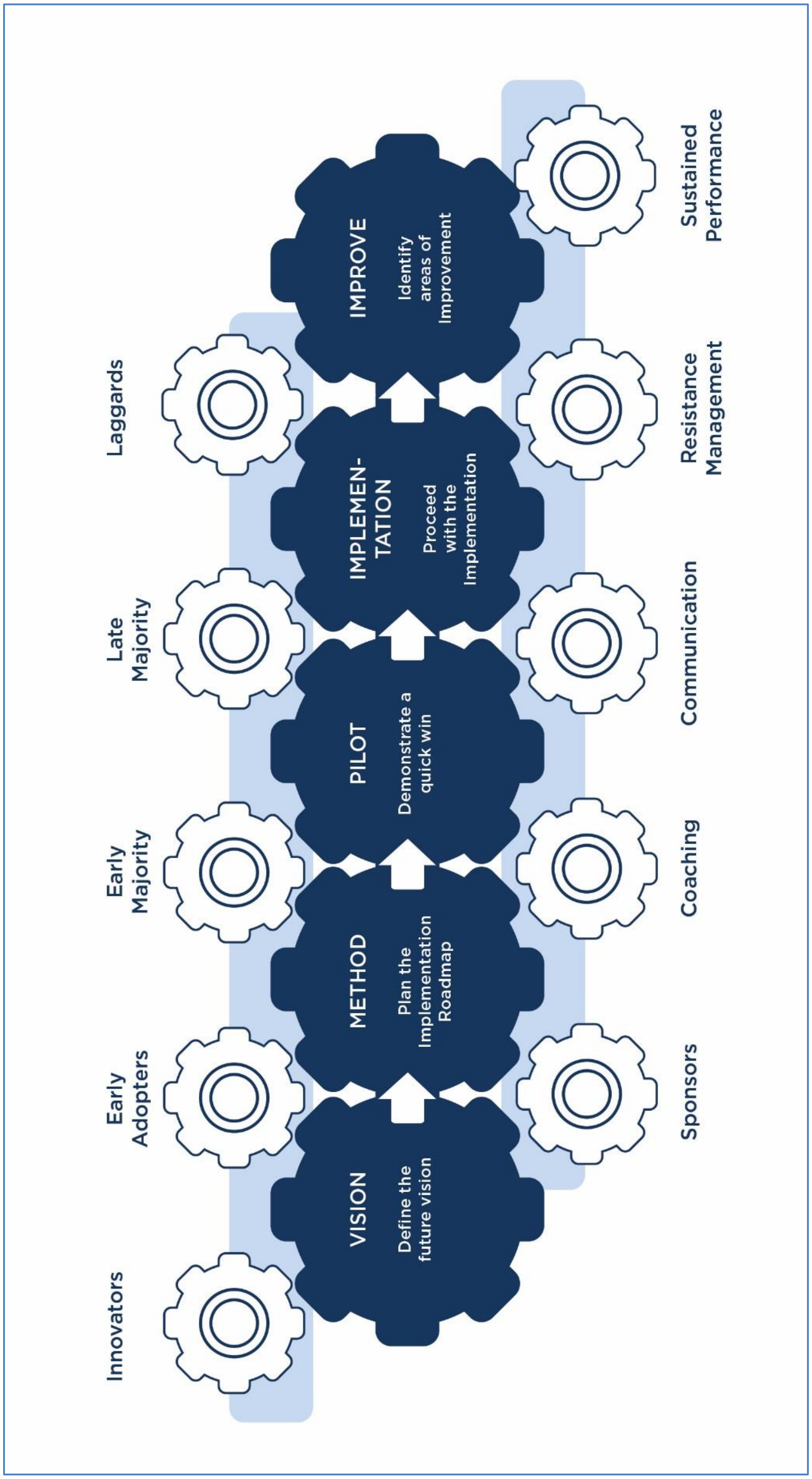
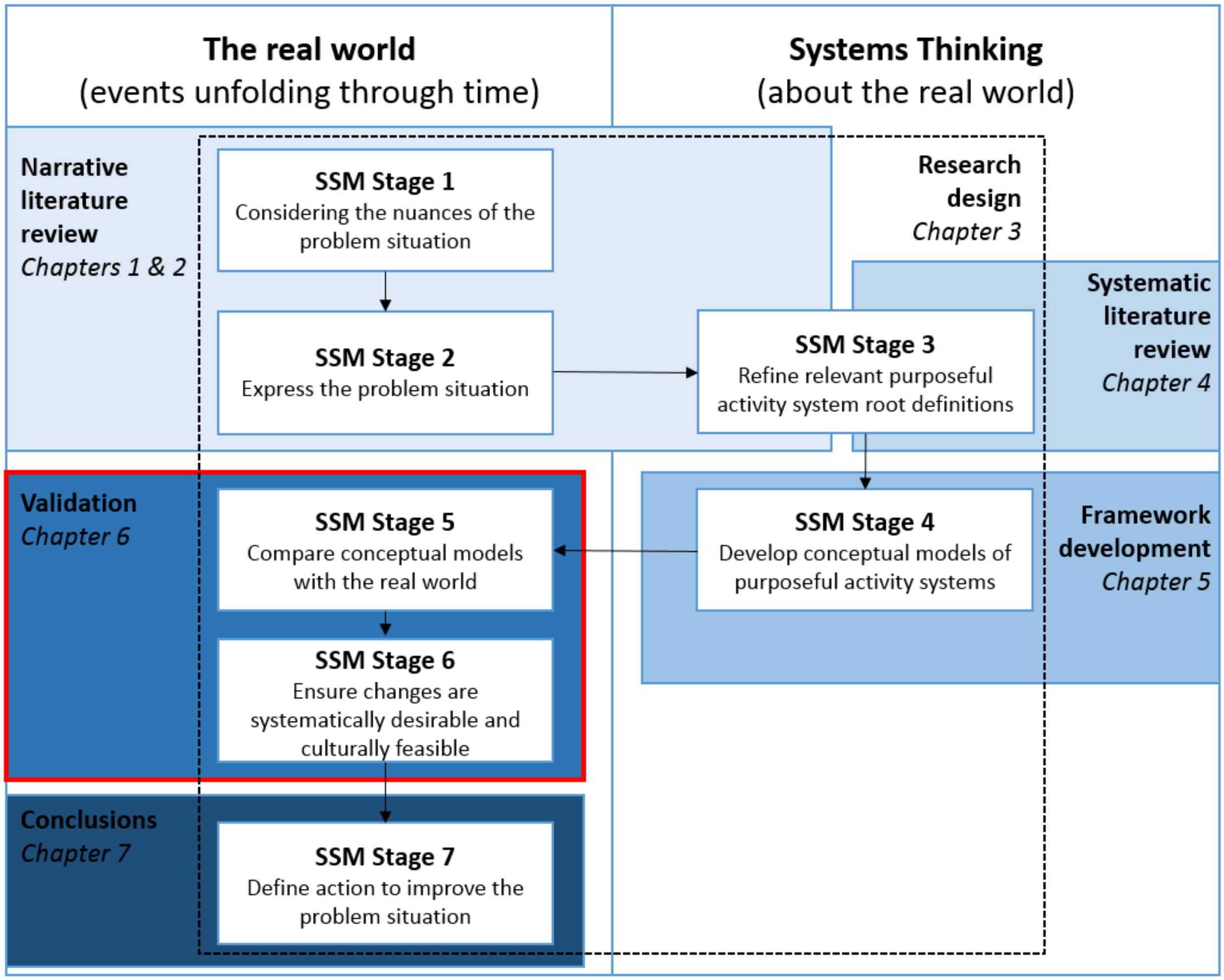


Figure 59: Conceptual Implementation Framework for Automotive Technology

Figure 60: Detailed processes of the IFAT

6. VERIFICATION AND VALIDATION



6.1 *Verification*

The Conceptual Framework must be verified against the research requirements set out in Chapter 5.2, to ensure all requirements are satisfied. Before the Conceptual Framework can be tested against a real world Case Study, it is first necessary that it be theoretically tested (verified) to ensure it meets the requirements that it was designed to fulfil. The Conceptual Framework was tested against the requirements set forth on a theoretical basis, with each requirement needing to be specifically met by one or more process steps from the framework. Table 17 demonstrates that the Conceptual Framework meets all these identified requirements. The assigned numbers of the applicable processes meeting each requirement, as summarised in Figure 60, is reflected, with additional clarification of how each requirement is met in the IFAT.

Table 17: Requirement verification

Req.	Requirement	Verified in Process nr.	Notes / Details
F1	The framework must be able to facilitate the introduction of HV technology into automotive manufacturing plants.	O3, O4	While all IFAT processes are aimed at this central Research Aim, the efficacy of the framework is proven quantitatively in these Output steps.
F2	The framework must specifically address Change Resistance in the context of HV implementation projects.	A1, S1, O1, A3, O3, A4	Change Resistance in a HV context is largely due to safety concerns. This must be addressed immediately in the Vision step and monitored later to avoid project failure.
F3	The framework must address HV safety and suggest ways of safeguarding staff and on-site contractors.	A1, S1-5, F2-5	Safety and legality are central to Project success and must be conceptually addressed in the Vision step, with detailed planning in the Method.
F4	The framework must address required HV facilities and equipment.	A1, F1-5	A long-term strategy is required in the Vision Step, with detailing and rollout in the further Steps.
F5	The framework must address HV training requirements.	A1, S1-5	A clear concept is necessary in the Vision Step, with detailing and rollout in the further Steps.
F6	The framework must address HV production process and resource efficiency, offering complexity-mitigating approaches.	P1-P5	A conceptual plan in formulated in the Vision Step, while the main mitigation preparations are in the Method Step and validation in further steps.

Req.	Requirement	Verified in Process nr.	Notes / Details
F7	The framework must address HV component supply chains, their limitations and how product complexity can be mitigated.	C1-5	The optimal 'Vertical Integration' and localisation levels (considering HV constraints) are detailed in the Method step.
F8	The framework must define ways how to measure efficiency and its impact on production performance indicators, when HV technology is introduced on the line.	O3-5	The Pilot step qualitatively ascertains efficiencies. In the Implementation Step this is one of the main focusses, with a quantitative evaluation template suggested in the IFAT.
F9	The framework must provide/suggest tools that can be used to identify all areas affected by the HV technology introduction, as this knowledge may not necessarily pre-exist in the country of application, or may be substantially different from previous implementations.	A2	The CATWOE analysis template is provided as a way of facilitating a root definition investigation in the Method Step.
F10	The framework must provide/suggest tools that can evaluate the criticality of the various factors or activities necessary for HV introduction and assess their influence.	A2	The IFAT suggests the use of a Risk Assessment and a Risk:Impact matrix to determine critical points for further preparation.
F11	The framework must provide for iterative maturity loops of trial vehicles builds.	O3-4	The Pilot and Implementation Steps are iterative loops, with maturity related improvement requirements between each.

Req.	Requirement	Verified in Process nr.	Notes / Details
F12	The framework should leverage the differences of rates at which people adopt new technologies.	R1-5	The Diffusion of Innovation groups are leveraged to use both strengths and weaknesses at the appropriate times to support the implementation.
F13	Differences in organisational change capabilities should be acknowledged and the levers be used appropriately to support HV implementation.	A1-5	Change Capability levers are utilised in each of the IFAT Steps to promote effective implementation.
F14	The framework must become part of standard procedure, so that it can be used repeatedly for future product introductions.	O5	The Improve Step is designed to facilitate knowledge retention and continuous improvement.
U1	The framework should consider the special context of automotive manufacturing plants, specifically regarding OEM constraints e.g. a plant's ability to influence product design or construction decisions.	A1-2, F1-2, C1-2	Limitations on decision making are considered primarily in the Vision and Method steps, including limitations on facilities and equipment that are necessitated by limitations on component selection.
U2	The framework must provide a clear step-by-step approach or roadmap that an Implementation Team can use to introduce a new technology.	O2	The entire IFAT is described in a step-by-step approach, with the detail activities of every project being planned in the Implementation Roadmap.

Req.	Requirement	Verified in Process nr.	Notes / Details
U3	The framework must clarify for the users the context, pre-requisites and timing of each step, as well as detail the main resources and activities.	O1	This can primarily be seen in the detail process layout of the IFAT, with the specific application to a project demonstrated in the Vision Step's Project Charter.
U4	The framework should suggest roles and responsibilities for all steps and activities.	A1-2, O1-2	The Stratified Systems Theory concept is applied to the IFAT specifically in the Vision and Method steps, to create detailed responsibility matrixes.
U5	The framework should be robust enough to be used by manufacturing plants in developing countries, physically far removed from the OEM's home-country and the responsible R&D centre.	A1-2, S1-2, F1-2, P2, C2, O2	In the early stages of the application it is critical to plan with the assumption that not all knowledge will be on-site in the manufacturing plant and specific and detailed root definition and further planning are needed to mitigate this risk.
U6	The use of the framework should allow sufficient flexibility to apply discretion and effectively leverage prior knowledge.	A2, O2	The framework encourages flexibility in the selection of tools and use of prior knowledge, specifically in the detail planning of the Method Step.
U7	The framework should be user-friendly.	O1, O2	The Project Charter and Implementation Roadmap are designed to specify exactly what needs to be done and by when, to facilitate easier implementation and support user-friendliness.

Req.	**Requirement**	**Verified in Process nr.**	**Notes / Details**
R1	The framework must be presented practically as a linear, step-by-step construct that an Implementation Team can follow to introduce HV technological change.	O1-5	The IFAT is designed in a 5 step linear approach, with clear outputs after each Step.
R2	The framework should facilitate implementation in existing automotive production lines.	A1-2, O1-2	The limitations of brownfield sites are specifically considered in the Vision and Method steps and mitigation attempted where feasible.
R3	The framework must not be too prescriptive and should allow user flexibility in the selection of tools.	A2, O4	The framework suggests a number of tools and templates, but their specific use is not mandated, only that their functions be performed.
R4	The framework is intended for automotive high voltage technology, though it could also be used for other implementations.	O1	The Project Charter will be clear on the automotive application, though applications outside the original intent may be considered after further investigation.
R5	The framework itself is not a legislative document and can’t prescribe specific legal requirements, as these will differ depending on the country of application.	A2	Specific legislative requirements are considered in the recommended root definition investigation and detailed planning of the Method Step.

Req.	Requirement	Verified in Process nr.	Notes / Details
A1	The framework may contain discretionary items due to inherent factors pertaining to the implementation.	A1	Organisational culture and other unique characteristic of the specific area of implementation is considered at the start of each project's Vision Step.
A2	The framework should be seen in the context of an evolving field of knowledge.	A1, O5	The IFAT is the first of its kind for the automotive sector. The lack of knowledge is recognised in the Vision Step and the Improve Step attempts to correct this fact.
A3	The framework should be designed to achieve its objective of implementing high voltage technology in an automotive context.	O1-5	The outputs of each Step in the IFAT are designed to facilitate implementation of HV technology, though with updates it could potentially be applied to wider fields.
B1	The framework must not break any laws or legal regulations.	O1-2	Legal adherence and a preference for international best-practise is firmly established and reiterated in the Vision and Method Steps.
B2	The framework must not be used to put any individuals at undue risk.	S1-5, O1-5	Safety is the main concern in HV implementation projects and is addressed in each Step of the IFAT

Having demonstrated and verified that the Conceptual Framework complies fully with all identified research requirements, it is still necessary to validate the framework against a case study from industry. The C350e Plug-in Hybrid Project of Mercedes-Benz SA will be used for this purpose.

6.2 Validation: Introducing the Mercedes-Benz C350e

In November 2015 Daimler AG decided to introduce Plug-in Hybrid vehicles to the East London factory of its local subsidiary, Mercedes-Benz South Africa. The C350e, a variant of the popular C Class model, would pioneer 'high-voltage automotive manufacturing' in South Africa, becoming the first hybrid vehicle to be mass manufactured in the country. The new variant would introduce to MBSA a powerful Lithium-Ion battery operating at a potentially lethal 300 Volt.

The C350e formed part of the model-mix of the W205 C Class model, but at the time that the model was introduced to the East London plant in 2014 the planning premise was that this variant would not be built locally. Each production location is unique and their production lines vary depending on numerous factors, including local legislation, the allocated model mix and to a large degree the vertical integration of the local suppliers. The W205 production lines were set up to exclude the additional work content and components of the Hybrid, avoiding the expenditure of preparing for a model that was not planned to be built.

To meet global sales and production demands, Daimler AG needed this variant of the C Class to be built in South Africa and instructed MBSA to prepare its manufacturing facility as quickly as possible. The multi-million Euro project was kicked off a few days later in MBSA's East London factory, with the goal of delivering units to market by the 3rd Quarter of 2016. The factory was given less than a year to prepare and to integrate this potentially dangerous new technology at a level meeting the stringent international safety and quality standards of Mercedes-Benz. No local automotive OEM had any experience with 'high voltage automotive manufacturing' prior to the implementation decision taken in Germany and the safety risk initially prompted significant resistance in the South African factory. The risk and the associated resistance had to be carefully managed by the Project Leader and the Implementation Team against the backdrop of a lack of applicable safety legislation in the country.

While this is a retrospective Case Study, the elements of the Framework were nevertheless followed by the researcher as the Project Leader of this implementation. Having previously done research on e-mobility for Daimler's 'Society and Technology Research Group', as well as having a strong background in change management from many years' experience as Change Management Specialist for MBSA, the researcher was in a unique position to lead this challenging, multi-million Euro implementation. While not yet codified, the Framework presented in this study was the meta-theoretical construct used to lead one of the most successful projects at MBSA and arguably in the South African automotive sector in recent years. The process followed by the researcher and his Implementation Team, as well as the project output, will be further detailed in this chapter, in the 5-Step linear format of the Implementation Framework for Automotive Technology.

6.2.1 Step 1: Vision

Figure 61: Validation requirements of IFAT Step 1

The Vision of the C350e Plug-in Hybrid project was clear and binding. A directive had been given to MBSA by its mother company to deliver Hybrid vehicles to market by the 3rd Quarter of 2016 and senior management, both in Germany and in South Africa were committed to supporting this implementation. To ensure that the objective was achieved in the given timeframe and that the necessary safety and quality levels could be reached in time, the project was given a R100-million budget. The Project Leader was officially assigned to the project within days of the decision and instructed to start the preparations before the annual factory shutdown in mid-December. The Project Leader and the core members of the Implementation Team met on-site that same week.

While the majority of the Implementation Team members can be classified as Innovators and some Early Adopters, the technical expertise of a few Late Majority or Laggard specialists was also needed. The Project Leader had to take special care to not let the overly cautious nature of these individuals derail the project before it properly started. The commitment of the sponsors, particularly the CEO of MBSA at the time, as well as the global Strategic Project Leader for the C Class, was of critical importance in this regard. Most resistance was easily dispelled simply by reaffirming the commitment of these individuals to the project. Both personally requested regular feedback on the progress of the project and any delays would have to be reported to them. The Project Leader could effectively nullify any resistance from the Late Majority and Laggards, whether inside or outside the Implementation Team, simply by leveraging this knowledge, as no one wanted to disappoint these influential and popular leaders.

MBSA already had a long and proud history of innovation and flexibility. Being the first OEM not only in the Eastern Cape or South Africa, but on the entire African continent to build a Hybrid vehicle in series production, was an opportunity that inspired the Implementation Team, creating enthusiasm for the challenge. This challenge and opportunity were highlighted regularly by the Project Leader and the Sponsors, further negating change resistance in the Implementation Team and the broader plant. The Vision of the implementation was shared with the Trade Union as early as possible. While they expressed reservations concerning the safety of the new technology, the Union was pleased with the precautionary measures proposed. Another major benefit of the introduction was the additional production volume that the project would bring to East London, as well as the additional jobs that the project would create in the factory and the broader supply chain. With MBSA being one of the biggest employers in the city, improvements at the plant have a measurable and leveraging effect for the wider community. The additional flexibility and capability that the project would bring to MBSA was not to be underestimated and the potential positive impact of the project was regularly highlighted and reaffirmed. The skills and technical expertise of the Implementation Team's Innovators were also highlighted and leveraged regularly, to create a balance between the enthusiasm for the project and the practical elements of feasibility.

While it was an ambitious undertaking, the Implementation Team assigned to the project was highly experienced, instilling belief in the broader plant of the high probability of successfully meeting the challenging timeline. The project was by no means easy, but it was seen and highlighted to be in capable hands.

MBSA would be the first OEM in South Africa to manufacture vehicles with High Voltage components and as such would be pioneering a new field in local manufacturing. There was no legislation in South Africa specifically covering this new field and the most relevant legislation (Appendix C - Occupational Health and Safety Act of 1993) only goes so far as to cover general duties of employers to their employees - it does not state specific safety measures required for manufacturing with High Voltage components [20] [21]. While it is not the aim of the dissertation to bridge the legislation gap that still exists, it is the hope of the researcher that the application of this Framework to the case study of MBSA's C350e Hybrid Project will aid government in creating applicable regulations to ensure all local OEMs adhere to the strict safety measures necessary for the production of High Voltage vehicles. It was critically important to understand the risks of High Voltage manufacturing already at the Vision step even before exact countermeasures were defined in the Method, as this was likely to be the Achilles-heel of the entire project.

The 'P2-60' battery used in the C350e operates at approximately 300V, exceeding the maximum contact for standard manufacturing as defined by the VDE. The battery therefore is classified as "High Voltage" for automotive manufacturing. It uses Direct Current with a converter to change AC into DC when charging from a standard wall socket. Direct Current powers the vehicle drivetrain and propels the vehicle. According to MBSA's Chief Electrical Specialist, Mr. Donovan Leiberum, "DC at this high voltage is dangerous when there is a disconnection while there is a load present, or where there is a short circuit on the battery side. This will result in a High Voltage arc (flash) which happens very quickly and can burn. If someone creates the short circuit with his body, then he has the chance of a DC shock and burns which could send the heart into fibrillation" [239]. Thermal effects include not only burns, but also possible coagulation and rapturing of blood cells, while the chemical effects can even lead to cellular damage [243].

As the technology was only contextually new, rather than conceptually, the Implementation Team could benchmark against international standards and norms. In lieu of applicable local legislation at the Vision step MBSA already committed to installing the same safety measures as its mother-company, Daimler AG. MBSA would thereby comply with the German (VDE) and wider European (ECE) regulations. Safety in this case relates not only to the training of operators, but also to safely warehousing and quarantining HV components. It also further relates to safety signage, emergency response requirements and personal protective equipment, etc. [239]. The Sponsors, Project Leader and Implementation Team made it abundantly clear to all stakeholders that there would be no compromises on safety and that international best-practise would be followed, helping to alleviate many fears around this potentially dangerous technology and firmly establishing the Vision for the implementation as one that places safety at the forefront.

On a strategic level, the Implementation Team understood the requirements for the required facilities and equipment, as these formed part of prior feasibility studies by Daimler AG, before the decision was made to introduce the C350e in East London. A general concept of production processes was developed in tandem with the equipment planning, though not very detailed with regard to efficiency factors. In terms of components and supply chain, it was broadly believed that since the model was already being assembled in Germany, that all components were available and that if parts could not be localised in time, that they could simply be imported until the localisation was finalised. This strategic oversight eventually resulted in a SOP delay.

Within days of Daimler AG's implementation decision, the local manufacturing plant in East London had already enlisted strong Sponsors, appointed a Project Leader and formed the Implementation Team. The Vision for the change was clearly communicated and a Project Charter (Figure 62) was formalised. A summary of the activities can be seen in Table 18.

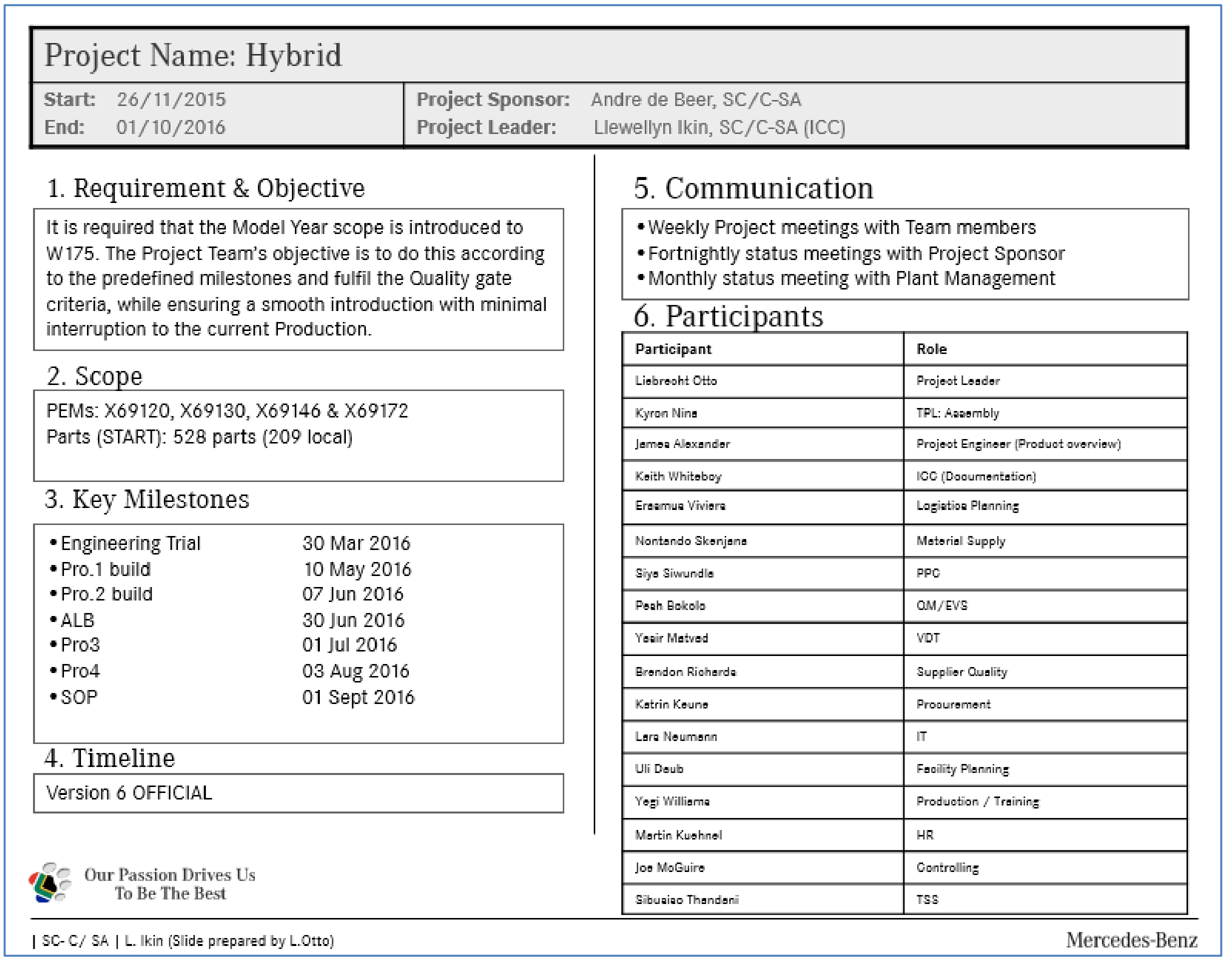


Figure 62: Project charter for the C350e introduction

Table 18: Validation of Step 1

Process nr	IFAT requirement	Case Study observation and Notes
R1	Innovators Sponsors	Effective use of Innovators. International coalition of very senior project Sponsors, with clearly communicated project support.
A1	Clarify change reason Conform to organisational culture Avoid resistance	Clear reason for change communicated, conforming to prevalent organisational culture of innovation and flexibility. Resistance effectively nullified.

Process nr	IFAT requirement	Case Study observation and Notes
S1	HV Safety concepts at strategic level	HV Safety addressed early by Sponsors, Project Leader and Implementation Team. In lieu of locally applicable legislation, there was unanimous decision to follow German safety legislation and strive for international best-practise.
F1	Determine long term strategic intent for facility and equipment	Understood from feasibility study by Daimler AG
P1	Determine long term strategic intent for Process and Resource efficiency	Understood from feasibility study by Daimler AG
C1	Determine long term strategic intent for Components and Supply Chain	All parts were already available in Germany, but not all parts could practically be imported. Mistake in strategic understanding eventually led to SOP delay.
O1	Clear Vision. Project Charter	Sponsors, Project Leader and Implementation Team communicated clear vision for the change. Project Charter was formalised.

6.2.2 Step 2: Method

Figure 63: Validation requirements of IFAT Step 2

To diffuse the technology to the Early Adopters the Project Leader assembled the full Implementation Team in January 2016, immediately after the annual shutdown. The plant already had a project team responsible for model year changes, but this team had to be supplemented by several additional experts owing to the nature of the technology.

Key among the additional members of the expanded Implementation Team was Mr. Donovan Leiberum. As a departmental manager and a qualified electrical engineer, he had both the necessary hierarchical status and the required technical ability to serve as Chief Electrical Specialist (CES). The German VDE regulations require that all manufacturing plants building Hybrids or EVs appoint a Chief Electrical Specialist. In lieu of applicable local legislation, the Implementation Team and Sponsors unanimously agreed to adopt German laws, regulations and norms to ensure that the safety of MBSA staff and contractors is beyond question. Fortuitously Mr. Leiberum happened to be an Early Adopter of technology and volunteered to fulfil the CES role for the East London factory. As required by German law his appointed was ratified by MBSA's CEO.

As part of the (yet to be codified) Method step, the Project Leader and Implementation Team focussed on Coaching. Managers from various divisions and departments were consulted and trained on the new technology. The benefits to the organisation were highlighted to them and regular communication channels were established to keep them updated on the project's progress. The potential negative aspects, specifically those related to their individual areas were explored, to ensure they understand the associated risks and were capable of managing them. In this role the CES strongly supported the Implementation Team to explain the risks associated with HV technology and to ensure all managers were aware of the dangers, as well as the best-practise mitigations reaffirming the company's commitment to world-class safety.

Due to the challenging nature of the project the Implementation Team based the project timeline (Figure 64) on the standard Change Year project concept that the plant was familiar with, to avoid non-standard processes and likely misunderstandings as far as possible. The Project was codenamed ME06, the production code linked to C350e orders in Germany and the plan was to build the Pilot (Engineering Trial) as early as possible to identify technical and process issues as early as possible. The ME06 Engineering Trial was scheduled for March 30th, with three Production Trials (PT) planned to serve as iterative loops of the Implementation Step. The three PTs were scheduled for April 26th, June 1st and June 29th, with the Start of Production for the series volume planned for July 8th.

The project would introduce 528 unique parts to MBSA's existing production line, 209 of which could be locally sourced. Not all parts were HV related (Figure 65), but all were necessary to introduce the C350e variant. As the IFAT was not yet codified, a CATWOE analysis and Risk Assessment were not completed at the time. Had this been done, the Implementation Team would have realised significantly earlier that crucial local components could not be approved in time and that the planned introduction date was in fact a month too early. Instead of a CATWOE analysis and the associated risk assessment process, the Implementation Team as well as the necessary planning and production teams of MBSA, analysed the list of parts to define the requirements e.g. facilities, equipment, line-side space, processes, etc.

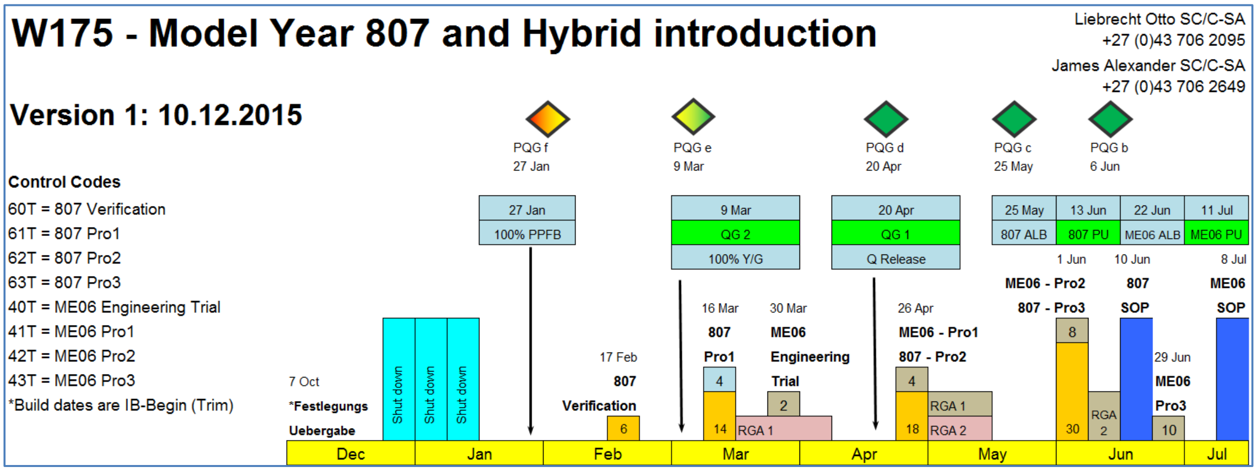


Figure 64: The initial timeline proposed for the introduction of the C350e

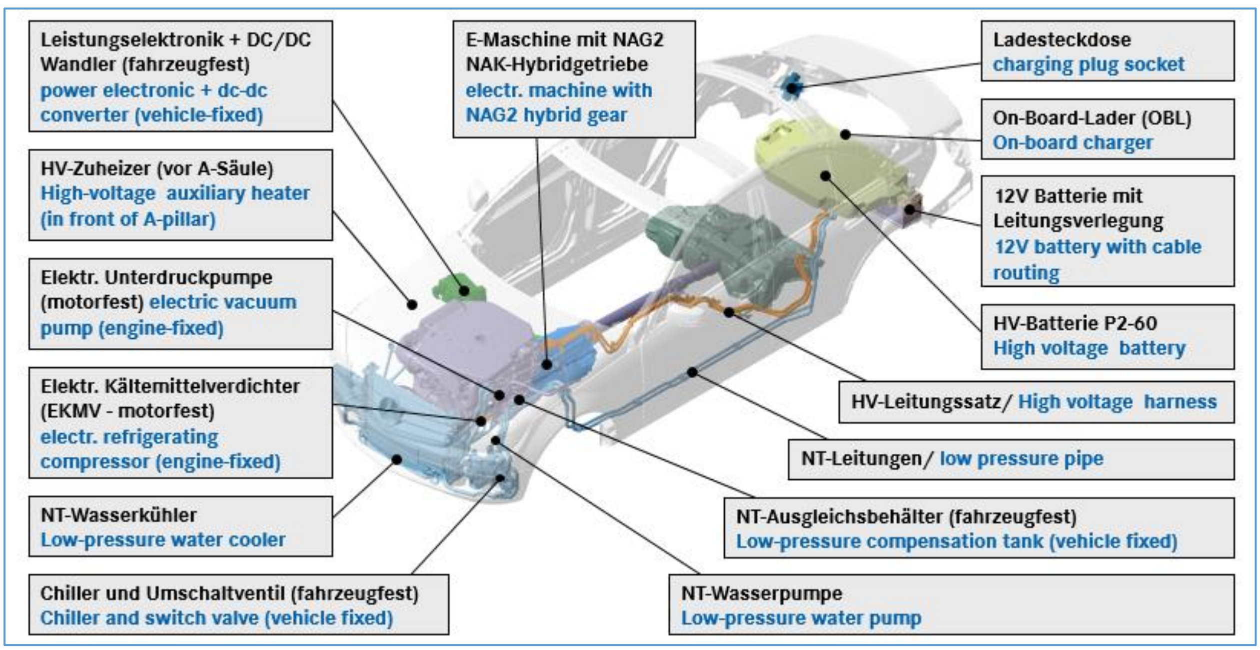


Figure 65: The HV components of a Plug-in Hybrid C Class

High Voltage safety is perhaps the most significant consideration that must be taken into account when introducing Hybrids or EVs into the production lines of automotive OEMs. Safety in this case is not just about the training of operators, but also safe warehousing and quarantine of HV components, safety signage, emergency response requirements and personal protective equipment (Appendix D - Blast boxes and other safety installations).

When the adoption decision was made by Daimler AG, the necessary know-how to safely introduce HV technology did not exist in South Africa. MBSA had to look at international organisations for the training of its staff. In addition to ensuring the knowledge transfer MBSA also had to ensure that the training competence was transferred too, otherwise it would create a dependency on this international company for local competence. This was necessary to ensure that future employees could be trained locally and that in the future management of the technology could be done competently in South Africa.

Trainers and trained personnel would be leveraged to encourage others and to ease safety concerns. An informal reward process was planned for these employees and it accelerated the technology adoption by generating excitement and eagerness in other employees. This both removed obstacles in the change management process and demonstrated a "quick win" in terms of morale for the project team, securing momentum for the project as a whole.

	Body	Paint	Assy	CV	TSS	Log	PPD	QM	Proc	F&C	IT	GrHR	HR	SLO	Total
Band 1														1	1
Band 2												1			1
Band 3	1	1	1	1	1	1	1	1	1	1	1	1	1		14
Band 4	6	4	3	6	4	6	8	4	5	3	6	3	3		61
Band 5	48	41	53	30	58	34	62	41	43	16	29	6	28	1	490
Band 6	84	23	39	21	118	25	10	31	13	19	2	8	21	1	415
Hourly	379	347	835	252	46	45	16	12	3			1	164		2100
Total	518	416	931	310	227	112	97	89	65	39	38	20	217	3	3082
HV2			947			74	30	21					50		App.1300
HV3			62			1		25					4		92

Figure 66: The training plan for MBSA High Voltage Safety

Figure 66 shows that approximately 1300 MBSA and contractor staff would require safety training to the German HV2 standard. This level is required for anyone coming into direct contact with the HV components or an HV vehicle while it is being assembled. The HV1 level is required for staff that do not come into contact with these, but work in a factory with HV components. The four-hour training necessary to receive the HV2 accreditation presented many challenges, as facilitators were not available in-country and had to be flown in from Germany. Training for the production staff could only be done before or after their shifts to avoid disruptions to series production, further restricting the roll-out.

To comply with the VDE and ECE regulations, MBSA had to install a High Voltage responsibility structure. The structure had to be in place before the first HV batteries arrived at the plant, not just before the first live units were assembled. Regardless of the production volumes planned, in order to set a benchmark for the South African automotive industry in lieu of local applicable legislation, MBSA committed to establishing a complete HV responsibility structure. This structure was established parallel to existing functional reporting lines. Qualified auto-electricians, while functionally reporting to the Assembly Production structure, would for High Voltage topics report to Mr. Leiberum, the Chief Electrical Specialist. MBSA's Organisation Culture and the firm commitment to world-class safety standards, helped to cement the new High Voltage manufacturing capability and responsibilities within the organisation in very limited time. It is known that Organisation Culture can counteract or mitigate increases in organisational complexity and this was clearly demonstrated by MBSA during this project. In addition to the training of staff and contractors, a number of safety installations and changes had to be made to safely receive, warehouse and assemble the High Voltage batteries. Some could be done prior to the build of the Pilot (Engineering Trial), but not everything could be in place. Alternative concepts had to be investigated to further project maturity without putting any staff or contractors at risk.

In the case of the C350e Project, both Product and Process complexity significantly increased and the production lines at MBSA had to be re-engineered to accommodate the added variant. Some parts could not be accommodated though, due to the design of the vehicle and the layout of the existing lines. This required an innovative approach as the current production could not be stopped in order for the series equipment to be upgraded or adapted to accommodate the Hybrid work-content. Representative teams from management and supervisory levels met with technical experts to determine the fundamental value-adding flows and find alternatives to the existing stations. After examining the required tasks, processes and potential work cycles, it was determined that a modular approach was required for a large portion of the additional scope. This modularity to a large part contributed to the project's eventual success by limiting the increase in process complexity on the existing production lines and allowing major construction to take place during running production.

Figure 67 shows the existing production lines and the major facility and equipment changes required to introduce the C350e. The Assembly facility comprised three Trim lines, where predominantly interior and exterior components were fitted to the vehicle, as well as three Mechanical lines, where the powertrain and chassis were incorporated and final assembly completed. As none of these lines could be stopped for any major period of time due to running production, an innovative modular approach was taken. This both mitigated the increase in complexity on the existing lines and allowed for installation during running production. Unfortunately, due to the practicalities of vehicle construction, not all components could be accommodated in this modular station.

While significant amounts of components could be added and processes completed in the new modular "Hybrid Lift Station" the C350e's Lithium-Ion battery, one of the biggest and most unique components, had to be installed on the existing production (Trim) line. The battery had to be installed after some components from the series production lines and so could not be accommodated in the modular station. A special manipulator also had to be installed to allow the HV battery to be mounted in the vehicle. Due to its colossal weight (100kg), the battery could not be fitted by hand and special equipment (Figure 68) had to be designed and installed for this purpose. Besides the modular station and battery manipulator the Multi-function Well manipulator also had to be adapted to cater for a Hybrid-specific component. The acquisition, installation and commissioning of these facilities and equipment were key considerations when the Change Implementation Roadmap was created. Many of the facilities and equipment could only be sourced internationally, but innovative approaches allowed for some local sourcing, reducing long-term international dependence.

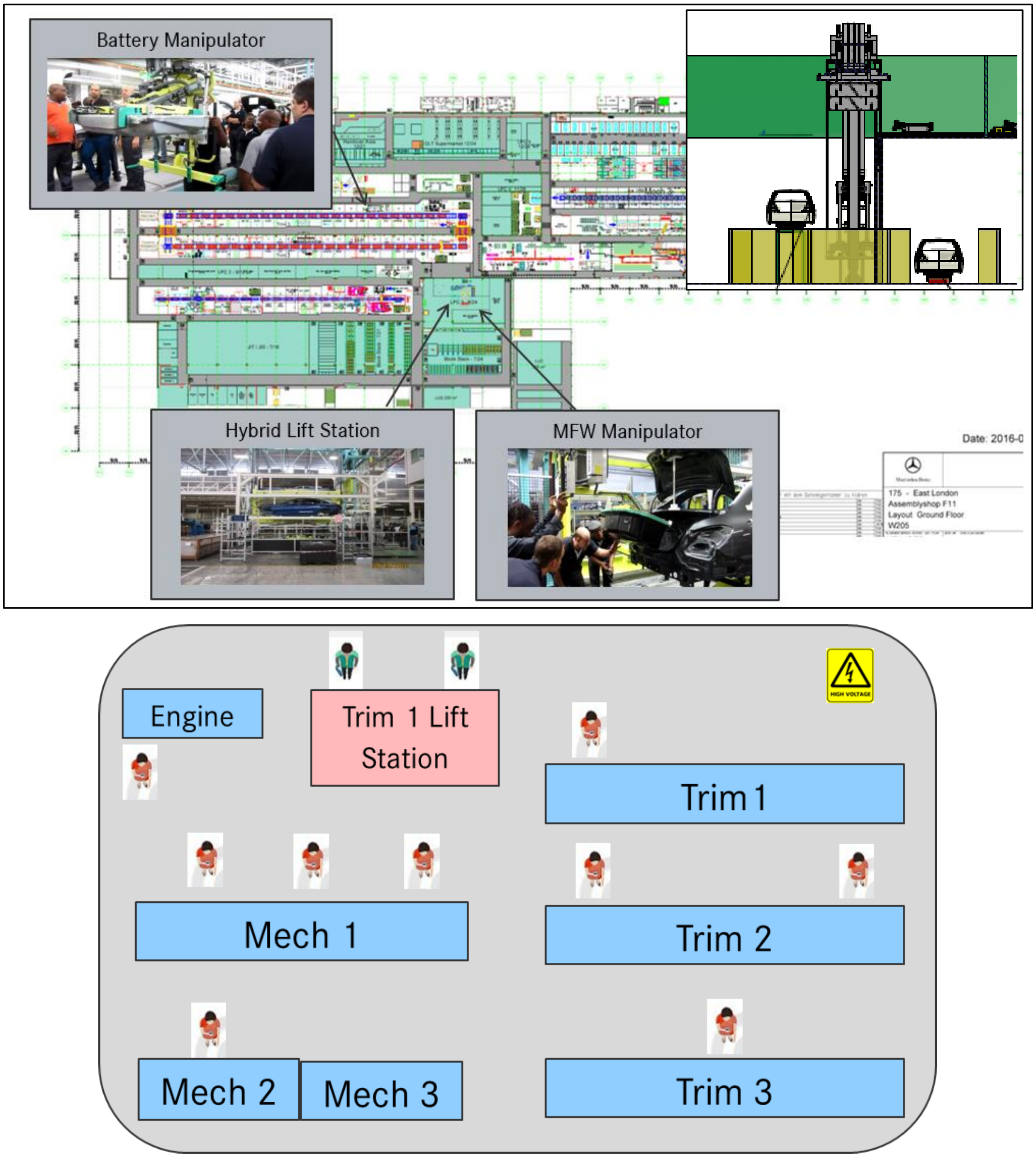


Figure 67: The C350e's major additions to MBSA production lines (Adapted from [244])

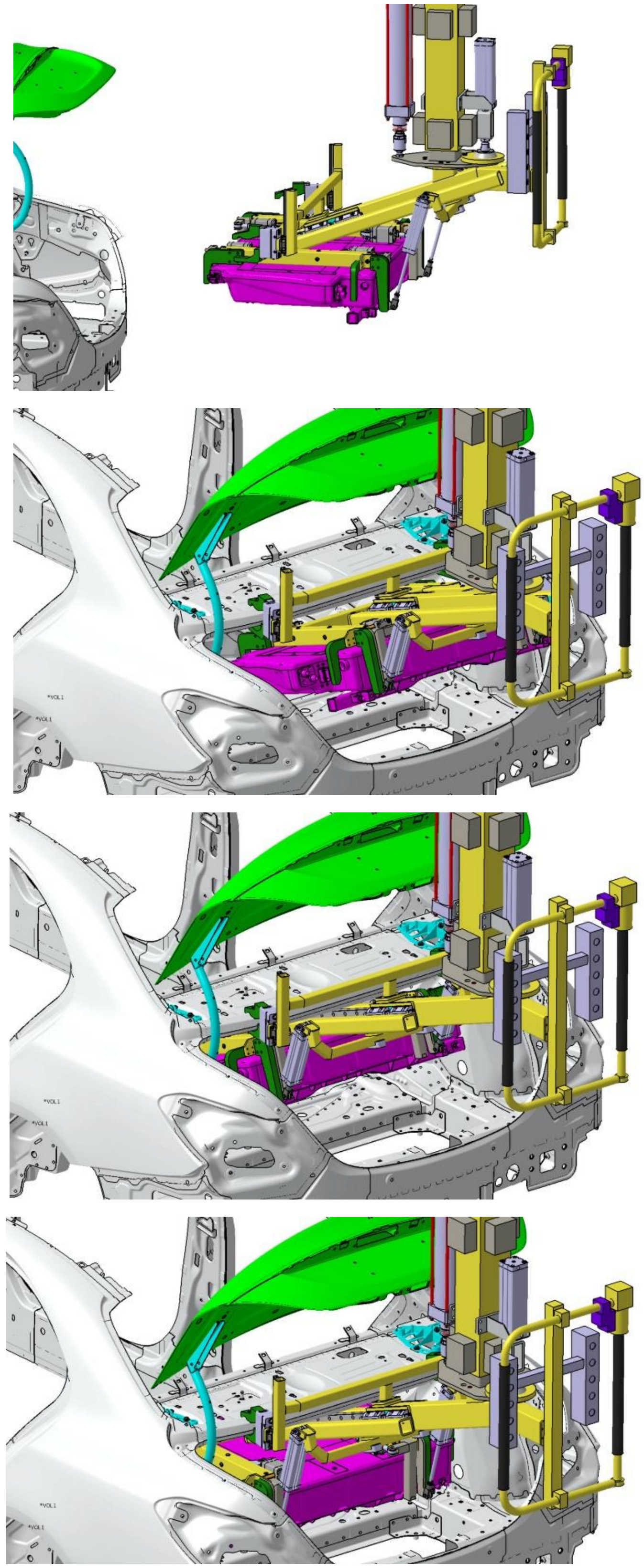


Figure 68: The manipulator to install the P2-60 HV battery of the C350e

Due to relatively low volumes and high variant-specific work content, it was unlikely that Hybrid vehicles could be fully accommodated on existing production lines in a resource efficient way, even if production could be stopped to facilitate this. Whether the HV components would be assembled on the existing production lines or not would depend greatly on the context e.g. whether or not all the additional work content could be physically accommodated on the existing lines, whether or not accommodating additional work content on the line would negatively affect other models or variants, operator loading and other capacity constraints, etc.

It is assumed that other South African OEMs would have similar concerns on initial introduction, due to the limited volumes of Hybrids still sold worldwide. Modularity therefore should be seriously and specifically considered as part of any HV Change Implementation Roadmap. As discussed, Figure 67 shows the existing production lines at the MBSA facility in East London at the time of the implementation decision and also shows the major new additions required to accommodate the additional High Voltage variant. The majority of the additional work content would be completed in a modular station separate from the existing production lines, the so-call "Hybrid Lift Station". To facilitate this a lift had to be installed to move the vehicle from the transport conveyor level to the operational level. The installation of this the modular station and its equipment was started in April and operational by mid-May. This was only possible because of the modular concept. The construction could never have been completed in time if it could only be worked on during weekends, as would have been necessary if it was done on the existing production lines, as series production could not be interrupted. In addition to the facility and equipment, the processes for this station had to be carefully planned to ensure maximum efficiency.

Due to the low volumes and high variant-specific work content, it was calculated that the most resource efficient way to introduce the C350e would be to have as much of the work content practically possible done in the modular station, to avoid increases of complexity on the production line and to keep all non-standard work in the non-standard station. This would minimise time lost in the series production lines, as production time would not need to be sacrificed for vehicles that were not of this specific variant. If the work content would be incorporated in the series stations and a different variant vehicle was in that station, then no value-adding work would be done, leading to a time and efficiency loss. Avoiding this scenario was calculated as the most resource efficient approach, though as previously mentioned some work content like the installation of the HV battery, could only be done on the existing lines due to the practicalities of vehicle assembly. Simply put, some parts can only be fitted to a vehicle after some others.

Prior to the start of the Pilot, the Standard Work Instructions (SWIs) were drafted for each station and training provided to affected operators. As the Pilot would only be built on one shift, this limited the amount of training that needed to be completed by that time. The training of the 2nd and 3rd shifts would happen during the Implementation Step.

The sourcing of HV components is a topic that must expressly be considered during the formulation of the Roadmap for any HV implementation by local automotive OEMs. South African OEMs are all subsidiaries of larger multi-national manufacturers headquartered in America, Japan or Germany. The local management teams have little to no influence over the design of the vehicles they manufacture and are essentially contract manufacturing plants that manufacture to the specification that their international mother companies define. Local plants, if they have local procurement functions, do however have an influence over the amount of part numbers that are directly purchased. Depending on the decided level of vertical integration they can influence to some degree the increase or mitigation of the added product complexity brought by the HV implementation decision. The level of vertical integration decided on should be the best mix between cost and complexity mitigation.

The vast majority of high voltage components are not manufactured in South Africa and therefore have to be imported. The import of HV batteries specifically is very strict due to packaging and shipping regulations. Retrospectively it is easy to see that the Implementation Team for the C350e focussed too much on the complexities surrounding the import components and neglected to investigate in detail the timelines of the parts that would in fact could be manufactured locally. As the Pilot would be built almost exclusively with imported parts due to the tight timeline, the parts that would later be sourced locally under series production conditions (and specifically their readiness timelines) were overlooked at this stage and the impact on the Project timeline not realised.

The Change Implementation Roadmap that was created from the review of the partslist, with the focus on safety, facilities and equipment, processes and resource efficiency, as well as the components and supply chain was, as mentioned, not comprehensive enough to avoid project disruptions. A retrospective CATWOE analysis was done with members of the C350e Implementation Team for the purposes of this research (Appendix B - CATWOE Analysis: C350e Project) and the resultant root definitions were used to create a Risk:Impact matrix representative of the situation at the time. This matrix, as proposed in the conceptual framework, would have highlighted a key shortcoming of the project had it been codified, suggested and used at the time of the C350e planning. This shortcoming will be expanded on during the evaluation of the Pilot.

As envisioned in the Conceptual Framework specific areas of focus were investigated and catered for, even though the framework was not yet codified. These specific areas included safety, facilities and equipment, processes and resource efficiency, as well as components and supply chain. It is with this last aspect that specific focus, as codified in the framework, would have resulted in a better Roadmap, as it was due to this aspect that the Start of Production had to be delayed by a few weeks. A part of the Implementation Roadmap, as it would later be codified in the IFAT, is shown in Figure 69 and a summary of the Method Step validation can be seen in Table 19.

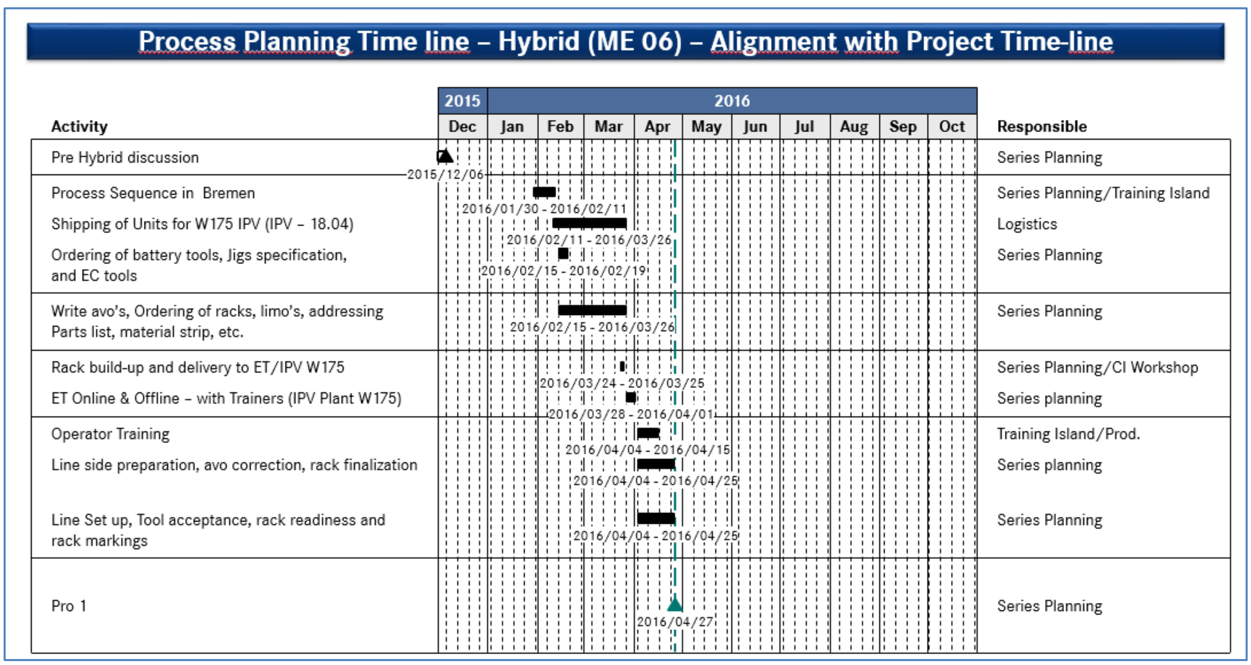


Figure 69: A portion of the C350 Implementation Plan at MBSA

Table 19: Validation of Step 2

Process nr	**IFAT requirement**	**Case Study observation and Notes**
R2	Early Adopters Managers	Acceptance of the technology diffused to Early Adopters. Various managers consulted and trained on benefits and dangers of HV technology.
A2	Coach managers Pursue root definitions Rate readiness and impact Mitigate complexity	Managers coached. CATWOE analysis and Risk:Impact assessment performed retrospectively. If done at the time, the SOP delay might have been avoided. Complexity mitigation through modularity.
S2	Detail planning. Consider applicable legislation, 'Best Practice' and trainer availability	Detailed safety planning. Approximately 1300 people identified for training at German HV2 level, with international trainers brought in and local trainers up-skilled to ensure sustainability.
F2	Detail requirements Consider power balance Plan import strategy	Facilities and equipment planned in detail, specifically since running production could not be halted. Innovative local solutions were pursued where possible, to reduce long-term international dependency.
P2	Complexity mitigating strategies: Modularity, Warenkorb/Shopping Cart. Consider volumes	A modular concept was followed, with the majority of work content being accommodated in the Hybrid Lift Station.
C2	Optimise Vertical Integration & Localisation levels. Plan Supply chains with HV constraints	The import of batteries was found to be extremely difficult, due to strong regulations. Localisation was neglected and later found to be a critical path, leading to a delay of the SOP.
O2	Implementation Roadmap	Implementation Roadmap was based an existing Change Year project timelines and an investigation of the Bill of Material.

6.2.3 Step 3: Pilot

Figure 70: Validation requirements of IFAT Step 3

After the Change Implementation Roadmap was created and the necessary activities for an early test were completed, the Pilot step was undertaken. The Engineering Trial (ET) was initially planned as an offline verification of the technical content of the project. The goal was to prove that the technical content could effectively be built in the plant and to use this 'quick win' as a way of targeting the Early Majority for diffusion.

In automotive production a Pilot is typically a small batch of test vehicles, built to prove technical content and to verify operator training. In the case of the C350e Project, it was necessary to do this as soon as possible, both to showcase the 'Strategic Intent' of the project, as well as to confirm what information, equipment, processes, etc. were missing. The IFAT did not exist at the time and as this was the first introduction of its kind, the Implementation Team wanted to do a trial as soon as practically feasible, to ascertain if anything was missing from the Change Implementation Roadmap.

Communication is the key change lever of this Step and numerous channels were used to highlight to the East London plant that the Hybrids were coming soon. The managers who were coached in the previous Step had disseminated the information to their departments and numerous company notices were made available to increase staff awareness. Additional copies of the German newsletter detailing aspect of international operator training were ordered and placed in the offices and on the production line, to further enhance the Project's visibility (Figure 71).

2 Werk Bremen | März 2016

Stimmen aus dem Werk

LEADWERK C- KLASSE:
QUALIFIZIERUNG SÜDAFRIKANER

Das Werk Bremen hat im Rahmen des Leadwerks C-Klasse die Hybrid-Qualifizierung unserer Kollegen in Südafrika übernommen.

Vom 01.02.-11.02.2016 waren insgesamt 24 Kollegen, aus den Fachbereichen Planung, Logistik und Montage aus dem Werk East London zur Planung der Produktionsabläufe und zu Qualifizierungsmaßnahmen zum Thema „Hybridumfänge W206" im Schulungszentrum in Bremen zu Besuch.

Einige Kollegen aus Bremen und East London berichten über die gemeinsame Zeit:

Detlef Töhl (Mitarbeiter, SEC/MC 206, Schulungszentrum)
„Die Mitarbeiter aus East London haben das vermittelte Wissen wie ein Schwamm aufgesaugt. Für uns ist der Austausch mit den Kollegen aus Südafrika etwas Besonderes. Und ganz nebenbei halten wir so unser Englisch fit!"

Lwazola Christopher Macklein (SEC/A-SA, Co-ordinator Trainer)
„Es ist mein erster Besuch im Werk Bremen. Ich bin fasziniert, wie diszipliniert die Mitarbeiter hier arbeiten. Innerhalb von zwei Wochen konnten wir sehr viel lernen. Ich freue mich, dieses neue Wissen mit nach East London zu nehmen, um es dort weiterzugeben. Für die Zukunft wünsche ich mir noch mehr Kooperation, weil ich mir sicher bin, dass gegenseitiges voneinander Lernen uns alle weiterbringt.

Eric Kalipa (SEC/A-SA, Co-ordinator Trainer)
„Fasziniert hat mich insbesondere die gute Arbeitssicherheit an dem Hybrid. Und mein persönliches Highlight waren die kalten, nordischen Temperaturen."

Ronald Tietjen (SEC/MC206, Meister Schulungszentrum)
„Die zwei Wochen haben wir intensiv genutzt, um unsere Kollegen zu qualifizieren. Es ist toll anzusehen, wie sich die Trainer aus beiden Werken anspornen, um das Projekt gemeinsam zum Erfolg zu bringen. So macht die freundschaftliche Zusammenarbeit viel Spaß und ist zudem sehr erfolgsorientiert. Mein Team freut sich jedes Mal, wenn der Flieger mit den Kollegen aus Südafrika bei uns landet."

Figure 71: Newsletter from Bremen, Germany

As the on-site safety training could not be completed before the ET units were built in March, the batteries that were installed into these units were not live. Live batteries could not be shipped to South Africa, because the personnel who would receive and warehouse them were not yet certified to do so under Daimler's safety protocol. Production operators were also not yet certified to install them. The warehouse was not yet set up to deal with HV components and safe quarantine equipment was not yet available. The decision to operate according to German legislation meant there was no way of using live HV components during the Pilot Step.

ET units are typically deemed to not meet Mercedes-Benz standards and therefore cannot be sold, so the cost of the pilot had to be taken into account by the Implementation Team. For this reason, it was decided to build only two units, one Left Hand Drive and one Right Hand Drive, to check the technical content of both while minimising the cost impact. The plan was to build the units offline in the manufacturing plant's 'Training Island', but the uncertainty of how the units would affect the production lines once integrated, prompted the Implementation Team to look at alternatives. Instead of the first phase of the Implementation Step (Production Trial 1) being the first units built on the existing production lines, there was an idea to build the ET "on-line". The Implementation Team did a detailed assessment of all production lines and assembly stations, to identify areas of potential impact if the ET units were to be built on the line. After reviewing the initial results and mitigating as much impact as possible (Figure 72), a proposal to build the ET units on the line instead of in the Training Island was presented to senior management (Figure 73). The Implementation Team wanted to avoid the risk of the higher number of units during the Implementation Step disrupting series production more than strictly necessary, by testing the facilities, equipment, processes and supply chains as early as possible. It was calculated that with all mitigation steps in place, the maximum disturbance to the series production would be the equivalent of approximately 20.5 series units lost per ET unit built. These 41 potentially lost units were less than 10% of the daily volume at the time. Although costly, the benefit of testing the ET units in an environment as close to series production as possible was deemed worth the risk, to avoid larger impacts later. Senior management approved the proposal and the ET units were built as close to series conditions as possible at the time. The work content of the modular Hybrid station had to be completed in the Training Island though, as the station was not yet ready for use and a 'dummy' (dead) battery had to be used to test the battery manipulator.

Hybrid Engineering Trial Potential Impact

Line	Planner	Minutes - Initial	Reason	Mitigation	Minutes - Mitigated
Trim 1	Mark	5	Subassembly of plug in harness to bumper	Drift allowance possible on Trim 1	0
Trim 2	Anthony	20	Battery in firewall before cockpit	Drift allowance possible until cockpit	10
Trim 3	Nyaniso	15	Battery manipulator	Verification of manipulatorn to be established	15
AGV	Steven	3	Routing of HV harness	Absolute concern on HV routing	3
Mech 1	Steven	5	Marriage concerns	Marriage absolute stopper	5
Mech 1	Duncan	15	Adaptor plate and pumps	Adaptor plate and pumps concern	15
Mech 2/3	Ian	3	Combi filling	Filling requirement. Build with dummy - no fill	3
Engines	Craig	5	HV harness fitment	Preparation in advance - parts availability	2
		71			53
		27.4	Units	Units	20.5

Figure 72: Analysis of the Engineering Trial's impact on series production

Hybrid Project

Start: 26/11/2015
End: 01/08/2016
Project Sponsor: Andre de Beer, SC/C-SA
Project Leader: Llewellyn Ikin, SC/C-SA (ICC)

	Training Island build	Build on line
Guarantee no line impacts	✓	
Verify AGV Frames for new engine mounts		✓
Verify Marriage Station processes for HV harnesses		✓
Verify operator collision points		✓
Check HV Battery manipulator		✓
Confirm HV Harness through conveyor to Engine line		✓
Verification of EC tools		✓
Confirmation of Line stations		✓
Testing of emergency response time for HV Battery containment		✓
Improved maturity and reduced risk of unit loss at PT1		✓

Project Proposal: ET Build to be completed on line

Our Passion Drives Us To Be The Best

| SC- C/ SA | L. Otto   Mercedes-Benz

Figure 73: The Engineering Trial proposal

A number of facilities and equipment were identified during the Engineering Trial that had to be either significantly improved or rectified before the Production Trials could start. Some of these were operational findings, specifically those that led to disruptions of the series production during the build of the ET units.

- The Hybrid Lift station still had to be installed and commissioned

- The Buffer management had to be reviewed to correct Body Variant identification
- The racking for the HV batteries had to be adjusted
- EDI links to some suppliers had to be verified
- A dedicated rework area for HV units had to be demarked
- Blast boxes still had to be bought to secure damaged HV batteries
- etc.

Some of these aspects were already included in parts of the C350e's project plan (Figure 74), but the Pilot step revealed further details that necessitated updates to the timing or extent of the measures. Yet other aspects were completely new and only found due to the team having built the units on the existing production lines. These and other activities were updated from the "Post Build Meeting" held by the Implementation Team at the time. Viewed retrospectively, if the framework had been codified at this time, the formalised Change Implementation Roadmap would have been updated to reflect these requirements.

Work package	Targets and Milestones	Responsible	Dates						
			CW11	CW12	CW13	CW14	CW15	CW16	CW18
PPD/FP	Implementing a designated steel warehouse racking system containing sprinkler systems to store HV batteries	V.Erasmus			△				
PPD/FP	Stand by battery hoist that will also be used for the removal of battery from unit	U. Daub						△	
LOG/P	Identifying and allocating a designated emergency storage location to store damaged /defective batteries	V. Erasmus					△		
LOG/P PPD.FP	Procure/manufacture emergency container to store damaged/defective batteries	V. Erasmus		△					
PPD/FP	Manufacture emergency trolleys to contain leaking / defective batteries.	H. Sansom							
LOG/P PPD/SP	Safety Signage for processes and facilities - Information, Mandatory, Prohibition & Emergency . Who will procure, areas to be identified and quantities	V. Erasmus A. Bain C. Holloway N. Matiwane I.Cassels		△					
LOG/P	HV Dummy batteries for mock drills and ET build	L. Otto						△	
HR/FIRE DEPT	Creating documented emergency response procedure and test its effectiveness	D.Benneck W.Blair Brown					△		
HRD	Train 12 fire fighters, minimum 2 wastemen employees, team managers and electrical specialists	M.Kuehnel						△	
HR/Fire PROD/ASSY	Mock drill to be conducted	C.Holloway A.Bain W. Blair Brown							

Figure 74: Safety activities for HV introduction

In terms of facilities and equipment, the ET was largely effective, but it was found necessary to delay the start of the PT1. This was initially planned in April, but the Lifter and High Station (Figure 75) could only be completed over the Easter break. While the construction of the facility and the installation of the equipment could be done while the series production was running, it was not possible to link it to the series buffers without stopping production and this could only be afforded during an existing break, as the loss of series production for an extended period was not viable. The PT1 therefore had to be delayed until mid-May.

Figure 75: The Lifter and High Station installation

Learnings from the Supply Chain proved to have the largest impact to the overall project tough. The principal outcome from the Pilot step review was that the project timeline would need to be changed and the Start of Production (SOP) slightly delayed. When the original timeline was formulated, the focus was largely on when the local production facility could be ready and by when the necessary safety training and equipment could be in place. It was not known at the time that one of the local suppliers had a longer lead-time and that, due to the criticality of the parts, the implementation of the project would have to be delayed.

As MBSA could only officially contract the local suppliers after the decision by Daimler AG and as the local suppliers could only contract their sub-suppliers after receiving their Tier1 contracts, the supplier lead-times did not support the project timeline. The delays in contracting and the implementation lead-time of the local suppliers influenced the project's critical path. The largest impact was from the wiring harness, the electrical cabling at the heart of modern automobiles. As the wiring harnesses of each Mercedes is customer-specific and delivered "Just-in-Sequence", it is not possible (in series conditions) to supply these parts via an import supply chain and Mercedes standards do not allow a project to receive a Quality Release or Delivery Confirmation without having thoroughly proven its series readiness. In a typical Change Year or Facelift project, a Quality Release would be given after a successful Production Trial and a Delivery Confirmation that allows units to be sold to customers, would be granted only after a second such trial has successfully proven the series conditions. These measures ensuring Mercedes quality standards, are in addition to each part needing to undergo special testing and individual part approvals. In the "Post-Build Meeting" it was found that the wiring harness supplier could only start supplying in series conditions by the second or possibly third Production Trial. The Implementation Team was forced to take the decision to delay the official Start of Production by one month and use the additional time to schedule a fourth PT for improved product and process maturity. Using imported parts would still be necessary for PT1, but since the wiring harnesses would not be approved for local use, it meant that these units could also not be sold to customers and that the cost of these units would be carried by the Project. This was necessary to comply with the stringent safety and quality standards of the Mercedes-Benz brand and was thus unavoidable.

The Pilot was quite successful and both units were completed without major unforeseen disruptions to the series production. In total the losses on the day were less than 5% of the daily volume and less than half of the deemed acceptable risk. The IFAT requires that once complete, the Pilot introduction should be evaluated by the Implementation Team and the Change Implementation Roadmap updated. The review should focus on which aspects are not yet ready for the full implementation and if this is not accurately shown in the Roadmap it should be updated accordingly.

After they reviewed the performance of the Engineering Trial in the "Post Build Meeting", the Implementation Team updated the project plan with the findings from this step. The 'Quick Win' was celebrated together with the German colleauges (Figure 76) and the timeline was updated to reflect the delay of the PT1 and SOP (Figure 77). A summary of the validation of Pilot step can be seen in Table 20.

Figure 76: German and SA colleagues celebrating a successful Pilot build

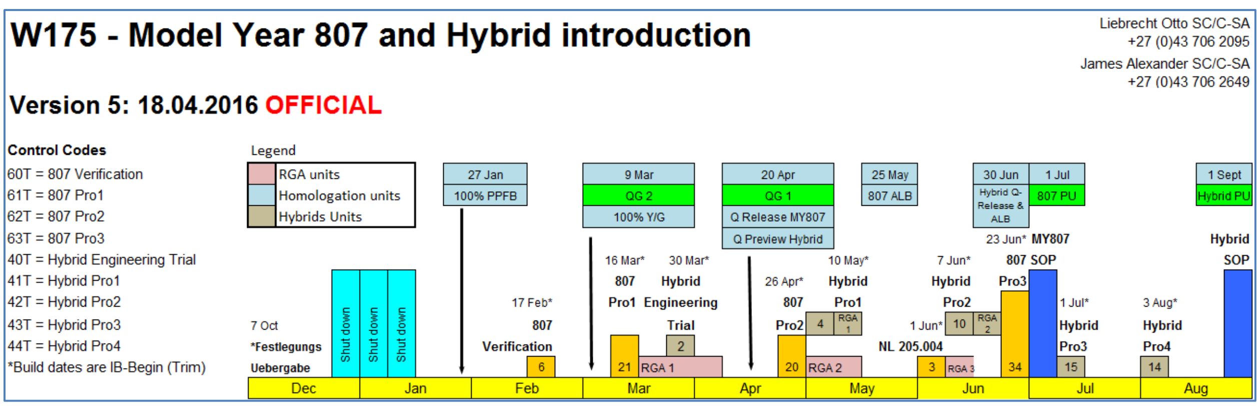


Figure 77: The updated project timeline after the Pilot step

Table 20: Validation of Step 3

Process nr	IFAT requirement	Case Study observation and Notes
R3	Early Majority	Quick win of Engineering Trial diffused the technology to the Early Majority.

Process nr	IFAT requirement	Case Study observation and Notes
A3	Communicate critical aspects. Highlight early successes. Mature Roadmap	Critical aspects of safety and training effectively communicated with newsletters etc. Early success of Engineering Trial highlighted and celebrated, specifically the better than expected on-line ET build. The Roadmap was matured through findings during the ET.
S3	Safety Qualification. Test training and assembly process familiarity	Training was done in Germany and tested during the Engineering Trial, though live batteries could not be used due to the tight timeline. Logistic staff that should receive the HV battery could not be trained in time.
F3	Early testing of facilities and equipment where available	The Lift Station was not yet operational, so the work content of the modular cell was tested in the 'Training Island'. A 'dummy' battery was used to test the manipulator on the line.
P3	Early testing of new processes. Efficacy focus	To test series processes as far as possible, the decision was made to build the ET on the existing production lines. This proved very effective and more efficient than initially thought.
C3	Early testing of Supply chain and Suppliers. Part Availability focus	Through the early ET it was found that the local wiring harnesses would not be ready in time for the SOP and a small delay would be required to meet international Mercedes-Benz quality standards.
O3	Effective Trial Build Solidified Quick Win Lessons Learnt Matured Roadmap	The Engineering Trial was very effective. Two early-stage units were built, largely on the existing production lines. Shortcomings of the original Roadmap were highlighted and the project timeline could be adapted early enough to keep to the original Vision of customer units by 3rd Quarter of 2016.

6.2.4 Step 4: Implementation (Iterations 1 – 4)

Figure 78: Validation requirements of IFAT Step 4

Following the success of the Engineering Trail, the project proceeded with what would be codified as the Implementation Step. The Change Implementation Roadmap called for an approach that is typical of automotive OEMs, namely a phased introduction with parallel production of the older models. The C350e was initially planned to be introduced in three separate Production Trials (PTs), all serving as iterations of the implementation, while the series production of the existing C Class models continued as before. After the ET the SOP was slightly delayed and a fourth PT was added for increased maturity. In contrast to the ET, the Production Trials are not a small pilot, but rather the full implementation of the new technology in the existing production lines. After the Production Trials, the official "Start of Production" would be signalled and the factory would be deemed ready to produce in series conditions at peak volume.

The targeted group of this Step is the Late Majority and the key change lever is Resistance Management. The literary 'chasm' had been crossed at this stage, with the new HV technology having diffused to the Early Majority during the ET phase of the Pilot Step. In the Implementation Step, the aim is to convince the Late Majority and get them on-board the project.

While the delay of the PT1 was not helpful in this regard, the better than expected Engineering Trial results were repeatedly highlighted and the High Voltage training provided reassurance to the employees still uncertain of the dangers of the technology.

Regular senior management briefings (Figure 79) and regular plant-wide communication emphasising High Voltage safety (Figure 80) served two purposes, namely reaffirming to the entire organisation that the senior management was still committed to the project and constantly reminding all employees to be vigilant about their safety in the new environment. Regular news articles highlighting the investment and job creation (Appendix A - C350e in local and international news) also helped to reiterate the company's commitment and helped convince the Late Majority of the benefits for the plant and the region.

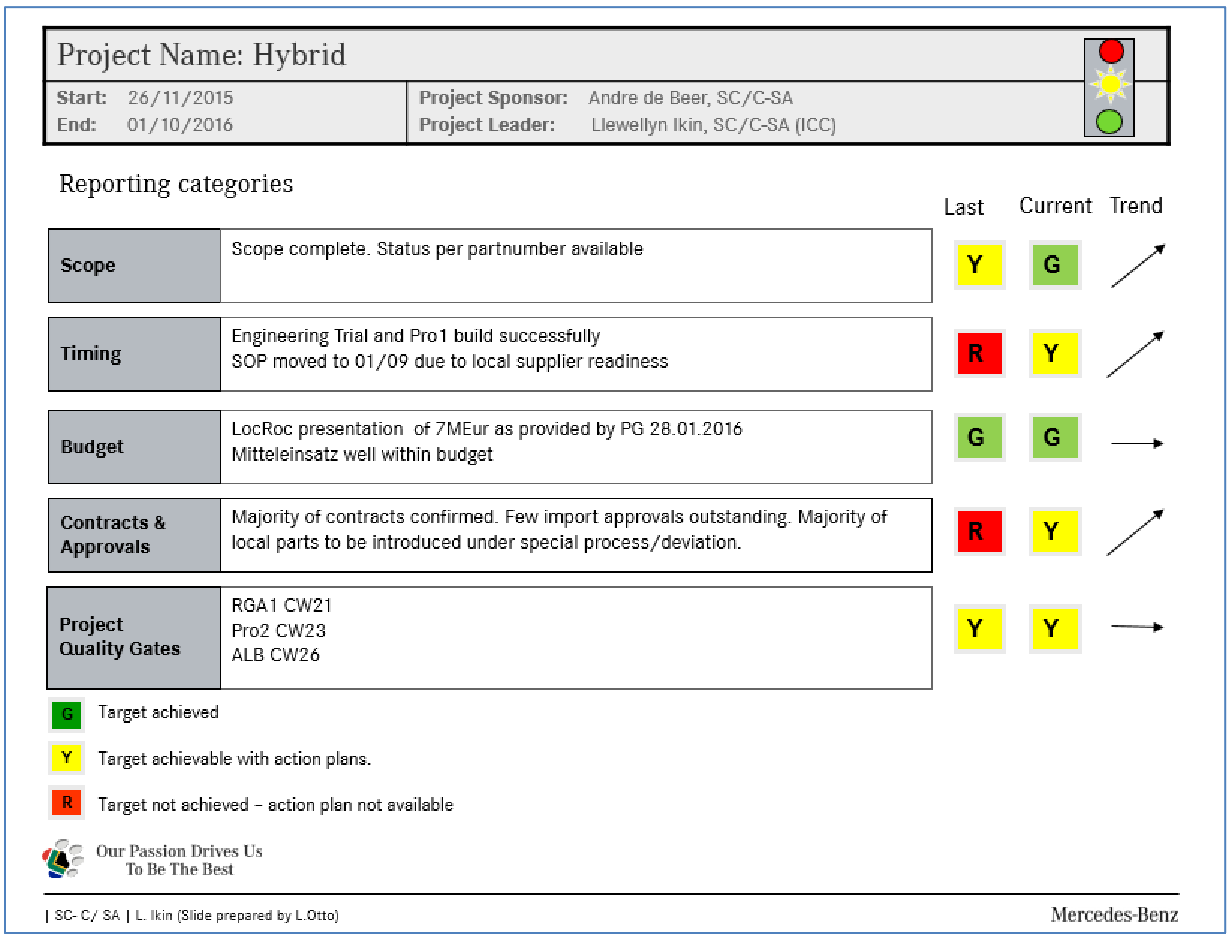


Figure 79: Regular feedback to the project Steering Committee and Sponsors

Mercedes-Benz South Africa

COMPANY NOTICE

SUBJECT : HYBRID SAFETY MEASURES: HV-1 INFORMATION

The new C350e Plug-in Hybrid vehicle currently produced in Plant requires stringent safety measures, as the car uses a very unique and powerful High Voltage Lithium-Ion Battery.

Due to this, the following safety measures must be followed when producing these units:

- Please note that no one is allowed to work on, or assemble these cars without first attending High Voltage training (HV2).
- In a case of rework after a hybrid unit has rolled-off the Mech3 line, the High Voltage Components must be powered down by a qualified Electrical Hybrid Specialist.
- As soon the car is customer ready, no one should work on it without permission.

HV2 training sessions on High Voltage-have been arranged for all Assembly Shopfloor employees, as well as all staff from other divisions that support / service Assembly to ensure that all individuals who will be working with the Hybrid vehicle receive proper training and knowledge.

Employees are urged to apply the knowledge acquired from this training to ensure that we meet the highest international safety standards, setting the benchmark in South Africa for safety as we do with quality.

A. VAN DER MERWE

G. LUCWABA

DISTRIBUTION:	ALL EMPLOYEES	DATE:	04/05/16	REF NO:	CN021/2016
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Mercedes-Benz

Team Weekly

Information for Communication to Shopfloor

19 May 2016

Company Notices

CN024.2016 : In memory of Ludwe Cingo

CN025.2016 : PBR Calculation and brief

CN122016 : EBP Functional approval requirements to be adher

Vacancies – Zwartkop

1 Manager Marketing Communications; Closing date 19 May 2016.

2 Specialist Accounting & Tax (Mercedes-Benz Cars); Closing date 2

Safety

Hybrid equals high voltage

- The voltage in most hybrid batteries can deliver a lethal shock, much li
- High voltage cables in hybrid vehicles are color-coded to warn you of t voltage cables are color-coded orange.
- Avoid contact with these cables unless the high voltage battery at the back of the vehicle has first been disconnected.
- All hybrid units have a safety switch or disconnect mechanism to disconnect the battery from the vehicle's electrical system.
- Please note: When witnessing an incident involving an HV battery please contact the responsible HV3 Electrical Specialist and dial 44 (Emergency Response Extension) to report such an incident.

See the accompanying supplement for further information.

Mercedes-Benz South Africa East London Plant 1 TW Pack_16_May_2016

Figure 80: Regular plant-wide communication emphasising High Voltage safety

Safety training was confirmed, as increasing numbers of units were built during the iterative Production Trials. All three shifts were given the opportunity to build with live HV batteries and each given opportunity to do rectifications and learn from small assembly mistakes. PT1 was built immediately after the Lifter and High Station were completed in May and small improvements were made with regard to buffer management for greater efficiency in PT2. PT3 was largely representative of series conditions and found to be both effective and efficient, also validating the production processes. The wiring harnesses for PT1 had to be imported and manually sequenced, but from PT2 the series local supplier was ready to supply. The local harnesses were approved in PT2, with further verification and maturity improvements in PT3 and PT4.

To validate the effectiveness of the Implementation Step is comparatively simple in this retrospective study, as it can be clearly proven that prior to the C350e Project there were no Hybrid vehicles being built in Africa and to date MBSA has produced thousands, exporting to countries like the UK, Japan and even Germany. While the IFAT was not codified at the time, it was nonetheless the methodology followed by the Project Leader and Implementation Team and its effectiveness therefore is beyond question. By the end of 2016, only a few months after implementation, MBSA had already produced over 1500 Plug-in Hybrid C350e's, with the vast majority being for the international market.

The target of introducing this technology within a year of the implementation decision was met. In September 2016 MBSA celebrated the official Start of Production of the C350e, quickly ramping up to near peak volume (Figure 81). Within less than a year, MBSA had gone from no High Voltage production, to a key producer of HV vehicles in the Daimler network and the only producer of HV vehicles in Africa. More than a thousand employees and contractors had been trained in HV safety and more than a thousand units produced, all in less than a year. The effectiveness of this project is clearly beyond question.

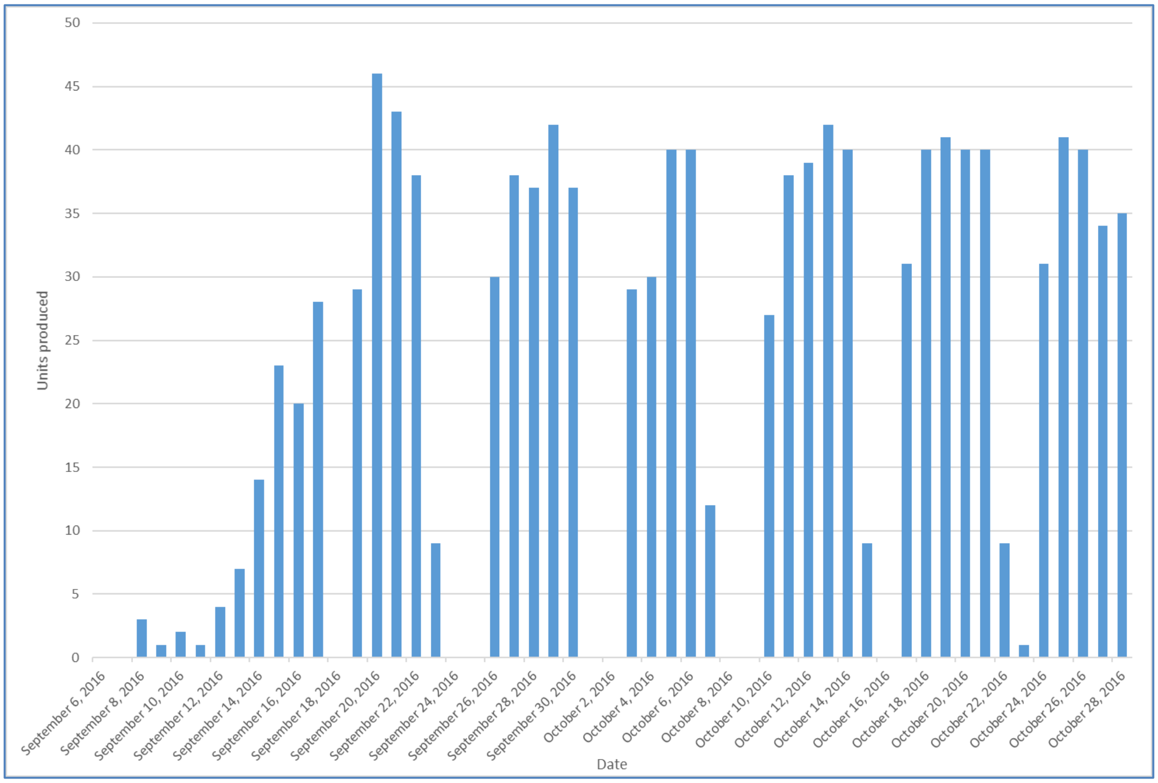


Figure 81: Production of the C350e immediately after SOP

To determine efficiency is more complex, as one needs to look at the factors considered in automotive production to be indicative of efficiency: time, cost and quality. These can be measured in various ways and each organisation likely would use its own metrics. For the purposes of this study, historical and comparative data from MBSA is used to validate these measurements.

Time in this context can be measured as the amount of series production time lost during trial builds i.e. the Engineering and Production Trials. Figure 82 shows the time lost during the Pilot (ET) and Implementation (PTs) Steps of the C350e Plug-in Hybrid Project. As the Engineer Trial units were built on the line, significant time was lost for series production. Typically this first build would happen off-line, but doing this on the existing production lines proved very valuable, as it allowed the Implementation Team to assess the areas impacted and resolve key issues before the first Production Trial. While PT1 doubled the amount of units, it had only half the lost time of the ET, showing that a significant improvement was enabled by the early lessons from the ET. By the second Production Trial in June the Implementation Team had completely eliminated the impacts. No time at all was lost due to Hybrid-related topics during PT2.

There was an impact during the third PT, when the Night Shift built the Hybrids for the first time, but this was quickly resolved with the support of the Implementation Team members who were on-site that evening, resulting in only 4 minutes of production time lost. PT4 also caused no time delays, making the final introduction of the C350e in September 2016 one of the most successful projects in recent years for Mercedes-Benz SA, with regard to production disruptions.

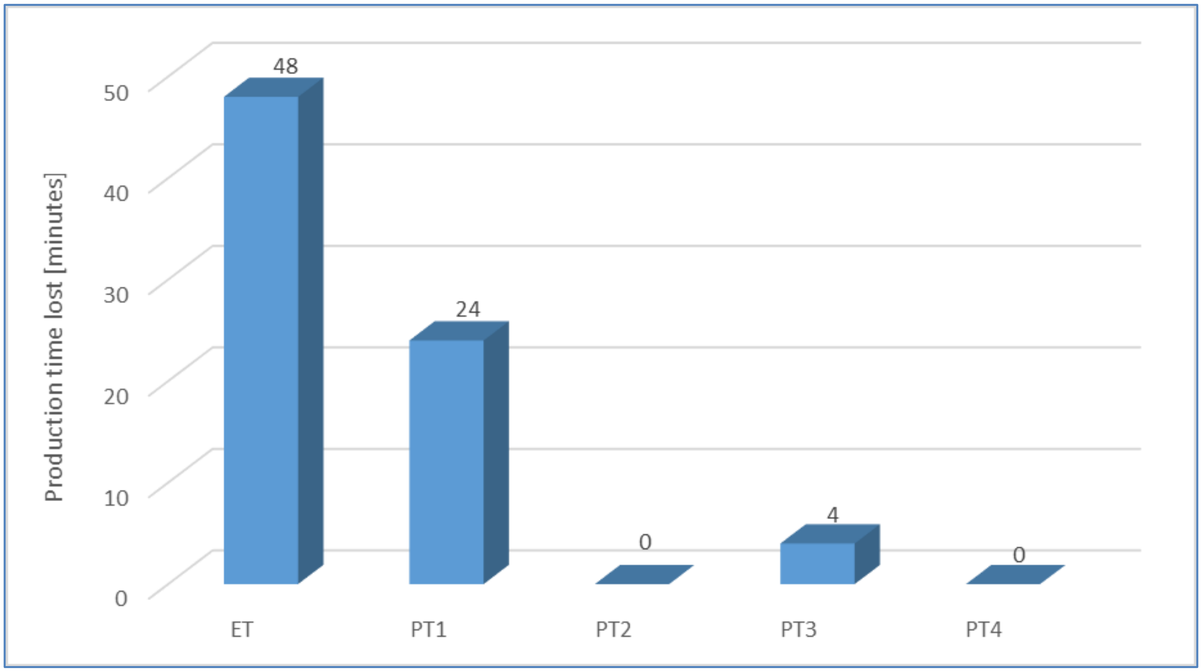


Figure 82: Series production time lost during the Production Trials

The budget provided for the C350e was aimed at guaranteeing effectiveness within the allowed timeframe. This effectiveness and specifically the timing was given clear priority over cost, due to the criticality for the organisation that MBSA be able to build this variant and supply the market by the required date. The major cost factors in the C350e Hybrid Project were the facility and equipment upgrades, costing millions of Rands, with the actual PTs having negligible cost impacts aside from lost production time. Aside from production time lost, the costs of the PTs were deemed so small that it was not recorded, though it is recommended that for future implementations, where cost efficiency will likely play a larger role, this criteria receives more focus.

Though there was significant time pressure, Mercedes-Benz would never compromise on Quality. For comparative purposes and for measuring efficiency as envisioned in the IFAT, quality can be measured as the number of deviations from the expected series quality output or target of the Mercedes-Benz production line. The faults are measured per hundred units (fph), with any customer-relevant failure counting against a unit. The ‘Voice of the Customer Audit’ (VoCA) is conducted by auditors from the Quality Management department and their findings form one of the fundamental pillars of approving a project’s Quality Release and Delivery Confirmation. A strict target of 100fph, only one fault per vehicle, was set for the Hybrid Project, with zero tolerance for High Voltage related failures. The PT1 and PT2 did not meet these standards (Figure 83). The PT1 units were already classified as not customer ready, but rectification and further quality checks had to be done on the PT2 units before they were deemed ready for customers according to Mercedes standards. Significant focus was placed on Quality related activities and the PT3 showed improvement, with zero faults found during the PT4 (Figure 83).

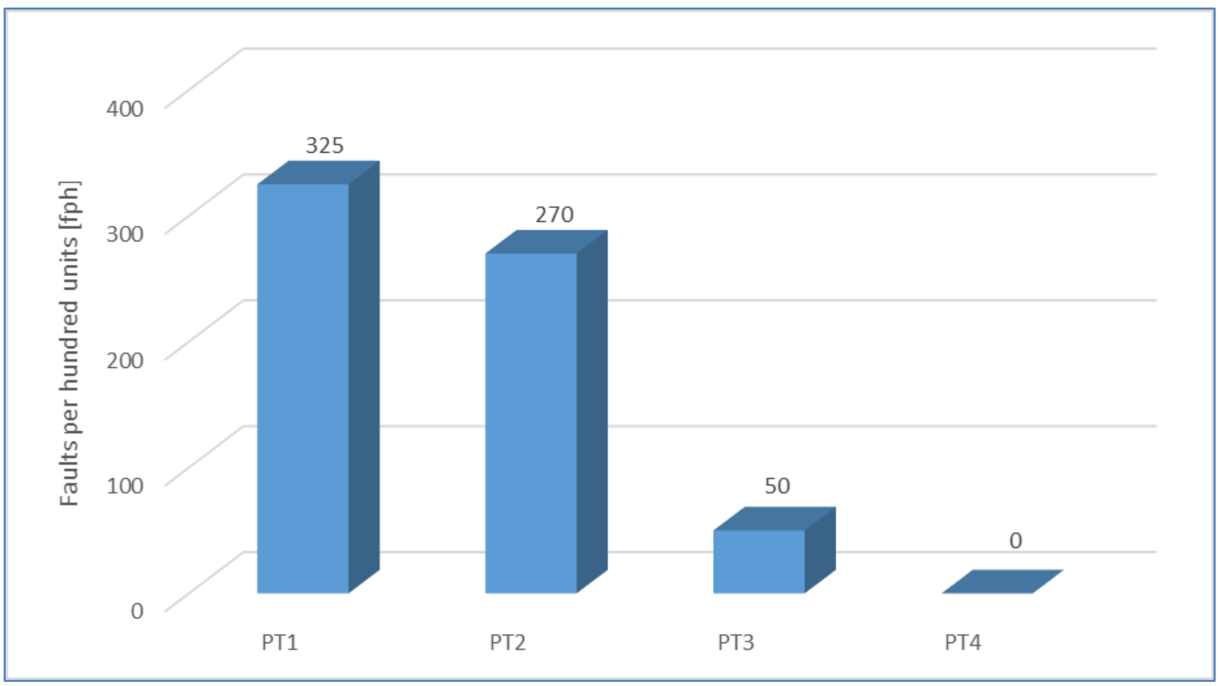


Figure 83: Voice of the Customer Audit findings

The Implementation of the C350e Project has been qualitatively and quantitatively proven both effective and efficient. A SOP date in the 3rd Quarter of 2016 was achieved, also meeting the compulsory quality and safety requirements of Mercedes-Benz. A summary of the validation can be seen in Table 21.

Table 21: Validation of Step 4

Process nr	IFAT requirement	Case Study observation and Notes
R4	Late Majority	Better than expected ET result used to diffuse the innovation to the Late Majority.
A4	Manage resistance Use Opinion Leaders for support	Regular ‘Company notices’ used to highlight HV safety and company’s commitment to it. Media articles were used instead of Opinion Leaders, to leverage broad support.
S4	Verify training Higher volumes and series conditions	Training was verified across all three shifts, with increasing unit volumes with the iterative Production Trials.
F4	Test Facilities and Equipment for series production conditions	Lifter and High Station tested in PT1 and improvements made to buffer management for PT2.
P4	Verify and improve new processes iteratively	Iterative improvements to production processes, with PT3 largely representing series conditions.
C4	Test component sourcing for series production conditions	PT1 built with imported harnesses, with local harnesses by PT2. Live HV batteries used from PT1.
O4	Evaluate iterative Implementation Trials. Confirm series Production Readiness	Effectiveness and efficiency proven in PT1-PT4, both qualitatively and quantitatively. Series production readiness confirmed and objective of official Start of Production in Q3 2016 reached.

6.2.5 Step 5: Improve

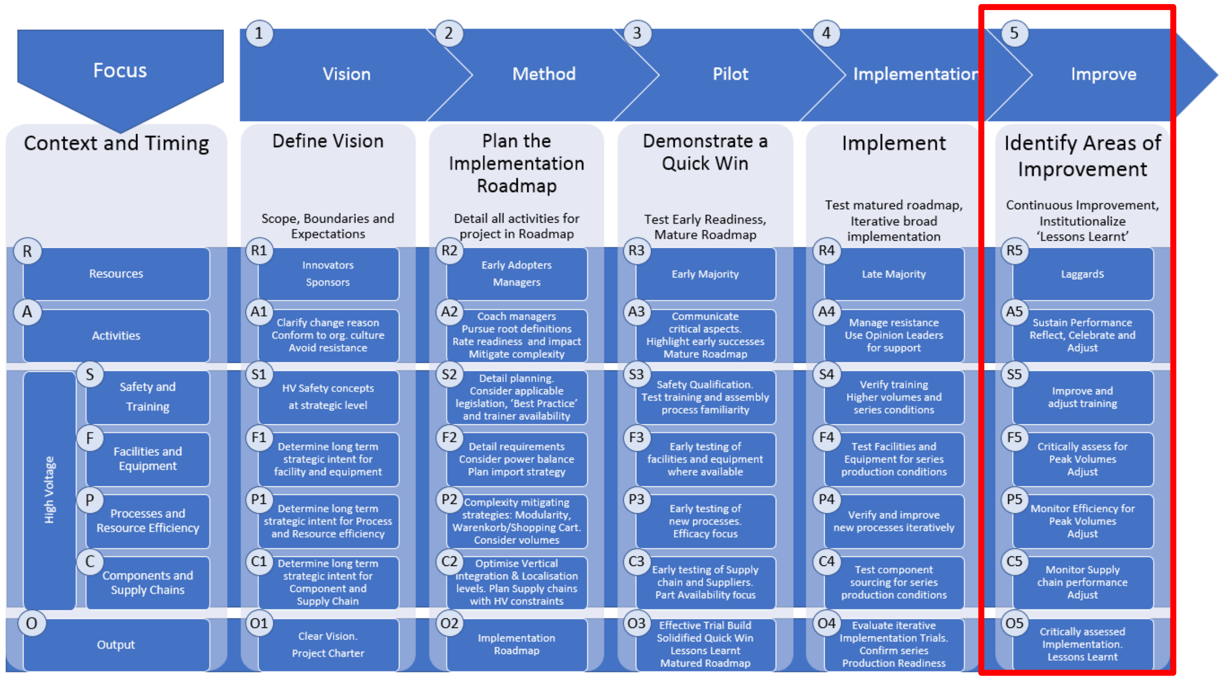


Figure 84: Validation requirements of IFAT Step 5

The last step of the Implementation Framework for Automotive Technology is to Improve. The key objective is to identify areas of improvement for future projects. The targeted group is the Laggards and the key change lever is Sustained Performance. Through the record fast implementation, MBSA strengthened its reputation in the Daimler network as a factory that rises to a challenge and the organisational culture was again bolstered by the success. The Laggards had little choice but to accept the Hybrid variant once production was at series volumes and regular media article were praising the company. After a while the variant was seen as just another C Class and almost all traces of resistance disappeared. This was supported by regular refresher training sessions, as well as incentive drives allowing staff from the factory to drive the C350e for a few days at a time to experience the product. This helped to sustain the performance and support future implementation projects.

Though the iterative maturity loops of the ET and PTs, many of the gaps in training could be found and corrected. By up-skilling local trainers, future HV training could be done locally for new staff. The facilities and equipment proved effective, though it was found that efficiency is strongly correlated to volume. If production volumes reduce, then the personnel at the High Station were not fully utilised, so a different concept had to be investigated for if this situation later materialised. A major lesson learnt in this Project was that not enough focus is placed on suppliers during implementation projects. Typically the factories look inward and reflect on which facilities, equipment or processes they need to facilitate an introduction, but vital outside influences are overlooked. To improve on this, a local Part Readiness organisation was formed for the next major project at MBSA, the Next Generation (new model) C Class. This team of localisation experts would focus specifically on the local suppliers, their part approvals and their delivery timelines, to ensure this R10billion project is not also postponed due to a lack of supplier readiness.

A summary of Step 5 Validation can be seen in Table 22. Many lessons were learnt in the C350e Plug-in Hybrid project, certainly chief among them was that there is a need for a codified framework detailing how to introduce HV technology into existing automotive production lines. Until the start of this study, no such framework existed and the Implementation Team felt strongly that a documented process could have greatly aided the implementation. This was the start of the Implementation Framework for Automotive Technology and hopefully something that will contribute to improving the competitiveness of the South African automotive industry.

Table 22: Validation of Step 5

Process nr	**IFAT requirement**	**Case Study observation and Notes**
R5	Laggards	The effective and efficient implementation, together with positive media attention served to diffuse the innovation to the Laggards.
A5	Sustain Performance Reflect, Celebrate and Adjust	By celebrating the project's success and giving staff the opportunity to experience the new project, the performance was sustained and the organisational culture strengthened for future projects. Major lessons were learnt and a Part Readiness team created for future implementations.

Process nr	IFAT requirement	Case Study observation and Notes
S5	Improve and adjust training	ET and PTs served to iteratively improve training. Local trainers were upskilled to facilitate future training on-site.
F5	Critically assess for Peak Volumes Adjust	Facilities and equipment found to be largely effective and efficient.
P5	Monitor Efficiency for Peak Volumes Adjust	Production processes found effective, though efficiency was found to be volume dependent. If volumes dropped, the High Station personnel would not be efficiently utilised and alternatives would have to be investigated.
C5	Monitor Supply chain performance Adjust	The main lesson learnt from the project was related to suppliers and supply chains. Localisation focus was greatly improved for future projects.
O5	Critically assessed Implementation. Lessons Learnt	The C350e Project was both effective and efficient, with many lessons learnt for future implementations. The largest contribution is likely the inspiration for the IFAT.

6.3 Summary of Verification and Validation

The project had proven itself both effective and efficient, while maintaining all the necessary pre-requisites (Figure 85). The introduction date in the 3rd Quarter of 2016 was reached, with over 1500 unit produced by the end of the first year, proving the project's effectiveness. The ETs and PTs proved the efficiency in terms of time and quality, while safety remained uncompromised and paramount. High voltage technology had been successfully introduced to the production lines of Mercedes-Benz South Africa in a safe, effective and efficient way, guided by the principles codified in this study. This successful implementation demonstrates the applicability of the IFAT to high voltage automotive manufacturing.

	Effectiveness	Efficiency		Pre-requisites
	Units produced (#)	Time (min lost)	Quality (fph)	Safety, Health & Environment (qualitative)
Pilot Engineering Trial	2	48	not measured	No live HV components
Iteration 1 Production Trial 1	4	24	325	No live HV components
Iteration 2 Production Trial 2	10	0	270	Safety training for all affected staff & contractors. Live HV components introduced – zero safety incidents
Iteration 3 Production Trial 3	16	4	50	Live HV components introduced on Night Shift – zero safety incidents
Iteration 4 Production Trial 4	14	0	0	Live HV components across all shifts – zero safety incidents

Figure 85: Evaluation framework applied to the C350e Hybrid Project

6.4 High Voltage recommendations for future implementations

In alignment with MBSA's Chief Electrical Specialist, a number of High Voltage related recommendations can be made from lessons learnt through the implementation of the C350e Plug-in Hybrid in East London. Table 23 summarises these HV-specific learnings, with the recommendation that they be specifically considered in future projects at the Method Step, regardless of whether they were found in the preceding CATWOE analysis or not [245].

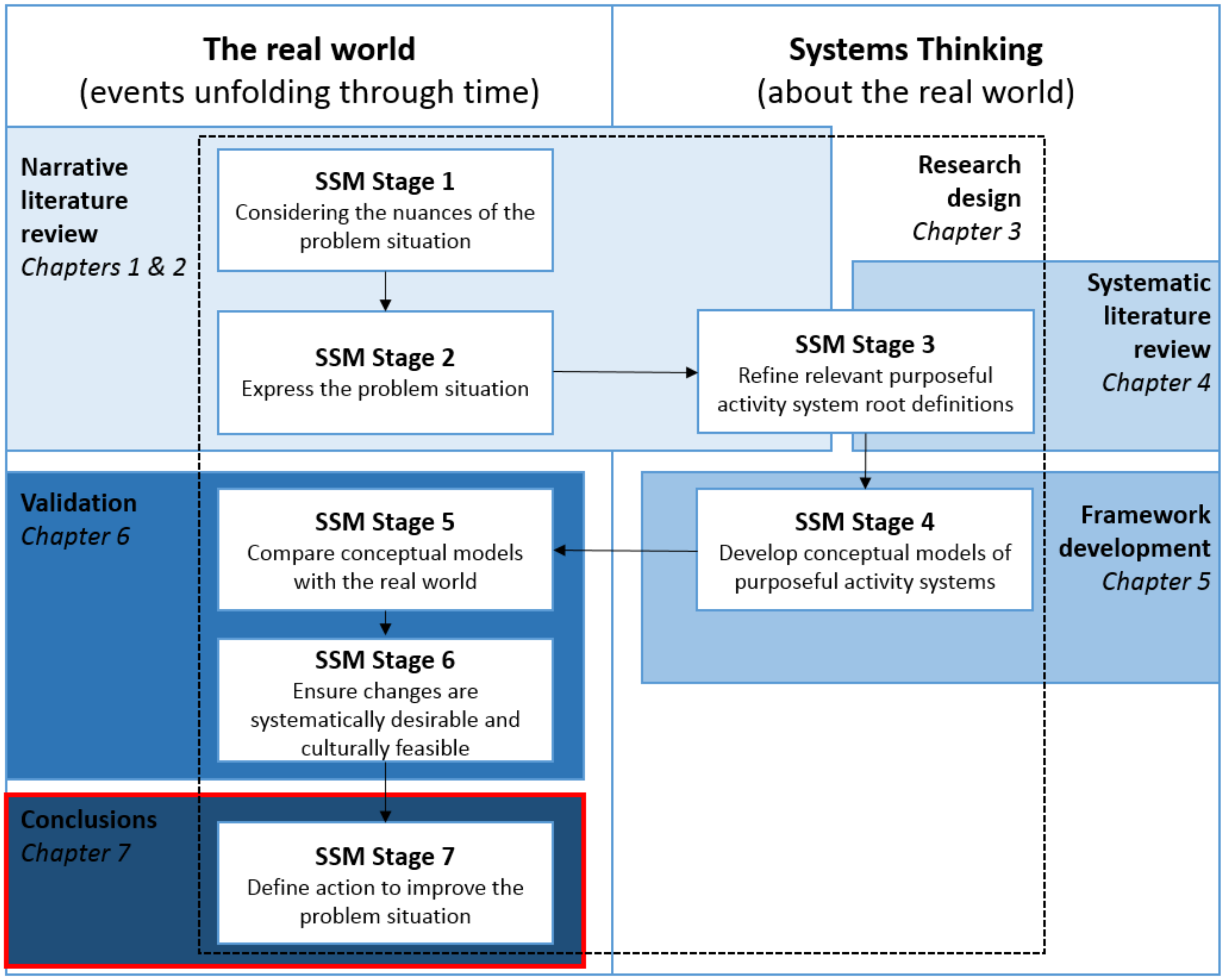
Table 23: High Voltage recommendations for future implementations

HV Focus area	Area of application	Recommendation for future implementations
Safety and Training	Legislation	Training at minimum needs to adhere to all local legislation/regulations where applicable. In locations where there are no local requirements, or where local requirements are not on par with international best practice, the recommendation should be to look at the VDE and ECE regulations.
Safety and Training	Training providers	In developed countries, training providers might be relatively easy to find e.g. TUV in Germany, but in many countries this may not be the case. In these examples, the recommendation would initially be to use an accredited international provider, to ensure the correct standard of training and to avoid change resistance due to safety risks. Care should be taken not to create a long-term dependency, so local trainers should be empowered as soon as practical. This will support the training of new personnel and refresher training of existing personnel. Untrained staff should not be allowed to work on live vehicles or even components, as accidents during the early project phases can completely derail the implementation.

HV Focus area	**Area of application**	**Recommendation for future implementations**
Safety and Training	Emergency response	Factory emergency response (incl. First Aiders) should be trained on electrical shock treatment (e.g. defibrillation), as well as treatment of chemical impacts. On-site and/or local firefighting units should receive Lithium-ion chemical fire training.
Facilities and equipment	Safety equipment	Apparatus that may be required include - Defibrillation machine (in case of severe shock) - Rescue hook (to pull a person away from a live connection without placing the rescuer in danger) - Protective gloves (e.g. EN 60903.2012 class 0) - Arc flash protective jacket (e.g. EN ISO 11612) - Face shield & helmet - Voltage meters - Blast boxes (for damaged batteries) - Hand and eye wash stations - etc.
Facilities and equipment	Safe storage	In addition to the blast boxes, it is recommended to have dedicated external areas for the emergency storage of damaged batteries, to prevent chemical spillage in production or warehouse locations. This should be augmented by barriers inside the affected areas to prevent damage to batteries. Fire detection and sprinkler/suppression systems are also recommended in the warehouse section to avoid fires spreading to other components or areas.
Processes and resource efficiency	Vehicle rework	It is recommended that dedicated High Voltage rework bays be made available, to ensure reworkers with the correct level of training are the only ones working on these units. Special signage for relevant units should also be looked at. In addition, it is recommended to have a quarantine area for fully built units that are at risk of ignition due to faulty installed components or process failures (e.g. internal fault with a HV battery or a screw accidentally through a HV harness).

HV Focus area	Area of application	Recommendation for future implementations
Processes and resource efficiency	Modularity	To reduce complexity and to support resource efficiency in the situation of a low-volume implementation, the project team can look at sourcing assembled components instead of assembly in-house and/or can look at a modular station decoupled from the existing production lines, to absorb some of the work content.
Components and supply chain	Packaging and Shipping	Many locations have special requirements for the shipping of high voltage components. Logistics companies should be consulted to ensure compliance with packaging requirements. Care should also be taken to understand limitations on airfreight as this could influence stock-keeping decisions. There may also be limitations on the amount of batteries that can be shipped at any given time and/or stacking heights in containers or warehouses – this should again be check with relevant experts.
Components and supply chain	Reverse logistics	Non-conforming or damaged batteries pose a unique challenge that need to be investigated in each location. Safe rectification or disposal on-site may not be possible everywhere and ways to return batteries to original manufacturers should be looked at. It is recommended that an in-country disposal and recycling facility be set up wherever possible, as Lithium-ion batteries cannot be sent to landfill and reverse logistics is not always possible.
Other	High Voltage organisation	It is recommended to install a High Voltage responsible structure with representatives of all relevant departments, specifically Production areas, Engineering and Logistics. Where the factory operates across multiple shifts there is recommended to be HV experts across all shifts to ensure safety remains paramount.

7. CONCLUSION



7.1 Revisiting the original Problem Statement

Manufacturing has been fundamental to prosperity around the world for centuries. It has contributed and continues to contribute to the growth of wealth, power and position of nations. It is the backbone of modern industrialised society and an important cornerstone of the world's economy. Manufacturing systems have evolved over the centuries though, shifting from one paradigm to the next. In recent years, competition has become truly global. The speed with which companies need to adapt to market requirements and with which they need to adopt new technologies is unprecedented. Companies that do not adapt quickly enough risk their continued existence.

There often remains a gap though, between the inherent values of a technology and the ability of organisations to effectively put it to work. With mounting global competition, the gap between a technology's promise and achievement is a major concern for all companies.

When Daimler AG instructed Mercedes-Benz South Africa to start producing the C350e Plug-in Hybrid, the East London factory was given less than a year to introduce a complex, potentially dangerous new high voltage technology and to deliver a product meeting international Mercedes-Benz quality and safety standards. While there have been many frameworks put forward to manage change and complexity, there was no practical and measurable framework available to guide the manufacturing plant to introduce a high voltage technological change. For the introduction of the C350e, the production lines required complex changes and the Implementation Team needed a framework with which to implement it safely, effectively and efficiently.

7.2 Reflecting on the Research aim and objectives

The aim of this research was to create the first practical and measurable linear framework to facilitate rapid implementation of high voltage technology in automotive manufacturing plants to support global competitiveness. To do this the researcher needed to understand the complexities of change management and complexity management, specifically the aspects applicable to introducing technological change to automotive production lines. Key elements necessary to aid manufacturers with these type of implementation projects were identified and focus placed on the high voltage technological change needed to produce hybrids and electric vehicles (EVs) in order to formulate the conceptual framework.

It was the objective of this dissertation to conceptualise, verify and validate a practical and measurable linear framework to facilitate rapid implementation of this type of technology, to strengthen manufacturers' competitiveness in the global automotive industry. It is hoped that this will be the foundation for a framework for the automotive sector, similar to what the Consolidated Framework for Implementation Research (CFIR) [26] is in the healthcare sector. The aim, similar to the CFIR, was to embrace rather than replace the existing literature and body of knowledge.

The Implementation Framework for Automotive Technology (IFAT) created in this study consolidates a myriad of different yet overlapping concepts and bridges their individual shortcomings to offer an overarching solution to introducing a new high voltage technology to an automotive OEM's production lines safely, effectively and efficiently.

By creating a practical and measurable Implementation Framework, it was the intention of the author to help equip manufacturers to participate competitively in global automotive manufacturing and supply chains of high voltage hybrid and electric vehicles and to strengthen the high voltage manufacturing skills of these manufacturers, particularly those in the researcher's home country of South Africa.

The research objectives met in this study were to:

- Obtain a comprehensive understanding of Change Management, Complexity Management and Implementation theory within the context of high voltage automotive technologies.
- Develop and verify a conceptual framework to introduce high voltage technological change in the existing production lines of automotive manufacturers.
- Validate the framework with data from Mercedes-Benz South Africa's pioneering C350e Plug-in Hybrid Project.
- Provide a validated, practical framework to introduce and implement High Voltage technology, maintaining the identified pre-requisites and automotive standards, while measuring associated impacts to production

7.3 Reflecting on the Methodology

A Soft Systems Methodology approach was followed by the researcher to meet all these research objectives. Where Systems Engineering focuses on techniques and methods of engineering *hard* systems to meet necessary objectives, SSM was specifically developed to handle the complexities of social/human situations, the so-called *soft* systems that cannot effectively be addressed by a *hard* Systems Engineering approach. Soft Systems Methodology is very well suited to management-related problematic situations in the organisational context [41]. *Hard* systems thinking could not account for the real-world impact of often poorly understood human activities and so led to the creation of *Soft* systems thinking and SSM. The development of the Soft Systems Methodology signalled a shift away from 'hard' ideas to 'soft' systems thinking (Figure 7). Models were used to facilitate discussion and debate about improving the status quo, rather than trying to perfectly represent reality. The objective changed from trying to create a system that can achieve a pre-determined goal, to learning about the real-world situation in order to effect an improvement to that situation. SSM shifted the focus from a systemic world to that of a systemic process of inquiry.

The SSM approach was well suited to the Research Aim and Objectives, as the framework that was developed in this study would not have been possible through a 'hard' Systems Engineering Approach. The progression of the dissertation matches closely in layout to the structure of the 7 stages of SSM. First the nuances of the problem situation were considered and described, next the research aim and objectives were clarified (Chapters 1 and 2, corresponding to SSM Stages 1 and 2). Thereafter the design of the research was discussed (Chapter 3) and the activity root definitions were defined through the Literature Review (Chapter 4 and SSM Stage 3). The Research Requirements were detailed and the Conceptual Framework was then developed, specifically the 5 Steps of the Implementation Framework for Automotive Technology (Chapter 5 and SSM Stage 4). The conceptual IFAT was then first verified against the Research Requirements and subsequently validated against the C350e Plug-in Hybrid project of MBSA (Chapter 6 and SSM Stages 5 and 6), before being concluded and future work to improve the situation discussed (Chapter 7 and SSM Stage 7). SSM was therefore the perfect approach for this study.

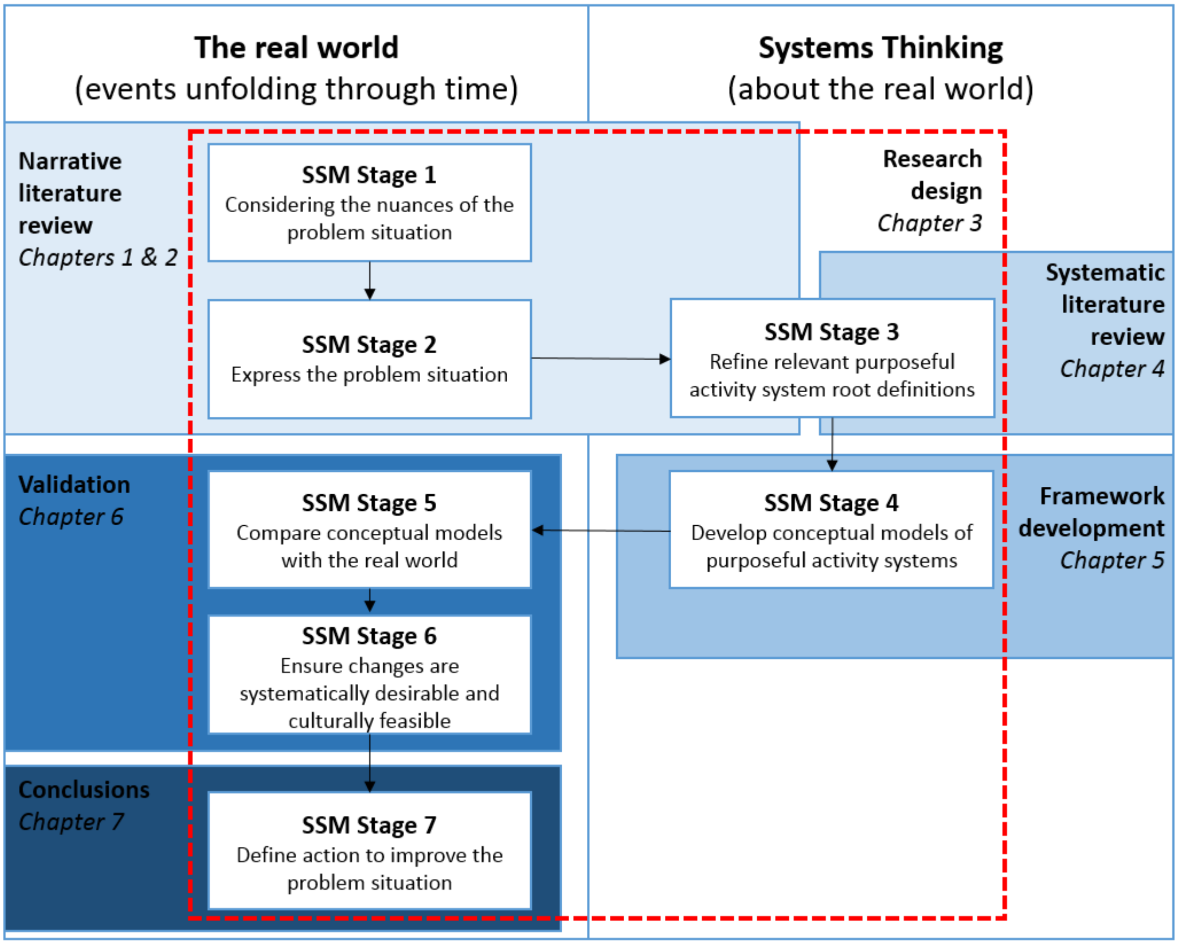


Figure 86: Revisiting the 7 Stages of SSM
(Adapted from [27])

7.4 Developing the Conceptual Framework

While Change Management is very useful in a theoretical approach, the fact that in large multinational companies like automotive OEMs the decision-making team, the technology development team and the implementation team might all reside on different continents, effectively rules out certain steps from many models, or alters them significantly from the initial intent. Most Change Management theories or frameworks are abstract and do not give concrete, practical guidance that can be followed by Implementation Teams in these situations. From the perspective of automotive OEMs' manufacturing plants, what was missing in the literature was a hands-on practical and measurable framework for the implementation of technological change in their production lines. Manufacturing plants needed something that an Implementation Team could practically use to safely, effectively and efficiently introduce High Voltage technology to their production lines and manage or mitigate the associated rise in complexity. The Research Aim was to create this framework.

Having reviewed the literature of change uptake concepts, psychological change experience models, organisational change capability models and linear change methodologies, the researcher could evaluate the strengths and weaknesses of the different constructs. The linear models lack depth with regard to aspects of successful implementation. The non-linear models provide insight into these success factors, but lack a practical step-by-step approach. To create a holistic meta-theoretical construct that addresses all the research requirements, the strengths of all these change management categories were required. To create the IFAT, the strengths of Change Management concepts had to be combined with the applicable aspects of Complexity Management, Implementation Theory and an understanding of High Voltage technology. These had to be filtered through the Research Requirements, to ensure applicability. The developed framework had to be formatted into a linear style to provide the practical step-by-step approach required by the Research Aim. Non-linear constructs are arguably more complex and likely more difficult to practically use in the rapid implementation projects that automotive manufacturing companies face. The 5 linear steps of developed Implementation Framework for Automotive Technology are “Vision”, “Method”, “Pilot”, “Implementation” and “Improve”. The framework is presented with the Steps in the centre driving the process (Figure 87). Each of the Steps is further detailed in terms of its

- **Purpose, context and timing**: Describing what the Step is trying to achieve, in which environment this is being done and within which timeframe.
- **Main resources and activities**: Detailing the main resources, whether people or other, as well as the actions that need to be completed in the Step.
- **High Voltage focus points**: Providing clarity on the HV aspects largely applicable to all implementation projects of this technology, namely safety and training, facilities and equipment, processes and resource efficiency, as well as components and supply chains.
- **Output requirements**: Specifying the required output that the Step should deliver.

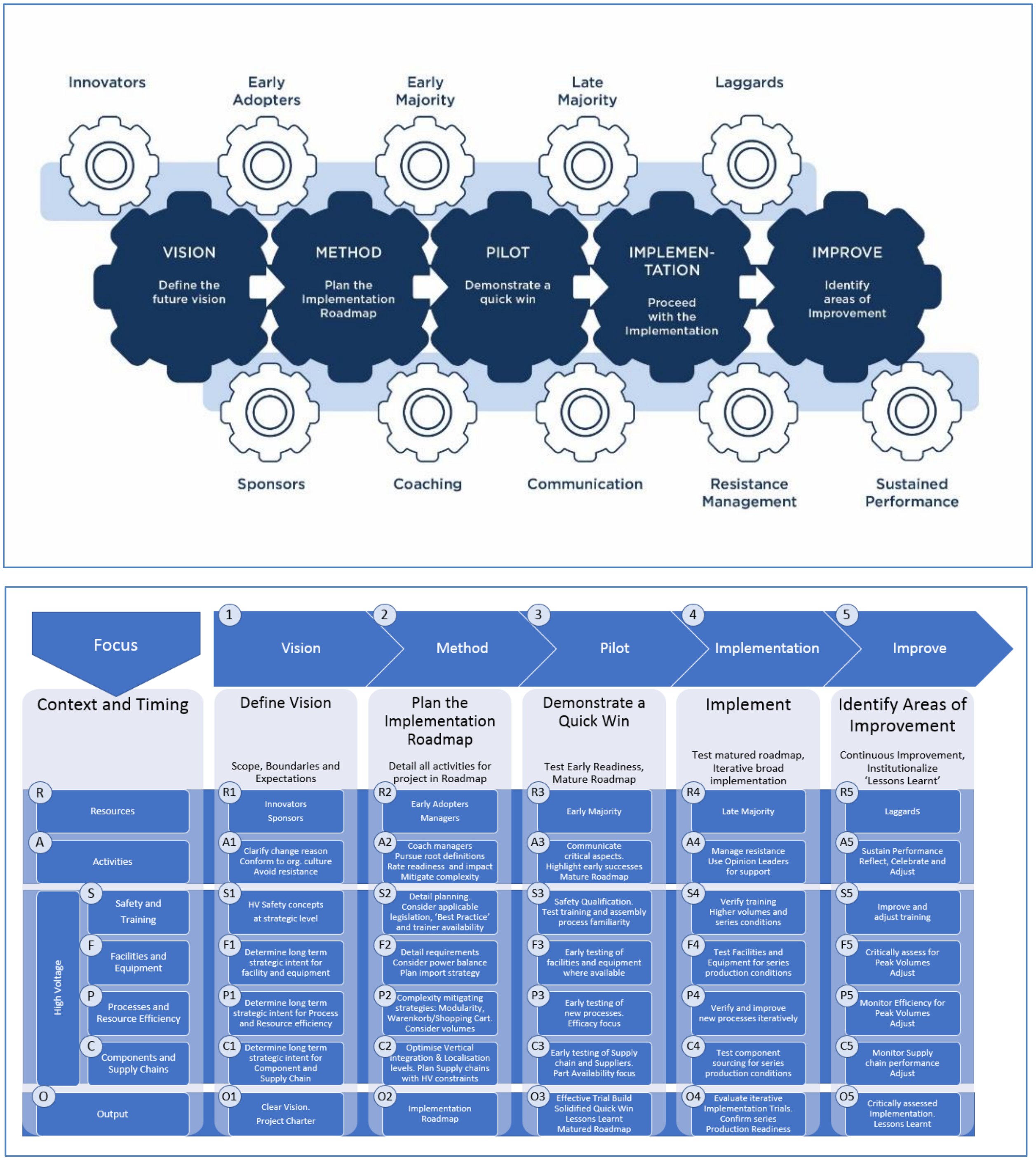


Figure 87: Holistic view of the IFAT

7.5 Verifying and validating the Framework

The conceptual framework was verified against the research requirements to ensure all requirements were satisfied. Having verified that the Conceptual Framework complied fully with all identified research requirements, it was still necessary to validate the framework against a case study from industry and the C350e Plug-in Hybrid Project of Mercedes-Benz SA was used for this purpose.

In November 2015 Daimler AG decided to introduce Plug-in Hybrid vehicles to the East London factory of its local subsidiary, Mercedes-Benz South Africa. The C350e, a variant of the popular C Class model, would pioneer 'high-voltage automotive manufacturing' in South Africa, becoming the first hybrid vehicle to be mass manufactured in the country. The new variant would introduce to MBSA a powerful Lithium-Ion battery operating at a potentially lethal 300 Volt. No local automotive OEM had any experience with 'high voltage automotive manufacturing' prior to the implementation decision taken in Germany and the safety risk initially prompted significant resistance in the South African factory. The risk and the associated resistance had to be carefully managed by the Project Leader and the Implementation Team against the backdrop of a lack of applicable safety legislation in the country. While this was a retrospective Case Study, the elements of the Framework were nevertheless followed by the researcher as the Project Leader of this implementation.

The project had proven itself both effective and efficient, while maintaining all the necessary pre-requisites. The introduction date in the 3rd Quarter of 2016 was reached, with over 1500 units produced by the end of the first year, proving the project's effectiveness. The Engineering and Production Trials proved the efficiency in terms of time and quality, while safety remained uncompromised and paramount throughout the project. HV technology had been successfully introduced to the production lines of Mercedes-Benz South Africa in a safe, effective and efficient way, guided by the principles codified in this study. This successful implementation demonstrates the applicability of the IFAT to HV automotive manufacturing, with all 5 Steps having been thoroughly verified and validated (Figure 88).

	Verification		Validation	
	Literature	Research Requirements	Case Study Qualitative	Case Study Quantitative
Vision	✓	✓	✓	
Method	✓	✓	✓	
Pilot	✓	✓	✓	✓
Implementation	✓	✓	✓	✓
Improve	✓	✓	✓	

Figure 88: Overview of verification and validation methods

In addition to the success of the implementation a number of High Voltage related recommendations are made, with the suggestion that they be specifically considered in future projects at the Method Step, regardless of whether they were found in the preceding CATWOE analysis or not.

7.6 Unique Contribution

The unique contribution of this completed study is a practical and measurable framework whereby automotive manufacturers can implement high voltage technological changes, such as the introduction of Hybrid and Electric Vehicles, in their production lines in a safe, effective and efficient way to strengthen global competitiveness. Focus is specifically placed on enabling automotive manufacturing plants outside their OEM’s home country, to support them with practical measures whereby they can introduce a technology that they likely played no role in the development of. The Implementation Framework for Automotive Technology has been conceptualised, verified and validated. It has embraced existing literature, frameworks, models and other constructs, to provide an overarching and holistic way of introducing High Voltage technology to automotive manufacturing plants and their production lines.

7.7 Future work

It is the author's sincere hope that the framework developed for this dissertation will stimulate further discussion and development in the academic community and that it will contribute to the further development of high-end, high voltage manufacturing competence and strengthen the automotive sector, particularly in South Africa.

The framework was verified against all research requirements and though it was validated with a Hybrid vehicle introduction, the author believes it is equally applicable for use in other new technology implementation projects. With little to no change, the author believes that the IFAT can be used for the effective and efficient implementation of Electric Vehicles, including Fuel Cell Electric Vehicles and although it was only validated in a South African context, it is believed to be applicable also in other countries. Future work can therefore test the expanded applicability of this framework.

The IFAT, by definition, was developed to implement automotive technology, though many of the individual elements of the Framework may be applicable to introducing practically any new technology. Reframing the IFAT into a framework capable of any and all technology implementations is a prospect for very interesting future work.

Figure 89: A proudly (Mercedes-Benz) South African moment

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9. *Appendix A - C350e in local and international news*

This appendix will highlight a few noteworthy publications about the success of the C350e Project in Mercedes-Benz South Africa's East London manufacturing plant.

CREAMER MEDIA'S ENGINEERING NEWS

http://www.engineeringnews.co.za/article/auto-industry-2016-04-01-3

MBSA moves to begin producing plug-in hybrids at East London plant

1ST APRIL 2016 BY: IRMA VENTER - CREAMER MEDIA SENIOR DEPUTY EDITOR

Mercedes-Benz South Africa (MBSA) is ramping up to start production of the C350e plug-in hybrid at the company's Eastern Cape plant, says MBSA CEO and executive director for manufacturing **Arno van der Merwe**.

Van der Merwe says the C-Class hybrid – most likely the first hybrid to be produced in a South African plant – will be a big step in "deve- loping MBSA's technical assembly capability".

The C350e will be available on the local market towards the end of the year. It will also be exported from East London.

MBSA last year produced 106 700 vehicles. The C-Class made up 102 200 of this number and trucks and buses 4 500 units.

This is a massive jump from the 54 400 units assembled in 2014, made up of 48 100 C-Class models and 6 300 trucks and buses.

C-Class exports to more than 80 countries totalled around 93 500 units in 2015, up from the 33 688 units exported in 2014, when the plant was still ramping up production of the new C-Class.

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Motoring > Latest Launches

C-Class plug-in hybrid switches on in SA

LATEST LAUNCHES / 6 July 2016, 11:37am

By: IOL Motoring Staff

East London - The Mercedes-Benz C350e, released this week in South Africa, is special in a number of ways, not least because it is the first plug-in hybrid model to be locally assembled, which has pushed the Mercedes plant in East London to raise its game, in terms of both quality and safety.

Daimler verschiebt Anlagenkapazitäten nach Südafrika

Künftig sollen Plug-In-Hybride im Daimler-Werk in East London gefertigt werden

Mercedes-Benz South Africa (MBSA) verkündete Pläne die Produktion von Plug-In-Hybride (PHEV) im Daimler-Werk in East London zu steigern. Ab Ende 2016 soll die Fertigung des Mercedes-Benz C350e in der südafrikanischen Hafenstadt erfolgen. Die meisten Plug-In-Hybride sind für den Export bestimmt, somit ist das Werk gut gelegen für die effiziente Ausfuhr der gefertigten Fahrzeuge.

4.4.2016 Johannes Brunner

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SA-built Mercedes C350 e all charged up

2016-07-06 07:15

SHARE:

Cape Town - Mercedes-Benz will offering its C-Class its hybrid guide.

The Mercedes-Benz East London factory will, for the first time, manufacture a C-Class with the latest plug-in-hybrid technology, for both local and export markets.

The order book for the Mercedes-Benz C350 e sedan, priced from from R804 900, is open at dealerships throughout SA with deliveries set to take place in August 2016.

Made in SA

The C350 e's electrical energy storage unit compromises of a high-voltage lithium-ion

REVEALED: The first hybrid-powered Mercedes-Benz

AUTOMOBIL PRODUKTION

HERSTELLER ZULIEFERER TECHNIK & PRODUKTION MÄRKTE MENSCHEN

Daimler-Werk Südafrika als Hub für Plug-In-Hybride?

Gabriel Pankow am 31. März 2016 um 15:13 Uhr

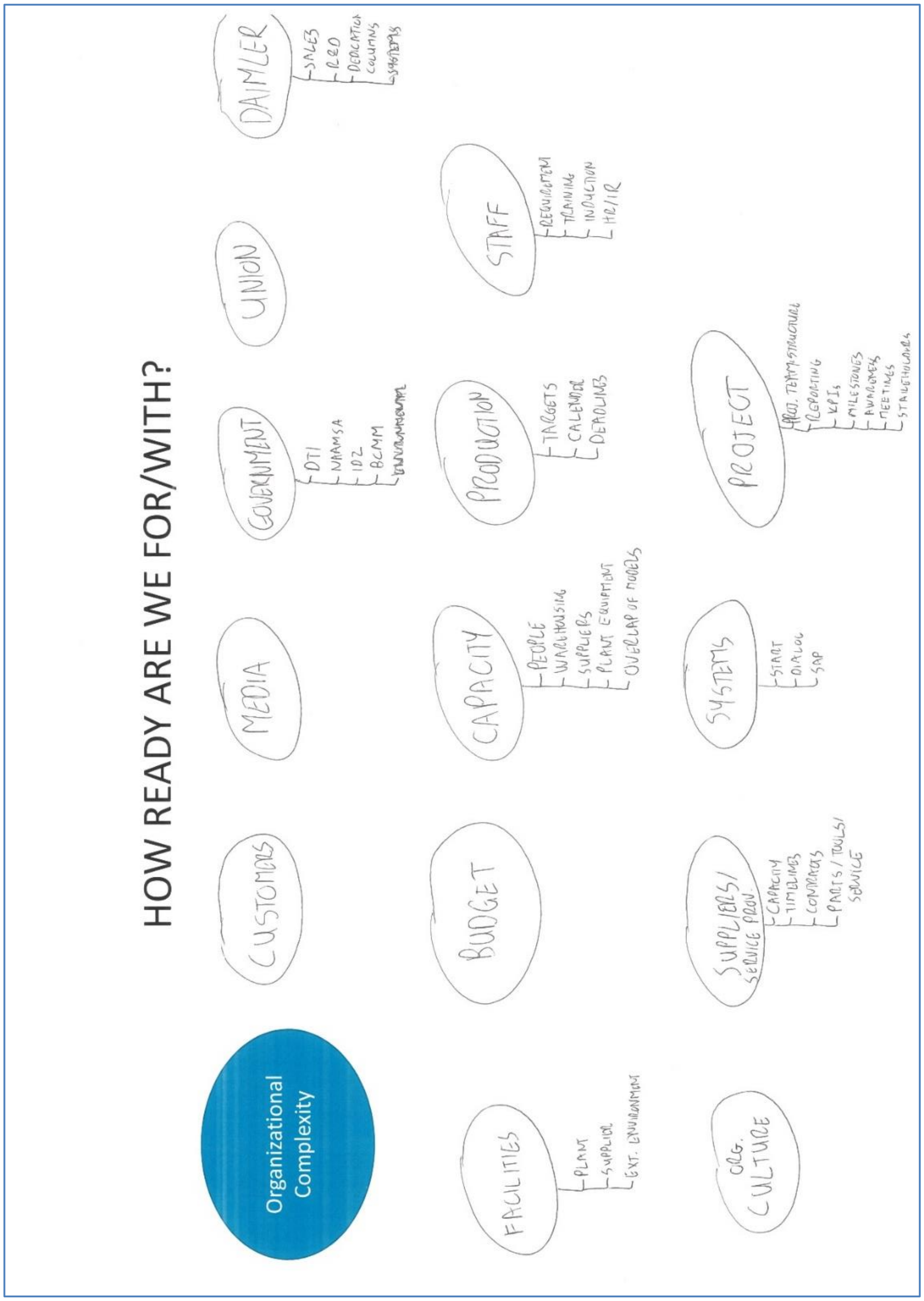
Artikel drucken

Im südafrikanischen Daimler-Werk in East London könnten künftig vermehrt Plug-In-Hybride vom Band laufen. Dank seiner Lage in Nähe des Hafens könnte der Standort damit zum Export-Hub für die Teilzeit-Stromer werden.

(Adapted from [246] [247] [248] [249] [250])

10. Appendix B - CATWOE Analysis: C350e Project

This appendix shows some of the results from the CATWOE Analysis done with the Implementation Team of the C350e in East London. While the case study was retrospective, the results give valuable insight for validation and for future work.




HOW READY ARE WE FOR/WITH?
EQUIPMENT & SPARES
SPECIFICATIONS
SUPPLIERS
TRAINING
COMPATIBILITY
MAINTENANCE
APPROVALS
MMK PARTS FOR TESTING
MATERIAL STRIPS
OLD REMOVAL
PREPARATION
LOG INTERFACE
BINS & LIMOS
SIZE
SPACE
RACKING
SAFETY
MEDICAL
FIRE
EMERG. SUPPORT
TRAINING
OPERATOR PROCESSES & LINE STATIONS
SWI / SMP / AVO
OPERATOR LOADING
TIME NEEDED
7 WASTES
ERGONOMICS
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TAKE RATES
PROD. CONSTRAINTS
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EC TOOLS
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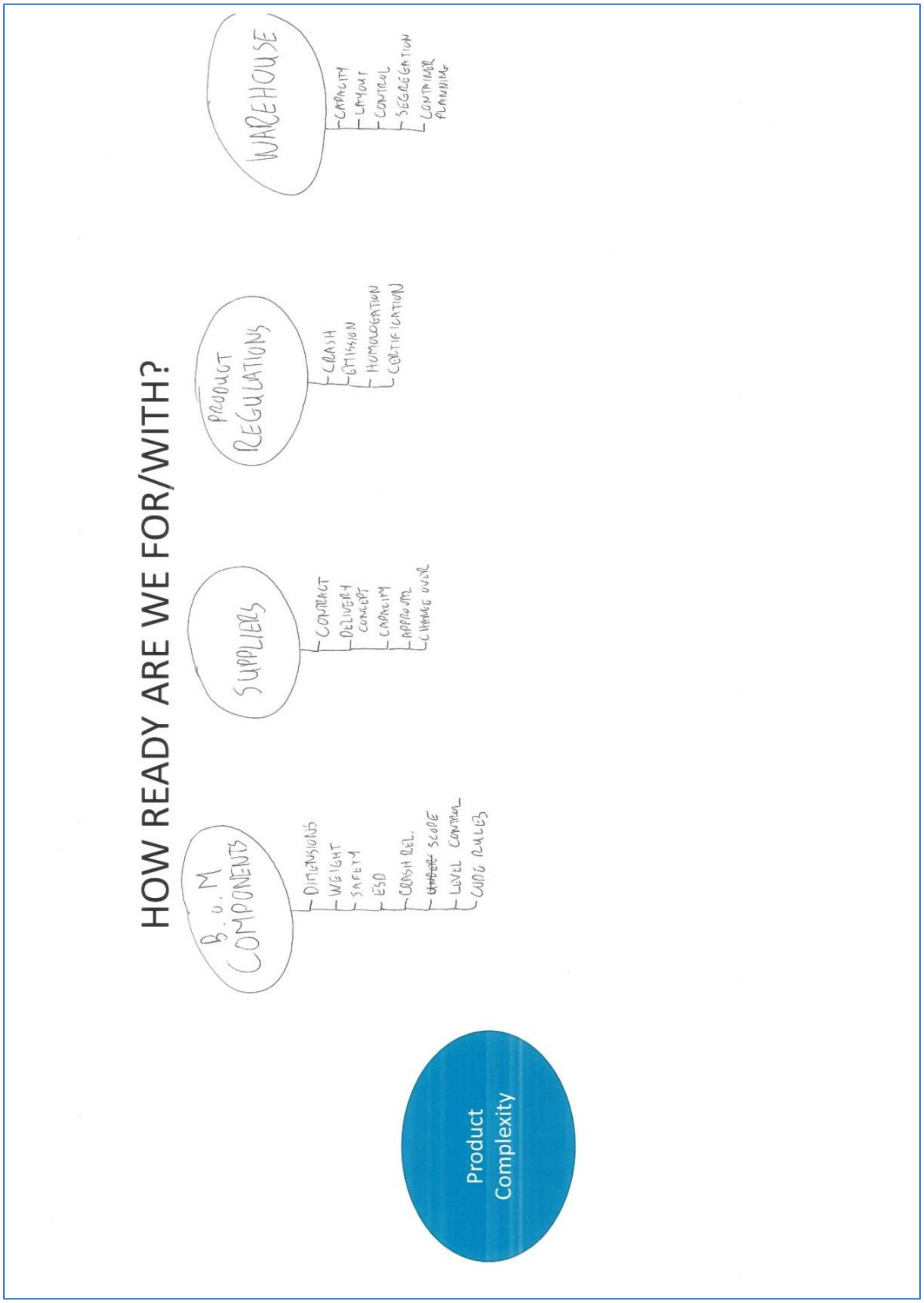
CALL-OFFS
MODEL CONTROL
JOB CARDS
AUTOMATION
DATA STORAGE
DATA SECURITY
Process Complexity


HOW READY ARE WE FOR/WITH?
Product Complexity
B.O.M COMPONENTS
DIMENSIONS
WEIGHT
SAFETY
ESD
CRASH REL.
SCOPE
LEVEL CONTROL
SUPPLIERS
CONTRACT
DELIVERY CONCEPT
CAPACITY
APPROVAL
CHANGE OVER
PRODUCT REGULATIONS
CRASH
EMISSION
HOMOLOGATION
CERTIFICATION
WAREHOUSE
CAPACITY
LAYOUT
CONTROL
SEGREGATION
CONTAINER PLANNING

11. *Appendix C - Occupational Health and Safety Act of 1993*

This appendix shows the full OHSAct of 1993 that is applicable in South Africa. Implementation projects using the IFAT would need to consider locally applicable legislation for each project.

Department of Labour

REPUBLIC OF SOUTH AFRICA

No. 85 of 1993: Occupational Health and Safety Act
as amended by
Occupational Health and Safety Amendment Act, No. 181 Of 1993

ACT

To provide for the health and safety of persons at work and for the health and safety of persons in connection with the use of plant and machinery; the protection of persons other than persons at work against hazards to health and safety arising out of or in connection with the activities of persons at work; to establish an advisory council for occupational health and safety; and to provide for matters connected therewith.

(English Text Signed By the State President)
(Assented To 23 June, 1993)

BE IT ENACTED by the State President and the Parliament of the Republic of South Africa, as follows:-

ARRANGEMENT OF SECTIONS

Department of Labour

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1. Definitions

(1) In this Act, unless the context otherwise indicates-

"**accident**" means an accident arising out of and in the course of an employee's employment and resulting in a personal injury, illness or the death of the employee;(xxiv)

"**approved inspection authority**" means an inspection authority approved by the chief inspector: Provided that an inspection authority approved by the chief inspector with respect to any particular service shall be an approved inspection authority with respect to that service only;

"**biological monitoring**" means a planned programme of periodic collection and analysis of body fluid, tissues, excreta or exhaled air in order to detect and quantify the exposure to or absorption of any substance or organism by persons;

"**building**" includes-

(a) any structure attached to the soil;

(b) any building or such structure or part thereof which is in the process of being erected; or

(c) any prefabricated building or structure not attached to the soil;

"**chief executive officer**", in relation to a body corporate or an enterprise conducted by the State, means the person who is responsible for the overall management and control of the business of such body corporate or enterprise;

"**chief inspector**" means the officer designated under section 27 as chief inspector, and includes any officer acting as chief inspector;

"**Council**" means the Advisory Council for Occupational Health and Safety established by section 2;

"**danger**" means anything which may cause injury or damage to persons or property;

"**Department**" means the Department of Manpower;

"**employee**" means, subject to the provisions of subsection (2), any person who is employed by or works for an employer and who receives or is entitled to receive any remuneration or who works under the direction or supervision of an employer or any other person;

"**employer**" means, subject to the provisions of subsection (2), any person who employs or provides work for any person and remunerates that person or expressly or tacitly undertakes to remunerate him, but excludes a labour broker as defined in section I (1) of the Labour Relations Act, 1956 (Act No. 28 of 1956);

"**employers' organization**" means an employers' organization as defined in section 1 of the Labour Relations Act, 1956 (Act No. 28 of 1956);

"**employment**" or "employed" means employment or employed as an employee;

"**explosives**" means any substance or article as listed in Class 1: Explosives in the South African Bureau of Standards Code of Practice for the Identification and Classification of Dangerous Substances and Goods, SABS 0228;

"**hazard**" means a source of or exposure to danger;

"**health and safety committee**" means a committee established under section 19;

"**health and safety equipment**" means any article or part thereof which is manufactured, provided or installed in the interest of the health or safety of any person;

"**health and safety representative**" means a person designated in terms of section 17 (1);

"**health and safety standard**" means any standard, irrespective of whether or not it has the force of law, which, if applied for the purposes of this Act, will in the opinion of the Minister promote the attainment of an object of this Act;

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"**healthy**" means free from illness or injury attributable to occupational causes;

"**incident**" means an incident as contemplated in section 24 (1);

"**industrial court**" means the industrial court referred to in section 17 of the Labour Relations Act, 1956 (Act No. 28 of 1956);

"**inspection authority**" means any person who with the aid of specialized knowledge or equipment or after such investigations, tests, sampling or analyses as he may consider necessary, and whether for reward or otherwise, renders a service by making special findings, purporting to be objective findings, as to-

(a) the health of any person;

(b) the safety or risk to health of any work, article, substance, plant or machinery, or of any condition prevalent on or in any premises; or

(c) the question of whether any particular standard has been or is being complied with, with respect to any work, article, substance, plant or machinery, or with respect to work or a condition prevalent on or in any premises, or with respect to any other matter, and by issuing a certificate, stating such findings, to the person to whom the service is rendered;

"**inspector**" means a person designated under section 28;

"**listed work**" means any work declared to be listed work under section II;

"**local authority**" means-

(a) any institution or body contemplated in section 84 (1) (f) of the Provincial Government Act, 1961 (Act No. 32 of 1961);

(b) any regional services council established under section 3 of the Regional Services Councils Act, 1985 (Act No. 109 of 1985);

(c) any other institution or body or the holder of any office declared by the Minister by notice in the Gazette to be a local authority for the purposes of this Act;

"**machinery**" means any article or combination of articles assembled, arranged or connected and which is used or intended to be used for converting any form of energy to performing work, or which is used or intended to be used, whether incidental thereto or not, for developing, receiving, storing, containing, confining, transforming, transmitting, transferring or controlling any form of energy;

"**major hazard installation**" means an installation-

(a) where more than the prescribed quantity of any substance is or may be kept, whether permanently or temporarily; or

(b) where any substance is produced, processed, used, handled or stored in such a form and quantity that it has the potential to cause a major incident;

"**major incident**" means an occurrence of catastrophic proportions, resulting from the use of plant or machinery, or from activities at a workplace;

"**mandatary**" includes an agent, a contractor or a subcontractor for work, but without derogating from his status in his own right as an employer or a user;

"**medical surveillance**" means a planned programme or periodic examination (which may include clinical examinations, biological monitoring or medical tests) of employees by an occupational health practitioner or, in prescribed cases, by an occupational medicine practitioner;

"**Minister**" means the Minister of Manpower;

"**occupational health**" includes occupational hygiene, occupational medicine and biological monitoring;

"**occupational health practitioner**" means an occupational medicine practitioner or a person who holds a qualification in occupational health recognized as such by the South African Medical and Dental Council as referred to in the Medical, Dental and Supplementary Health Service Professions Act, 1974

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(Act No. 56 of 1974), or the South African Nursing Council as referred to in the Nursing Act, 1978 (Act No. 50 of 1978);

"**occupational hygiene**" means the anticipation, recognition, evaluation and control of conditions arising in or from the workplace, which may cause illness or adverse health effects to persons;

"**occupational medicine**" means the prevention, diagnosis and treatment of illness, injury and adverse health effects associated with a particular type of work;

"**occupational medicine practitioner**" means a medical practitioner as defined in the Medical, Dental and Supplementary Health Service Professions Act, 1974 (Act No. 56 of 1974), who holds a qualification in occupational medicine or an equivalent qualification which qualification or equivalent is recognized as such by the South African Medical and Dental Council referred to in the said Act;

"**office**" means an office as defined in section 1 (1) of the Basic Conditions of Employment Act, 1983 (Act No. 3 of 1983);

"**officer**" means an officer or employee as defined in section 1 (1) of the Public Service Act, 1984 (Act No. 111 of 1984);

"**organism**" means any biological entity which is capable of causing illness to persons;

"**plant**" includes fixtures, fittings, implements, equipment, tools and appliances, and anything which is used for any purpose in connection with such plant;

"**premises**" includes any building, vehicle, vessel, train or aircraft; "prescribed" means prescribed by regulation;

"**properly used**" means used with reasonable care, and with due regard to any information, instruction or advice supplied by the designer, manufacturer, importer, seller or supplier;

"**reasonably practicable**" means practicable having regard to-

(a) the severity and scope of the hazard or risk concerned;

(b) the state of knowledge reasonably available concerning that hazard or risk and of any means of removing or mitigating that hazard or risk;

(c) the availability and suitability of means to remove or mitigate that hazard or risk; and

(d) the cost of removing or mitigating that hazard or risk in relation to the benefits deriving therefrom;

"**regulation**" means a regulation made under section 43;

"**remuneration**" means any payment in money or in kind or both in money and in kind, made or owing to any person in pursuance of such person's employment;

"**risk**" means the probability that injury or damage will occur;

"**safe**" means free from any hazard;

"**sell**" includes-

(a) offer or display for sale or import into the Republic for sale; or

(b) exchange, donate, lease or offer or display for leasing;

"**shop**" means a shop as defined in section I (1) of the Basic Conditions of Employment Act, 1983 (Act No. 3 of 1983);

"**standard**" means any provision occurring-

(a) in a specification, compulsory specification, code of practice or standard method as defined in section I of the Standards Act, 1993 (Act No. 29 of 1993); or

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(b) in any specification, code or any other directive having standardization as its aim and issued by an institution or organization inside or outside the Republic which, whether generally or with respect to any particular article or matter and whether internationally or in any particular country or territory, seeks to promote standardization;

"substance" includes any solid, liquid, vapour, gas or aerosol, or combination thereof;

"this Act" includes any regulation;

"trade union" means a trade union as defined in section 1 of the Labour Relations Act, 1956 (Act No. 28 of 1956);

"user", in relation to plant or machinery, means the person who uses plant or machinery for his own benefit or who has the right of control over the use of plant or machinery, but does not include a lessor of, or any person employed in connection with, that plant or machinery;

"work" means work as an employee or as a self-employed person, and for such purpose an employee is deemed to be at work during the time that he is in the course of his employment, and a self-employed person is deemed to be at work during such time as he devotes to work as a self-employed person;

"workplace" means any premises or place where a person performs work in the course of his employment.

(2) The Minister may by notice in the Gazette declare that a person belonging to a category of persons specified in the notice shall for the purposes of this Act or any provision thereof be deemed to be an employee, and thereupon any person vested and charged with the control and supervision of the said person shall for the said purposes be deemed to be the employer of such person.

(3) This Act shall not apply in respect of-

(a) a mine, a mining area or any works as defined in the Minerals Act, 1991 (Act No. 50 of 1991), except in so far as that Act provides otherwise;

(b) any load line ship (including a ship holding a load line exemption certificate), fishing boat, sealing boat and whaling boat as defined in section 2 (1) of the Merchant Shipping Act, 1951 (Act No. 57 of 1951), or any floating crane, whether or not such ship, boat or crane is in or out of the water within any harbour in the Republic or within the territorial waters thereof, (Date of commencement of para. (b) to be proclaimed.) or in respect of any person present on or in any such mine, mining area, works, ship, boat or crane.

2. Establishment of Advisory Council for Occupational Health and Safety

There is hereby established an Advisory Council for Occupational Health and Safety.

3. Functions of Council

(1) The Council shall-

(a) advise the Minister with regard to-

(i) matters of policy arising out of or in connection with the application of the provisions of this Act;

(ii) any matter relating to occupational health and safety;

(b) perform the functions assigned to it by this Act or referred to it by the Minister.

(2) The Council may-

(a) with a view to the performance of its functions, do such research and conduct such investigations as it may deem necessary;

(b) make rules relating to the calling of meetings of the Council, the determining of a quorum for and the procedure at such meetings, and generally relating to all matters which may be necessary for the effective performance of the functions of the Council or, subject to section 6, of a technical committee;

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(c) advise the Department concerning-

(i) the formulation and publication of standards, specifications or other forms of guidance for the purpose of assisting employers, employees and users to maintain appropriate standards of occupational health and safety;

(ii) the promotion of education and training in occupational health and safety; and

(iii) the collection and dissemination of information on occupational health and safety.

(3) The Council may for the purposes of the performance of any of its functions, with the approval of the Minister, and with the concurrence of the Minister of State Expenditure, enter into an agreement for the performance of a particular act or particular work or for the rendering of a particular service, on such conditions and at such remuneration as may be agreed upon, with anybody who in the opinion of the Council is fit to perform such act or work or to render such service.

(4) Subject to the laws governing the Public Service, the Minister shall provide the Council with such personnel as he may deem necessary for the effective performance of the functions of the Council, and such persons shall perform their functions subject to the control and directions of the chief inspector.

4. Constitution of Council

(1) The Council shall consist of 20 members, namely-

(a) the chief inspector, ex officio, who shall be the chairman;

(b) one officer serving in the Department;

(c) the Compensation Commissioner, or his nominee;

(d) one person nominated by the Minister for National Health and Welfare;

(e) one person nominated by the Minister of Mineral and Energy Affairs; six persons to represent the interests of employers from a list of the names of persons nominated by employers' organizations or federations of employers' organizations;

(f) *[Substituted by s. 2 of Act No. 181 of 1993]*

(g) six persons to represent the interests of employees from a list of the names of persons nominated by trade unions or federations of trade unions; *[Para. (g) substituted by s. 2 of Act No. 181 of 1993.]*

(h) one person who in the opinion of the Minister has knowledge of occupational safety matters;

(i) one person who in the opinion of the Minister has knowledge of occupational medicine and who was recommended by the Minister for National Health and Welfare;

(j) one person who in the opinion of the Minister has knowledge of occupational hygiene.

(2) The members referred to in subsection (1) (b) up to and including (j) shall be appointed by the Minister.

5. Period of office and remuneration of members of Council

(1) The members of the Council referred to in section 4 (2) shall be appointed for a period of three years, and on such conditions as the Minister may determine with the concurrence of the Minister of State Expenditure.

(2) Any person whose period of office as a member of the Council has expired shall be eligible for reappointment.

(3) A member referred to in section 4 (1) (f), (g), (h), (i) or (j) who is not an officer may be paid from money appropriated for such purpose by Parliament such allowances as the Minister may determine with the concurrence of the Minister of State Expenditure.

6. Establishment of technical committees of Council

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(1) The Council may with the approval of the Minister establish one or more technical committees to advise the Council on any matter regarding the performance by the Council of its functions.

(2) A member of a technical committee shall be appointed by the Council by reason of his knowledge of the matter for which the committee is established, and such a member need not be a member of the Council.

(3) A meeting of a technical committee shall be held at such time and place as may be determined by the chairman of the Council, and in accordance with rules approved by the Council.

(4) A member of a technical committee who is not an officer may be paid from money appropriated for such purpose by Parliament such allowances as the Minister may determine with the concurrence of the Minister of State Expenditure.

7. Health and safety policy

(1) The chief inspector may direct-

(a) any employer in writing; and

(b) any category of employers by notice in the Gazette, to prepare a written policy concerning the protection of the health and safety of his employees at work, including a description of his organization and the arrangements for carrying out and reviewing that policy.

(2) Any direction under subsection (1) shall be accompanied by guidelines concerning the contents of the policy concerned.

(3) An employer shall prominently display a copy of the policy referred to in subsection (1), signed by the chief executive officer, in the workplace where his employees normally report for service.

8. General duties of employers to their employees

(1) Every employer shall provide and maintain, as far as is reasonably practicable, a working environment that is safe and without risk to the health of his employees.

(2) Without derogating from the generality of an employer's duties under subsection (1), the matters to which those duties refer include in particular-

(a) the provision and maintenance of systems of work, plant and machinery that, as far as is reasonably practicable, are safe and without risks to health;

(b) taking such steps as may be reasonably practicable to eliminate or mitigate any hazard or potential hazard to the safety or health of employees, before resorting to personal protective equipment;

(c) making arrangements for ensuring, as far as is reasonably practicable, the safety and absence of risks to health in connection with the production, processing, use, handling, storage or transport of articles or substances;

(d) establishing, as far as is reasonably practicable, what hazards to the health or safety of persons are attached to any work which is performed, any article or substance which is produced, processed, used, handled, stored or transported and any plant or machinery which is used in his business, and he shall, as far as is reasonably practicable, further establish what precautionary measures should be taken with respect to such work, article, substance, plant or machinery in order to protect the health and safety of persons, and he shall provide the necessary means to apply such precautionary measures;

(e) providing such information, instructions, training and supervision as may be necessary to ensure, as far as is reasonably practicable, the health and safety at work of his employees;

(f) as far as is reasonably practicable, not permitting any employee to do any work or to produce, process, use, handle, store or transport any article or substance or to operate any plant or machinery, unless the precautionary measures contemplated in paragraphs (b) and (d), or any other precautionary measures which may be prescribed, have been taken;

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(g) taking all necessary measures to ensure that tire requirements of this Act are complied with by every person in his employment or on premises under his control where plant or machinery is used;

(h) enforcing such measures as may be necessary in the interest of health and safety;

(i) ensuring that work is performed and that plant or machinery is used under the general supervision of a person trained to understand the hazards associated with it and who have the authority to ensure that precautionary measures taken by the employer are implemented; and

(j) causing all employees to be informed regarding the scope of their authority as contemplated in section 37 (1) (b).

9. General duties of employers and self-employed persons to persons other than their employees

(1) Every employer shall conduct his undertaking in such a manner as to ensure, as far as is reasonably practicable, that persons other than those in his employment who may be directly affected by his activities are not thereby exposed to hazards to their health or safety.

(2) Every self-employed person shall conduct his undertaking in such a manner as to ensure, as far as is reasonably practicable, that he and other persons who may be directly affected by his activities are not thereby exposed to hazards to their health or safety.

10. General duties of manufacturers and others regarding articles and substances for use at work

(1) Any person who designs, manufactures, imports, sells or supplies any article for use at work shall ensure, as far as is reasonably practicable, that the article is safe and without risks to health when properly used and that it complies with all prescribed requirements.

(2) Any person who erects or installs any article for use at work on or in any premises shall ensure, as far as is reasonably practicable, that nothing about the manner in which it is erected or installed makes it unsafe or creates a risk to health when properly used.

(3) Any person who manufactures, imports, sells or supplies any substance for use at work shall-

(a) ensure, as far as is reasonably practicable, that the substance is safe and without risks to health when properly used; and

(b) take such steps as may be necessary to ensure that information is available with regard to the use of the substance at work, the risks to health and safety associated with such substance, the conditions necessary to ensure that the substance will be safe and without risks to health when properly used and the procedures to be followed in the case of an accident involving such substance.

(4) Where a person designs, manufactures, imports, sells or supplies an article or substance for or to another person and that other person undertakes in writing to take specified steps sufficient to ensure, as far as is reasonably practicable, that the article or substance will comply with all prescribed requirements and will be safe and without risks to health when properly used, the undertaking shall have the effect of relieving the firstmentioned person from the duty imposed upon him by this section to such an extent as may be reasonable having regard to the terms of the undertaking.

11. Listed work

(1) The Minister may, subject to the provisions of subsections (2) and (3), by notice in the Gazette declare any work, under the conditions or circumstances specified in the notice, to be listed work.

(2) (a) Before the Minister declares any work to be listed work, he shall cause to be published in the Gazette a draft of his proposed notice and at the same time invite interested persons to submit to him in writing within a specified period, comments and representations in connection with the proposed notice.

(b) A period of not less than three months shall elapse between the publication of the draft notice and the notice under subsection (1).

(3) The provisions of subsection (2) shall not apply-

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(a) if the Minister in pursuance of comments and representations received in terms of subsection (2) (a), decides to publish the notice referred to in subsection (1) in an amended form; and

(b) to any declaration in terms of subsection (1) in respect of which the Minister is of the opinion that the public interest requires that it be made without delay.

(4) A notice under subsection (1) may at any time be amended or withdrawn by like notice.

12. General duties of employers regarding listed work

(1) Subject to such arrangements as may be prescribed, every employer whose employees undertake listed work or are liable to be exposed to the hazards emanating from listed work, shall, after consultation with the health and safety committee established for that workplace-

(a) identify the hazards and evaluate the risks associated with such work constituting a hazard to the health of such employees, and the steps that need to be taken to comply with the provisions of this Act;

(b) as far as is reasonably practicable, prevent the exposure of such employees to the hazards concerned or, where prevention is not reasonably practicable, minimize such exposure; and

(c) having regard to the nature of the risks associated with such work and the level of exposure of such employees to the hazards, carry out an occupational hygiene programme and biological monitoring, and subject such employees to medical surveillance.

(2) Every employer contemplated in subsection (1) shall keep the health and safety representatives designated for their workplaces or sections of the workplaces, informed of the actions taken under subsection (1) in their respective workplaces or sections thereof and of the results of such actions: Provided that individual results of biological monitoring and medical surveillance relating to the work of the employee, shall only with the written consent of such employee be made available to any person other than an inspector, the employer or the employee concerned.

13. Duty to inform

Without derogating from any specific duty imposed on an employer by this Act, every employer shall-

(a) as far as is reasonably practicable, cause every employee to be made conversant with the hazards to his health and safety attached to any work which he has to perform, any article or substance which he has to produce, process, use, handle, store or transport and any plant or machinery which he is required or permitted to use, as well as with the precautionary measures which should be taken and observed with respect to those hazards;

(b) inform the health and safety representatives concerned beforehand of inspections, investigations or formal inquiries of which he has been notified by an inspector, and of any application for exemption made by him in terms of section 40; and

(c) inform a health and safety representative as soon as reasonably practicable of the occurrence of an incident in the workplace or section of the workplace for which such representative has been designated.

14. General duties of employees at work

Every employee shall at work-

(a) take reasonable care for the health and safety of himself and of other persons who may be affected by his acts or omissions;

(b) as regards any duty or requirement imposed on his employer or any other person by this Act, co-operate with such employer or person to enable that duty or requirement to be performed or complied with;

(c) carry out any lawful order given to him, and obey the health and safety rules and procedures laid down by his employer or by anyone authorized thereto by his employer, in

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the interest of health or safety;

(d) if any situation which is unsafe or unhealthy comes to his attention, as soon as practicable report such situation to his employer or to the health and safety representative for his workplace or section thereof, as the case may be, who shall report it to the employer; and

(e) if he is involved in any incident which may affect his health or which has caused an injury to himself, report such incident to his employer or to anyone authorized thereto by the employer, or to his health and safety representative, as soon as practicable but not later than the end of the particular shift during which the incident occurred, unless the circumstances were such that the reporting of the incident was not possible, in which case he shall report the incident as soon as practicable thereafter.

15. Duty not to interfere with, damage or misuse things

No person shall intentionally or recklessly interfere with, damage or misuse anything which is provided in the interest of health or safety. *[S. 15 substituted by s. 3 of Act No. 181 of 1993.]*

16. Chief executive officer charged with certain duties

(1) Every chief executive officer shall as far as is reasonably practicable ensure that the duties of his employer as contemplated in this Act, are properly discharged.

(2) Without derogating from his responsibility or liability in terms of subsection (1), a chief executive officer may assign any duty contemplated in the said subsection, to any person under his control, which person shall act subject to the control and directions of the chief executive officer.

(3) The provisions of subsection (1) shall not, subject to the provisions of section 37, relieve an employer of any responsibility or liability under this Act.

(4) For the purpose of subsection (1), the head of department of any department of State shall be deemed to be the chief executive officer of that department.

17. Health and safety representatives

(1) Subject to the provisions of subsection (2), every employer who has more than 20 employees in his employment at any workplace, shall, within four months after the commencement of this Act or after commencing business, or from such time as the number of employees exceeds 20, as the case may be, designate in writing for a specified period health and safety representatives for such workplace, or for different sections thereof.

(2) An employer and the representatives of his employees recognized by him or, where there are no such representatives, the employees shall consult in good faith regarding the arrangements and procedures for the nomination or election, period of office and subsequent designation of health and safety representatives in terms of subsection (1): Provided that if such consultation fails, the matter shall be referred for arbitration to a person mutually agreed upon, whose decision shall be final: Provided further that if the parties do not agree within 14 days on an arbitrator, the employer shall give notice to this effect in writing to the President of the Industrial Court, who shall in consultation with the chief inspector designate an arbitrator, whose decision shall be final. *[Sub-s. (2) substituted by s. 4 of Act No. 181 of 1993.]*

(3) Arbitration in terms of subsection (2) shall not be subject to the provisions of the Arbitration Act, 1965 (Act No. 42 of 1965), and a failure of the consultation contemplated in that subsection shall not be deemed to be a dispute in terms of the Labour Relations Act, 1956 (Act No. 28 of 1956): Provided that the Minister may prescribe the manner of arbitration and the remuneration of the arbitrator designated by the President of the Industrial Court. *[Sub-s. (3) substituted by s. 4 of Act No. 181 of 1993.]*

(4) Only those employees employed in a full-time capacity at a specific workplace and who are acquainted with conditions and activities at that workplace or section thereof, as the case may be, shall be eligible for designation as health and safety representatives for that workplace or section.

(5) The number of health and safety representatives for a workplace or section thereof shall in the case of shops and offices be at least one health and safety representative for every 100 employees or part thereof, and in the case of all other workplaces at least one health and safety representative for every 50 employees or part thereof: Provided that those employees performing work at a workplace other than that where they ordinarily report for duty, shall be deemed to be working at the workplace where they

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so report for duty.

(6) If an inspector is of the opinion that the number of health and safety representatives for any workplace or section thereof, including a workplace or section with 20 or fewer employees, is inadequate, he may by notice in writing direct the employer to designate such number of employees as the inspector may determine as health and safety representatives for that workplace or section thereof in accordance with the arrangements and procedures referred to in subsection (2).

(7) All activities in connection with the designation, functions and training of health and safety representatives shall be performed during ordinary working hours, and any time reasonably spent by any employee in this regard shall for all purposes be deemed to be time spent by him in the carrying out of his duties as an employee.

18. Functions of health and safety representatives

(1) A health and safety representative may perform the following functions in respect of the workplace or section of the workplace for which he has been designated, namely-

(a) review the effectiveness of health and safety measures;

(b) identify potential hazards and potential major incidents at the workplace;

(c) in collaboration with his employer, examine the causes of incidents at the workplace;

(d) investigate complaints by any employee relating to that employee's health or safety at work;

(e) make representations to the employer or a health and safety committee on matters arising from paragraphs (a), (b), (c) or (d), or where such representations are unsuccessful, to an inspector;

(f) make representations to the employer on general matters affecting the health or safety of the employees at the workplace;

(g) inspect the workplace, including any article, substance, plant, machinery or health and safety equipment at that workplace with a view to, the health and safety of employees, at such intervals as may be agreed upon with the employer: Provided that the health and safety representative shall give reasonable notice of his intention to carry out such an inspection to the employer, who may be present during the inspection;

(h) participate in consultations with inspectors at the workplace and accompany inspectors on inspections of the workplace;

(i) receive information from inspectors as contemplated in section 36; and

(j) in his capacity as a health and safety representative attend meetings of the health and safety committee of which he is a member, in connection with any of the above functions.

(2) A health and safety representative shall, in respect of the workplace or section of the workplace for which he has been designated be entitled to-

(a) visit the site of an incident at all reasonable times and attend any inspection in loco;

(b) attend any investigation or formal inquiry held in terms of this Act;

(c) in so far as it is reasonably necessary for performing his functions, inspect any document which the employer is required to keep in terms of this Act;

(d) accompany an inspector on any inspection;

(e) with the approval of the employer (which approval shall not be unreasonably withheld), be accompanied by a technical adviser, on any inspection; and

(f) participate in any internal health or safety audit. *[Sub-s. (2) substituted by s. 5 of Act No. 181 of 1993.]*

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(3) An employer shall provide such facilities, assistance and training as a health and safety representative may reasonably require and as have been agreed upon for the carrying out of his functions.

(4) A health and safety representative shall not incur any civil liability by reason of the fact only that he failed to do anything which he may do or is required to do in terms of this Act.

19. Health and safety committees

(1) An employer shall in respect of each workplace where two or more health and safety representatives have been designated, establish one or more health and safety committees and, at every meeting of such a committee as contemplated in subsection (4), consult with the committee with a view to initiating, developing, promoting, maintaining and reviewing measures to ensure the health and safety of his employees at work.

(2) A health and safety committee shall consist of such number of members as the employer may from time to time determine: Provided that-

(a) if one health and safety committee has been established in respect of a workplace, all the health and safety representatives for that workplace shall be members of the committee;

(b) if two or more health and safety committees have been established in respect of a workplace, each health and safety representative for that workplace shall be a member of at least one of those committees; and

(c) the number of persons nominated by an employer on any health and safety committee established in terms of this section shall not exceed the number of health and safety representatives on that committee.

(3) The persons nominated by an employer on a health and safety committee shall be designated in writing by the employer for such period as may be determined by him, while the health and safety representatives shall be members of the committee for the period of their designation in terms of section 17 (1).

(4) A health and safety committee shall hold meetings as often as may be necessary, but at least once every three months, at a time and place determined by the committee: Provided that an inspector may by notice in writing direct the members of a health and safety committee to hold a meeting at a time and place determined by him: Provided further that, if more than 10 per cent of the employees at a specific workplace has handed a written request to an inspector, the inspector may by written notice direct that such a meeting be held.

(5) The procedure at meetings of a health and safety committee shall be determined by the committee.

(6) (a) A health and safety committee may co-opt one or more persons by reason of his or their particular knowledge of health or safety matters as an advisory member or as advisory members of the committee.

(b) An advisory member shall not be entitled to vote on any matter before the committee.

(7) If an inspector is of the opinion that the number of health and safety committees established for any particular workplace is inadequate, he may in writing direct the employer to establish for such workplace such number of health and safety committees as the inspector may determine.

20. Functions of health and safety committees

(1) A health and safety committee-

(a) may make recommendations to the employer or, where the recommendations fail to resolve the matter, to an inspector regarding any matter affecting the health or safety of persons at the workplace or any section thereof for which such committee has been established;

(b) shall discuss any incident at the workplace or section thereof in which or in consequence of which any person was injured, became ill or died, and may in writing report on the incident to an inspector; and

(c) shall perform such other functions as may be prescribed.

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(2) A health and safety committee shall keep record of each recommendation made to an employer in terms of subsection (1) (a) and of any report made to an inspector in terms of subsection (1) (b).

(3) A health and safety committee or a member thereof shall not incur any civil liability by reason of the fact only that it or he failed to do anything which it or he may or is required to do in terms of this Act.

(4) An employer shall take the prescribed steps to ensure that a health and safety committee complies with the provisions of section 19 (4) and performs the duties assigned to it by subsections (1) and (2).

21. General prohibitions

(1) The Minister may by notice in the Gazette declare-

(a) that no employer shall require or permit any employee belonging to a category of employees specified in the notice to perform work on or in any premises on or in which an activity specified in the notice is carried out which in the opinion of the Minister is an activity which threatens or is likely to threaten the health or safety of an employee belonging to that category of employees, or that no employer shall require or permit any such employee to perform any work on or in such premises otherwise than on the conditions specified in the notice;

(b) that no employer shall require or permit any employee to perform any work in connection with the carrying out of a process specified in the notice which in the opinion of the Minister is a process which threatens or is likely to threaten the health or safety of an employee, or that no employer shall require or permit an employee to perform any work in connection with the carrying out of such a process otherwise than on the conditions specified in the notice; and

(c) that no employer shall require or permit any employee, otherwise than on the conditions specified in the notice, to perform any work on or in any premises where an article or substance specified in the notice is produced, processed, used, handled, stored or transported which in the opinion of the Minister is an article or substance which threatens or is likely to threaten the health or safety of an employee.

(2) (a) The Minister shall, before he publishes a notice under subsection (1), cause a draft of his proposed notice to be published in the Gazette and at the same time invite interested persons to submit to him in writing, within a specified period, comments and representations in connection with the proposed notice.

(b) The provisions of paragraph (a) shall not apply if the Minister, in pursuance of comments and representations received, decides to publish the notice referred to in subsection (1) in an amended form.

(3) A notice under subsection (1) may at any time be amended or withdrawn by like notice.

(4) A notice shall not be issued under subsection (1) or (3) unless the Minister for National Health and Welfare and the Council have been consulted.

(5) A notice issued or deemed to have been issued under section 13 of the Machinery and Occupational Safety Act, 1983 (Act No. 6 of 1983), and which was in force immediately prior to the commencement of this Act, shall be deemed to have been issued under this section.

22. Sale of certain articles prohibited

Subject to the provisions of section 10 (4), if any requirement (including any health and safety standard) in respect of any article, substance, plant, machinery or health and safety equipment or for the use or application thereof has been prescribed, no person shall sell or market in any manner whatsoever such article, substance, plant, machinery or health and safety equipment unless it complies with that requirement.

23. Certain deductions prohibited

No employer shall in respect of anything which he is in terms of this Act required to provide or to do in the interest of the health or safety of an employee, make any deduction from any employee's remuneration or require or permit any employee to make any payment to him or any other person. *[S. 23 substituted by s. 6 of Act No. 181 of 1993.]*

24. Report to inspector regarding certain incidents

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(1) Each incident occurring at work or arising out of or in connection with the activities of persons at work, or in connection with the use of plant or machinery, in which, or in consequence of which-

(a) any person dies, becomes unconscious, suffers the loss of a limb or part of a limb or is otherwise injured or becomes ill to such a degree that he is likely either to die or to suffer a permanent physical defect or likely to be unable for a period of at least 14 days either to work or to continue with the activity for which he was employed or is usually employed;

(b) a major incident occurred; or

(c) the health or safety of any person was endangered and where-

(i) a dangerous substance was spilled;

(ii) the uncontrolled release of any substance under pressure took place;

(iii) machinery or any part thereof fractured or failed resulting in flying, falling or uncontrolled moving objects; or

(iv) machinery ran out of control, shall, within the prescribed period and in the prescribed manner, be reported to an inspector by the employer or the user of the plant or machinery concerned, as the case may be.

(2) In the event of an incident in which a person died, or was injured to such an extent that he is likely to die, or suffered the loss of a limb or part of a limb, no person shall without the consent of an inspector disturb the site at which the incident occurred or remove any article or substance involved in the incident therefrom: Provided that such action may be taken as is necessary to prevent a further incident, to remove the injured or dead, or to rescue persons from danger.

(3) The provisions of subsections (1) and (2) shall not apply in respect of-

(a) a traffic accident on a public road;

(b) an incident occurring in a private household, provided the householder forthwith reports the incident to the South African Police; or

(c) any accident which is to be investigated under section 12 of the Aviation Act, 1962 (Act No. 74 of 1962).

(4) A member of the South African Police to whom an incident was reported in terms of subsection (3) (b), shall forthwith notify an inspector thereof.

25. Report to chief inspector regarding occupational disease

Any medical practitioner who examines or treats a person for a disease described in the Second Schedule to the Workmen's Compensation Act, 1941 (Act No. 30 of 1941), or any other disease which he believes arose out of that person's employment, shall within the prescribed period and in the prescribed manner report the case to the person's employer and to the chief inspector, and inform that person accordingly. *[S. 25 substituted by s. 7 of Act No. 181 of 1993.]*

26. Victimization forbidden

(1) No employer shall dismiss an employee, or reduce the rate of his remuneration, or alter the terms or conditions of his employment to terms or conditions less favourable to him, or alter his position relative to other employees employed by that employer to his disadvantage, by reason of the fact, or because he suspects or believes, whether or not the suspicion or belief is justified or correct, that that employee has given information to the Minister or to any other person charged with the administration of a provision of this Act which in terms of this Act he is required to give or which relates to the terms, conditions or circumstances of his employment or to those of any other employee of his employer, or has complied with a lawful prohibition, requirement, request or direction of an inspector, or has given evidence before a court of law or the industrial court, or has done anything which he may or is required to do in terms of this Act or has refused to do anything which he is prohibited from doing in terms of this Act.

(2) No employer shall unfairly dismiss an employee, or reduce the rate of his remuneration, or alter the terms or conditions of his employment to terms or conditions less favourable to him, or alter his position relative to other employees employed by that employer to his disadvantage, by reason of the information that the employer has obtained regarding the results contemplated in section 12 (2) or by

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reason of a report made to the employer in terms of section 25. *[Sub-s. (2) added by s. 8 of Act No. 181 of 1993.]*

27. Designation and functions of chief inspector

(1) The Minister shall designate an officer serving in the Department as chief inspector for the purposes of this Act.

(2) The chief inspector shall perform his functions subject to the control and supervision of the Director-General of the Department and may perform any function assigned to an inspector by this Act.

(3) (a) The chief inspector may delegate any power conferred upon him by this Act, excluding a power referred to in section 35 (1) or delegated to him under section 42, to any other officer or authorize any such officer to perform any duty assigned to him by this Act.

(b) No delegation of a power under paragraph (a) shall prevent the exercise of such power by the chief inspector himself.

(4) Whenever the chief inspector is absent or unable to perform his functions as chief inspector or whenever the designation of a chief inspector is pending, the Minister may designate any other officer serving in the Department to act as chief inspector during the chief inspector's absence or incapacity or until a chief inspector is designated.

(5) Any person who immediately prior to the commencement of this Act was designated as chief inspector under section 19 of the Machinery and Occupational Safety Act, 1983 (Act No. 6 of 1983), shall be deemed to have been designated as chief inspector under subsection (1) of this section.

28. Designation of inspectors by Minister

(1) The Minister may designate any person as an inspector to perform, subject to the control and directions of the chief inspector, any or all of the functions assigned to an inspector by this Act.

(2) Each inspector designated under subsection (1) shall be furnished with a certificate signed by or on behalf of the Minister and stating that he has been designated as an inspector: Provided that if his designation as inspector is limited to any particular function or functions, his certificate shall state such limitation.

(3) Whenever an inspector designated under subsection (1) performs a function under this Act in the presence of any person affected thereby the inspector shall on demand by such person produce to him the certificate referred to in subsection (2).

(4) Any officer who immediately prior to the commencement of this Act was designated as an inspector under section 20 of the Machinery and Occupational Safety Act, 1983 (Act No. 6 of 1983), shall be deemed to have been designated as an inspector under subsection (1) of this section.

29. Functions of inspectors

(1) An inspector may, for the purposes of this Act-

(a) without previous notice, at all reasonable times, enter any premises which are occupied or used by an employer or on or in which an employee performs any work or any plant or machinery is used, or which he suspects to be such premises;

(b) question any person who is or was on or in such premises, either alone or in the presence of any other person, on any matter to which this Act relates;

(c) require from any person who has control over or custody of a book, record or other document on or in those premises, to produce to him forthwith, or at such time and place as may be determined by him, such book, record or other document;

(d) examine any such book, record or other document or make a copy thereof or an extract therefrom;

(e) require from such a person an explanation of any entry in such book, record or other document;

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(f) inspect any article, substance, plant or machinery which is or was on or in those premises, or any work performed on or in those premises or any condition prevalent on or in those premises or remove for examination or analysis any article, substance, plant or machinery or a part or sample thereof;

(g) seize any such book, record or other document or any such article, substance, plant or machinery or a part or sample thereof which in his opinion may serve as evidence at the trial of any person charged with an offence under this Act or the common law: Provided that the employer or user of the article, substance, plant or machinery concerned, as the case may be, may make copies of such book, record or document before such seizure;

(h) direct any employer, employee or user, including any former employer, employee or user, to appear before him at such time and place as may be determined by him and question such employer, employee or user either alone or in the presence of any other person on any matter to which this Act relates;

(i) perform any other function as may be prescribed.

(2) (a) An interpreter, a member of the South African Police or any other assistant may, when required by an inspector, accompany him when he performs his functions under this Act.

(b) For the purposes of this Act an inspector's assistant shall, while he acts under the instructions of an inspector, be deemed to be an inspector.

(3) When an inspector enters any premises under subsection (1) the employer occupying or using those premises and each employee performing any work thereon or therein and any user of plant or machinery thereon or therein, shall at all times provide such facilities as are reasonably required by the inspector to enable him and his assistant (if any) to perform effectively and safely his or their functions under this Act.

(4) When an inspector removes or seizes any article, substance, plant, machinery, book, record or other document as contemplated in subsection (1) (f) or (g), he shall issue a receipt to the owner or person in control thereof.

30. Special powers of inspectors

(1) (a) Whenever an employer performs an act or requires or permits an act to be performed, or proposes to perform an act or to require or permit an act to be performed, which in the opinion of an inspector threatens or is likely to threaten the health or safety of any person, the inspector may in writing prohibit that employer from continuing or commencing with the performance of that act or from requiring or permitting that act to be continued or commenced with, as the case may be.

(b) Whenever a user of plant or machinery uses or proposes to use any plant or machinery, in a manner or in circumstances which in the opinion of an inspector threatens or is likely to threaten the health or safety of any person who works with such plant or machinery or who is or may come within the vicinity thereof, the inspector may in writing prohibit that user from continuing or commencing with the use of such plant or machinery or in that manner or those circumstances, as the case may be.

(c) An inspector may in writing prohibit an employer from requiring or permitting an employee or any employee belonging to a category of employees specified in the prohibition to be exposed in the course of his employment for a longer period than a period specified in the prohibition, to any article, substance, organism or condition which in the opinion of an inspector threatens or is likely to threaten the health or safety of that employee or the employee belonging to that category of employees, as the case may be.

(d) A prohibition imposed under paragraph (a), (b) or (c) may at any time be revoked by an inspector in writing if arrangements to the satisfaction of the inspector have been made to dispose of the threat which gave rise to the imposition of the prohibition.

(2) In order to enforce a prohibition imposed under subsection (1) (a) or (b), an inspector may block, bar, barricade or fence off that part of the workplace, plant or machinery to which the prohibition applies, and no person shall interfere with or remove such blocking, bar, barricade or fence.

(3) Whenever an inspector is of the opinion that the health or safety of any person at a workplace or in the course of his employment or in connection with the use of plant or machinery is threatened on account of the refusal or failure of an employer or a user, as the case may be, to take reasonable steps in the interest of such person's health or safety, the inspector may in writing direct that employer or user to

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take such steps as are specified in the direction within a specified period.

(4) Whenever an inspector is of the opinion that an employer or a user has failed to comply with a provision of a regulation applicable to him, the inspector may in writing direct that employer or user to take within a period specified in the direction such steps as in the inspector's opinion are necessary to comply with the said provision, and are specified in the direction.

(5) A period contemplated in subsection (3) or (4) may at any time be extended by an inspector by notice in writing to the person concerned.

(6) An employer shall forthwith bring the contents of a prohibition, direction or notice under this section to the attention of the health and safety representatives and employees concerned.

31. Investigations

(1) An inspector may investigate the circumstances of any incident which has occurred at or originated from a workplace or in connection with the use of plant or machinery which has resulted, or in the opinion of the inspector could have resulted, in the injury, illness or death of any person in order to determine whether it is necessary to hold a formal investigation in terms of section 32.

(2) After completing the investigation in terms of subsection (1) the inspector shall submit a written report thereon, together with all relevant statements, documents and information gathered by him, to the attorney-general within whose area of jurisdiction such incident occurred and he shall at the same time submit a copy of the report, statements and documents to the chief inspector.

(3) Upon receipt of a report referred to in subsection (2), the attorney-general shall deal therewith in accordance with the provisions of the Inquests Act, 1959 (Act No. 58 of 1959), or the Criminal Procedure Act, 1977 (Act No. 51 of 1977), as the case may be.

(4) An inspector holding an investigation shall not incur any civil liability by virtue of anything contained in the report referred to in subsection (2).

32. Formal inquiries

(1) The chief inspector may, and he shall when so requested by a person producing prima facie evidence of an offence, direct an inspector to conduct a formal inquiry into any incident which has occurred at or originated from a workplace or in connection with the use of plant or machinery which has resulted, or in the opinion of the chief inspector could have resulted, in the injury, illness or death of any person.

(2) For the purposes of an inquiry referred to in subsection (1) an inspector may subpoena any person to appear before him on a day and at a place specified in the subpoena and to give evidence or to produce any book, document or thing which in the opinion of the inspector has a bearing on the subject of the inquiry.

(3) Save as is otherwise provided in this section, the law governing criminal trials in magistrates' courts shall mutatis mutandis apply to obtaining the attendance of witnesses at an inquiry under this section, the administering of an oath or affirmation to them, their examination, the payment of witness fees to them and the production by them of books, documents and things.

(4) Any inquiry under this section shall be held in public: Provided that the presiding inspector may exclude from the place where the inquiry is held, any person whose presence is, in his opinion, undesirable or not in the public interest.

(5) (a) The presiding inspector may designate any person to lead evidence and to examine any witness giving evidence at a formal inquiry.

(b) Any person who has an interest in the issue of the formal inquiry may personally or by representative, advocate or attorney put such questions to a witness at the inquiry to such extent as the presiding inspector may allow.

(c) The following persons shall have an interest as referred to in paragraph (b), namely-

(i) any person who was injured or suffered damage as a result of the incident forming the subject of the inquiry;

(ii) the employer or user, as the case may be, involved in the incident;

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(iii) any person in respect of whom in the opinion of the presiding inspector it can reasonably be inferred from the evidence that he could be held responsible for the incident;

(iv) a trade union recognized by the employer concerned or any trade union of which a person referred to in subparagraph (i) or (iii) is a member;

(v) any owner or occupier of any premises where the said incident occurred;

(vi) any other person who, at the discretion of the presiding inspector, can prove such interest.

(6) (a) An inquiry may, if it is necessary or expedient, be adjourned at any time by the presiding inspector.

(b) An inquiry adjourned under paragraph (a) may at any stage be continued by an inspector other than the inspector before whom the inquiry commenced, and may after an adjournment again be continued by the inspector before whom the inquiry commenced.

(7) An affidavit made by any person in connection with the incident in respect of which the inquiry is held, shall at the discretion of the presiding inspector upon production be admissible as proof of the facts stated therein, and the presiding inspector may, at his discretion, subpoena the person who made such an affidavit to give oral evidence at the inquiry or may submit written interrogatories to him for reply, and such interrogatories and any reply thereto purporting to be a reply from such person shall likewise be admissible in evidence at the inquiry: Provided that the presiding inspector shall afford any person present at the inquiry the opportunity to refute the facts stated in such document, evidence or reply.

(8) (a) Whenever in the course of any inquiry it appears to the presiding inspector that the examination of a witness is necessary and that the attendance of such witness cannot be procured without a measure of delay, expense or inconvenience which in the circumstances would be unreasonable, the presiding inspector may dispense with such attendance and may appoint a person to be a commissioner to take the evidence of such witness, whether within or outside the Republic, in regard to such matters or facts as the presiding inspector may indicate.

(b) Any person referred to in subsection (5) (b) may in person or through a representative, advocate or attorney appear before such commissioner in order to examine the said witness.

(c) The evidence recorded in terms of this subsection shall be admissible in evidence at the inquiry.

(9) At the conclusion of an inquiry under this section, the presiding inspector shall compile a written report thereon.

(10) The evidence given at any inquiry under this section shall be recorded and a copy thereof shall be submitted by the presiding inspector together with his report to the chief inspector, and in the case of an incident in which or as a result of which any person died or was seriously injured or became ill, the inspector shall submit a copy of the said evidence and the report to the attorney-general within whose area of jurisdiction such incident occurred.

(11) Nothing contained in this section shall be construed as preventing the institution of criminal proceedings against any person or as preventing any person authorized thereto from issuing a warrant for the arrest of or arresting any person, whether or not an inquiry has already commenced.

(12) Upon receipt of a report referred to in subsection (10), the attorney-general shall deal therewith in accordance with the provisions of the Inquests Act, 1959 (Act No. 58 of 1959), or the Criminal Procedure Act, 1977 (Act No. 51 of 1977), as the case may be.

(13) An inspector presiding at any formal inquiry shall not incur any civil liability by virtue of anything contained in the report compiled in terms of subsection (9).

33. Joint inquiries

(1) The provisions of section 32 shall not affect the provisions of any law requiring and regulating inquests or other inquiries in case of death resulting from other than natural causes, and in respect of each incident referred to in that section in which or in consequence of which any person has died there shall be held, in addition to an inquiry under the said section, such inquest or inquiry as is required by any such law, but an inquiry under the said section and an inquest held by a judicial officer under the Inquests Act, 1959 (Act No. 58 of 1959), may be held jointly.

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(2) At such a joint inquiry and inquest the judicial officer shall preside and thereupon the provisions of the Inquests Act, 1959, shall apply, but the inspector and the judicial officer shall each make the report required of them by section 32 (9) and that Act, respectively.

34. Obstruction of investigation or inquiry or presiding inspector or failure to render assistance

No person shall, in relation to any investigation or inquiry held in terms of section 31 or 32-

(a) without reasonable justification fail to comply with any lawful direction, subpoena, request or order issued or given by the presiding inspector;

(b) refuse or fail to answer to the best of his knowledge any question lawfully put to him by or with the concurrence of the presiding inspector: Provided that no person shall be obliged to answer any question whereby he may incriminate himself;

(c) in any manner whatsoever advise, encourage, incite, order or persuade any person who has been directed, subpoenaed, requested or ordered to do something by the presiding inspector, not to comply with such direction, subpoena, request or order or in any manner prevent him from doing so;

(d) refuse or fail, when required thereto by the presiding inspector, to furnish him with the means or to render him the necessary assistance for holding such inquiry;

(e) refuse or fail, when required thereto by the presiding inspector, to attend an inquiry; or

(f) intentionally insult the presiding inspector or his assistant or intentionally interrupt the proceedings thereof.

35. Appeal against decision of inspector

(1) Any person aggrieved by any decision taken by an inspector under a provision of this Act may appeal against such decision to the chief inspector, and the chief inspector shall, after he has considered the grounds of the appeal and the inspector's reasons for the decision, confirm, set aside or vary the decision or substitute for such decision any other decision which the inspector in the chief inspector's opinion ought to have taken.

(2) Any person who wishes to appeal in terms of subsection (1), shall within 60 days after the inspector's decision was made known, lodge such an appeal with the chief inspector in writing, setting out the grounds on which it is made.

(3) Any person aggrieved by a decision taken by the chief inspector under subsection (1) or in the exercise of any power under this Act, may appeal against such decision to the industrial court, and the industrial court shall inquire into and consider the matter forming the subject of the appeal and confirm, set aside or vary the decision or substitute for such decision any other decision which the chief inspector in the opinion of the industrial court ought to have taken.

(4) Any person who wishes to appeal in terms of subsection (3), shall within 60 days after the chief inspector's decision was given, lodge such appeal with the registrar of the industrial court in accordance with the rules of the industrial court.

(5) An appeal under subsection (1) or (3) in connection with a prohibition imposed under section 30 (1) (a) or (b) shall not suspend the operation of such prohibition.

36. Disclosure of information

No person shall disclose any information concerning the affairs of any other person obtained by him in carrying out his functions in terms of this Act, except-

(a) to the extent to which it may be necessary for the proper administration of a provision of this Act;

(b) for the purposes of the administration of justice; or

(c) at the request of a health and safety representative or a health and safety committee entitled thereto.

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37. Acts or omissions by employees or mandataries

(1) Whenever an employee does or omits to do any act which it would be an offence in terms of this Act for the employer of such employee or a user to do or omit to do, then, unless it is proved that-

(a) in doing or omitting to do that act the employee was acting without the connivance or permission of the employer or any such user;

(b) it was not under any condition or in any circumstance within the scope of the authority of the employee to do or omit to do an act, whether lawful or unlawful, of the character of the act or omission charged; and

(c) all reasonable steps were taken by the employer or any such user to prevent any act or omission of the kind in question, the employer or any such user himself shall be presumed to have done or omitted to do that act, and shall be liable to be convicted and sentenced in respect hereof; and the fact that he issued instructions forbidding any act or omission of the kind in question shall not, in itself, be accepted as sufficient proof that he took all reasonable steps to prevent the act or omission.

(2) The provisions of subsection (1) shall mutatis mutandis apply in the case of a mandatary of any employer or user, except if the parties have agreed in writing to the arrangements and procedures between them to ensure compliance by the mandatary with the provisions of this Act.

(3) Whenever any employee or mandatary of any employer or user does or omits to do an act which it would be an offence in terms of this Act for the employer or any such user to do or omit to do, he shall be liable to be convicted and sentenced in respect thereof as if he were the employer or user.

(4) Whenever any employee or mandatary of the State commits or omits to do an act which would be an offence in terms of this Act, had he been the employee or mandatary of an employer other than the State and had such employer committed or omitted to do that act, he shall be liable to be convicted and sentenced in respect thereof as if he were such an employer.

(5) Any employee or mandatary referred to in subsection (3) may be so convicted and sentenced in addition to the employer or user.

(6) Whenever the employee or mandatary of an employer is convicted of an offence consisting of a contravention of section 23, the court shall, when making an order under section 38 (4), make such an order against the employer and not against such employee or mandatary.

38. Offences, penalties and special orders of court

(1) Any person who-

(a) contravenes or fails to comply with a provision of section 7, 8, 9, 10 (1), (2) or (3), 12, 13, 14, 15, 16 (1) or (2), 17 (1), (2) or (5), 18 (3), 19 (1), 20 (2) or (4), 22, 23, 24 (1) or (2), 25, 26, 29 (3), 30 (2) or (6), 34 or 36;

(b) contravenes or fails to comply with a direction or notice under section 17 (6), 19 (4) or (7), 21 (1) or 30 (1) (a), (b) or (c) or (3), (4) or (6);

(c) contravenes or fails to comply with a condition of an exemption under seetion 40 (1);

(d) in any record, application, statement or other document referred to in this Act wilfully furnishes information or makes a statement which is false in any material respect;

(e) hinders or obstructs an inspector in the performance of his functions; refuses or fails to comply to the best of his ability with any requirement or request made by an inspector in the performance of his functions;

(f) deleted

(g) refuses or fails to answer to the best of his ability any question which an inspector in the performance of his functions has put to him;

(h) wilfully furnishes to an inspector information which is false or misleading;

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(i) gives himself out as an inspector;

(j) having been subpoenaed under section 32 to appear before an inspector, without sufficient cause (the onus of proof whereof shall rest upon him) fails to attend on the day and at the place specified in the subpoena, or fails to remain in attendance until the inspector has excused him from further attendance;

(k) having been called under section 32, without sufficient cause (the onus of proof whereof shall rest upon him)-

(i) refuses to appear before the inspector;

(ii) refuses to be sworn or to make affirmation as a witness after he has been directed to do so;

(iii) refuses to answer, or fails to answer to the best of his knowledge and belief, any question put to him; or

(iv) refuses to comply with a requirement to produce a book, document or thing specified in the subpoena or which he has with him;

(l) tampers with or discourages, threatens, deceives or in any way unduly influences any person with regard to evidence to be given or with regard to a book, document or thing to be produced by such a person before an inspector under section 32;

(m) prejudices, influences or anticipates the proceedings or findings of an inquiry under section 32 or 33;

(n) tampers with or misuses any safety equipment installed or provided to any person by an employer or user;

(o) fails to use any safety equipment at a workplace or in the course of his employment or in connection with the use of plant or machinery, which was provided to him by an employer or such a user;

(p) wilfully or recklessly does anything at a workplace or in connection with the use of plant or machinery which threatens the health or safety of any person, shall be guilty of an offence and on conviction be liable to a fine not exceeding R50000 or to imprisonment for a period not exceeding one year or to both such fine and such imprisonment.

(2) Any employer who does or omits to do an act, thereby causing any person to be injured at a workplace, or, in the case of a person employed by him, to be injured at any place in the course of his employment, or any user who does or omits to do an act in connection with the use of plant or machinery, thereby causing any person to be injured, shall be guilty of an offence if that employer or user, as the case may be, would in respect of that act or omission have been guilty of the offence of culpable homicide had that act or omission caused the death of the said person, irrespective of whether or not the injury could have led to the death of such person, and on conviction be liable to a fine not exceeding R100 000 or to imprisonment for a period not exceeding two years or to both such fine and such imprisonment.

(3) Whenever a person is convicted of an offence consisting of a failure to comply with a provision of this Act or of any direction or notice issued thereunder, the court convicting him may, in addition to any punishment imposed on him in respect of that offence, issue an order requiring him to comply with the said provision within a period determined by the court.

(4) Whenever an employer is convicted of an offence consisting of a contravention of a provision of section 23, the court convicting him shall inquire into and determine the amount which contrary to the said provision was deducted from the remuneration of the employee concerned or recovered from him and shall then act with respect to the said amount mutatis mutandis in accordance with sections 28 and 29 of the Basic Conditions of Employment Act, 1983 (Act No. 3 of 1983), as if such amount is an amount underpaid within the meaning of those sections.

39. Proof of certain facts

(1) Whenever in any legal proceedings in terms of this Act it is proved that any person was present on or in any premises, that person shall, unless the contrary is proved, be presumed to be an employee.

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(2) In the absence of satisfactory proof of age, the age of any person shall, in any legal proceedings in terms of this Act, be presumed to be that stated by an inspector to be in his opinion the probable age of the person; but any person having an interest who is dissatisfied with that statement of opinion may, at his own expense, require that the person whose age is in question appear before and be examined by a district surgeon, and a statement contained in a certificate by a district surgeon who examined that person as to what in his opinion is the probable age of that person shall, but only for the purpose of the said proceedings, be conclusive proof of the age of that person.

(3) In any legal proceedings in terms of this Act, any statement or entry contained in any book or document kept by any employer or user or by his employee or mandatary, or found on or in any premises occupied or used by that employer or user, and any copy or reproduction of any such statement or entry, shall be admissible in evidence against him as an admission of the facts set forth in that statement or entry, unless it is proved that that statement or entry was not made by that employer or user or by any employee or mandatary of that employer or user within the scope of his authority.

(4) Whenever in any legal proceedings in terms of this Act it is proved that any untrue statement or entry is contained in any record kept by any person, he shall be presumed, until the contrary is proved, wilfully to have falsified that record.

(5) (a) Whenever at the trial of any person charged with a contravention of section 22 it is proved that the accused sold or marketed any article, substance, plant, machinery or health and safety equipment contemplated in that section, it shall be presumed, until the contrary is proved, that such article, substance, plant, machinery or health and safety equipment did not at the time of the sale or marketing thereof comply with the said requirements.

(b) At any trial any document purporting to be a certificate or statement by an approved inspection authority and in which it is alleged that the article, substance, plant, machinery or health and safety equipment forming the subject of the charge complies with the requirements prescribed in respect thereof or with any particular standard, shall on its mere production at that trial by or on behalf of the accused be accepted as prima facie proof of the facts stated therein.

(6) Notwithstanding the provisions of section 31 (3) of the Standards Act, 1993 (Act No. 29 of 1993), whenever in any legal proceedings in terms of this Act the question arises whether any document contains the text of a health and safety standard incorporated in the regulations under section 44, any document purporting to be a statement by a person who in that statement alleges that he is an inspector and that a particular document contains the said text, shall on its mere production at those proceedings by any person be prima facie proof of the facts stated therein.

(7) The records to be kept by a health and safety committee in terms of section 20 (2), including any document purporting to be certified by an inspector as a true extract from any such records, shall on their mere production at any legal proceedings by any person be admissible as evidence of the fact that a recommendation or report recorded in such records was made by a health and safety committee to an employer or inspector concerned.

40. Exemptions

(1) The Minister may, for such period and on such conditions as may be determined by him, exempt any employer or user or any category of employers or users, generally or with respect to any particular employee or category of employees or users or with respect to any matter, from any of or all the provisions of this Act or the provisions of a notice or direction issued under this Act.

(2) The period for which exemption may be granted under subsection (1) may commence on a date earlier than the date on which exemption is granted, but not earlier than the date on which application for such exemption was made to the Minister.

(3) An exemption under subsection (1) shall-

(a) in the case of the exemption of a particular employer or user, be granted by issuing to such employer or user a certificate of exemption in which his name and the scope, period and conditions of the exemption are specified;

(b) in the case of the exemption of a category of employers or of a category of such users, be granted by the publication in the Gazette of a notice in which that category of employers or users is described and the scope, period and conditions of the exemption are specified: Provided that the Minister may grant exemption-

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(i) to an organization of employers or an organization of users in accordance with the requirements of either paragraph (a) or paragraph (b);

(ii) from any health and safety standard incorporated in the regulations under section 44, in any manner which he may deem expedient.

(4) A certificate of exemption contemplated in subsection (3) (a) and a notice contemplated in subsection (3) (b) may at any time be amended or withdrawn by the Minister.

(5) An exemption under subsection (1) shall lapse-

(a) upon termination of the period for which it was granted;

(b) upon withdrawal of the relevant certificate or notice under subsection (4).

(6) Any exemption granted under section 32 of the Machinery and Occupational Safety Act, 1983 (Act No. 6 of 1983), to the extent to which it grants exemption from the operation of a provision similar to a provision in respect of which exemption may be granted under subsection (1) of this section, which exemption has at the commencement of this Act not lapsed as contemplated in subsection (5) of the said section 32, shall be deemed to have been granted under this section.

41. This Act not affected by agreements

Subject to the provisions of sections 10 (4) and 37 (2), a provision of this Act or a condition specified in any notice or direction issued thereunder or subject to which exemption was granted to any person under section 40, shall not be affected by any condition of any agreement, whether such agreement was entered into before or after the commencement of this Act or before or after the imposition of any such condition, as the case may be.

42. Delegation and assignment of functions

(1) The Minister may delegate any power conferred upon him by or under this Act, except the power contemplated in section 43, to an officer.

(2) A delegation under subsection (1) shall not prevent the exercise of the relevant power by the Minister himself.

(3) The Minister may authorize any provincial administration or local authority to perform any function referred to in this Act.

(4) An authorization under subsection (3) shall not prevent the performance of the relevant function by the Minister, the chief inspector or an inspector, as the case may be.

43. Regulations

(1) The Minister may make regulations-

(a) as to any matter which in terms of this Act shall or may be prescribed;

(b) which in the opinion of the Minister are necessary or expedient in the interest of the health and safety of persons at work or the health and safety of persons in connection with the use of plant or machinery, or the protection of persons other than persons at work against risks to health and safety arising from or connected with the activities of persons at work, including regulations as to-

(i) the planning, layout, construction, use, alteration, repair, maintenance or demolition of buildings;

(ii) the design, manufacture, construction, installation, operation, use, handling, alteration, repair, maintenance or conveyance of plant, machinery or health and safety equipment;

(iii) the training, safety equipment or facilities to be provided by employers or users, the persons to whom and the circumstances in which they are to be provided and the application thereof;

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(iv) the health or safety measures to be taken by employers or users;

(v) the occupational hygiene measures to be taken by employers or users;

(vi) any matter regarding the biological monitoring or medical surveillance of employees;

(vii) the production, processing, use, handling, storage or transport of, and the exposure of employees and other persons to, hazardous articles, substances or organisms or potentially hazardous articles, substances or organisms, including specific limits, thresholds or indices of or for such exposure;

(viii) the performance of work in hazardous or potentially hazardous conditions or circumstances;

(ix) the emergency equipment and medicine to be held available by employers and users, the places where such equipment and medicine are to be held, the requirements with which such equipment and medicine shall comply, the inspection of such equipment and medicine, the application of first-aid and the qualifications which persons applying first-aid shall possess;

(x) the compilation by employers of health and safety directives in respect of a workplace, the matters to be dealt with in such directives and the manner in which such directives shall be brought to the attention of employees and other persons at such a workplace;

(xi) the registration of persons performing hazardous work or using or handling plant or machinery, the qualifications which such persons shall possess and the fees payable to the State in respect of such registration;

(xii) the accreditation, functions, duties and activities of approved inspection authorities;

(xiii) the consultations between an employer and employees on matters of health and safety;

(xiv) subject to section 36, the provision of information by an employer or user to employees or the public on any matter to which this Act relates;

(xv) the conditions under which any employer is prohibited from permitting any person to partake of food or to smoke on or in any premises where a specified activity is carried out;

(xvi) the conditions under which the manufacture of explosives and activities incidental thereto may take place;

(c) as to the preventive and protective measures for major hazard installations with a view to the protection of employees and the public against the risk of major incidents;

(d) as to the registration of premises where employees perform any work or where plant or machinery is used and the fee payable to the State in respect of such registration;

(e) whereby provision is made for the continuation of any registration under this Act;

(f) as to the registration of plant and machinery and the fee payable to the State in respect of such registration;

(g) as to the establishment of one or more committees for the administration of a provision of the regulations, the constitution of such committees, the functions of such committees, the procedure to be followed at meetings of such committees, the allowances which may be paid to members of such committees from money appropriated by Parliament for such purpose and the person by whom such allowances shall be fixed;

(h) prescribing the records to be kept and the returns to be rendered by employers and users and the person or persons to whom such returns shall be rendered;

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(i) as to the designation and functions of health and safety representatives and health and safety committees and the training of health and safety representatives;

(j) as to the activities of self-employed persons; and

(k) as to any other matter the regulation of which is in the opinion of the Minister necessary or desirable for the effective carrying out of the provisions of this Act.

(2) No regulation shall be made by the Minister except after consultation with the Council, and no regulation relating to State income or expenditure or to any health matter shall be made by the Minister except after consultation also with the Minister of State Expenditure and the Minister for National Health and Welfare, respectively.

(3) In making regulations the Minister may apply any method of differentiation that he may deem advisable: Provided that no differentiation on the basis of race or colour shall be made.

(4) A regulation may in respect of any contravention thereof or failure to comply therewith prescribe a penalty of a fine, or imprisonment for a period not exceeding 12 months, and, in the case of a continuous offence, not exceeding an additional fine of R200 or additional imprisonment of one day for each day on which the offence continues: Provided that the period of such additional imprisonment shall not exceed 90 days.

(5) A regulation made under section 35 of the Machinery and Occupational Safety Act, 1983 (Act No. 6 of 1983), which was in force immediately prior to the commencement of this Act and which could have been made under this section, shall be deemed to have been made under this section.

44. Incorporation of health and safety standards in regulations

(1) The Minister may by notice in the Gazette incorporate in the regulations any health and safety standard or part thereof, without stating the text thereof, by mere reference to the number, title and year of issue of that health and safety standard or to any other particulars by which that health and safety standard is sufficiently identified.

(2) No health and safety standard shall be incorporated in the regulations except after consultation with the Council.

(3) Any health and safety standard incorporated in the regulations under subsection (1) shall for the purposes of this Act, in so far as it is not repugnant to any regulation made under section 43, be deemed to be a regulation, but not before the expiry of two months from the date of incorporation thereof.

(4) Whenever any health and safety standard is at any time after the incorporation thereof as aforesaid, amended or substituted by the competent authority, the notice incorporating that health and safety standard shall, unless otherwise stated therein, be deemed to refer to that health and safety standard as so amended or substituted, as the case may be.

(5) The chief inspector shall keep a register of particulars of every publication in which a health and safety standard incorporated in the regulations under subsection (1), and every amendment or substitution of any such health and safety standard, was published, and also of the place in the Republic where such publication is obtainable or otherwise available for inspection, and he shall make that register or an extract therefrom available free of charge to persons having an interest, for inspection.

(6) The provisions of section 31 of the Standards Act, 1993 (Act No. 29 of 1993), shall not apply to any incorporation of a health and safety standard or of any amendment or substitution of a health and safety standard under this section.

(7) Any safety standard which was immediately prior to the commencement of this Act incorporated under section 36 of the Machinery and Occupational Safety Act, 1983 (Act No. 6 of 1983), in the regulations made under that Act, shall be deemed to be a health and safety standard incorporated under this section.

45. Serving of notices

Unless another method is prescribed, a notice under this Act shall be served-

(a) by delivering a copy thereof to the person upon whom it is to be served;

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(b) by leaving such a copy at the usual or last known place of residence or business of such a person; or

(c) by sending such a copy by registered post to the usual or last known place of residence or business of such a person.

46. Jurisdiction of magistrates' courts

Notwithstanding anything to the contrary contained in any law-

(a) a magistrate's court shall have jurisdiction to impose any penalty or to make any order provided for in this Act;

(b) no magistrate's court shall be competent to pronounce upon the validity of any regulation made under this Act.

47. State bound

This Act shall bind the State.

48. Conflict of provisions

In so far as any provision of the Explosives Act, 1956 (Act No. 26 of 1956), is repugnant to a provision of this Act the provisions of this Act shall apply.

49. Repeal of laws

The Machinery and Occupational Safety Act, 1983 (Act No. 6 of 1983), the Machinery and Occupational Safety Amendment Act, 1989 (Act No. 40 of 1989), and the Machinery and Occupational Safety Amendment Act, 1991 (Act No. 97 of 1991), are hereby repealed.

50. Short title and commencement

(1) This Act shall be called the Occupational Health and Safety Act, 1993, and shall come into operation on a date fixed by the State President by proclamation in the Gazette.

(2) Different dates may be so fixed in respect of different provisions of this Act.

12. Appendix D - Blast boxes and other safety installations

This appendix shows some of the facility and equipment requirements encountered during the C350e's implementation in Mercedes-Benz South Africa's manufacturing plant.

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Transportbox TBK 200

Technisches Datenblatt

- Edelstahlbehälter durchgehend geschweißt
- Blechstärke 1,5 mm
- stapelbar
- staub- und spritzwasserdicht IP 54

- **Außenmaße (LxBxH):** 1410 mm x 860 mm x 758 mm
- **Nutzraum (LxBxH):** 1220 mm x 670 mm x 300 mm
- **Nutzlast:** 200 kg
- **Gesamtgewicht:** 500 kg

- UN-Zulassung für den Transport gefährlicher Güter: 4A/X500/S/13/D/BAM 14257-KE-TEC
- Rauchgasfilter
- Hochtemperaturbeständigkeit für große Batterien (Außentemperatur < 70 ° C)

Figure 90: Blast boxes for damaged HV batteries

Figure 91: Manual hoist to remove a damaged battery from a unit

Figure 92: Hand and eye-wash station at Battery fitment station

Figure 93: Dedicated emergency storage bay for damaged batteries

Figure 94: Sprinkler system in HV Battery warehouse section

Figure 95: Guarding poles in the warehouse to prevent HV battery damage

Figure 96: Safety signage

13. *Appendix E - Standard existing checklists*

This appendix depicts pre-existing checklists that MBSA standardly used during projects. In the context of the IFAT these types of institutional knowledge need to be critically examined for unique High Voltage nuances. Standard packaging concepts may not be feasible for HV components, safety aspects including chemical dangers need to be considered when signing off on equipment and many other factors need to be considered when introducing HV technology.

A. Business Allocation and part approval

	Yes	No
a1. LSA (Local Scheduling Agreement) created on SAP?		
a2. Source List Maintained in SAP?		
a3. PEM Date updated in DIALOG-P?		
a4. Has the part been quality approved (QPP)?		
a5. Was the correct delivery strategy included in the RFQ, and has the business been allocated on correct basis for all parts?		

B. Interface Data

b1. Logistics / Supply concept

			Yes	No
b1.1 Delivery / Supply Strategy stipulated (ExW, DAF WH, DAF JIT, DAF JIS)?	**Delivery Concept**			
b1.2 General LOG CRS available at supplier?				
b1.3 Specific CRS available at supplier (ExW, DAF WH, DAF JIT, DAF JIS)?				

b2. Organisational

	Name	Tel Nr	Yes	No	N A
b2.1 DCSA MRP Controller assigned and known to supplier?					
a. DCSA MRP Controller (Name, tel nr.)					
b. Stand-in Controller (Name , tel nr.)					

	Yes	No	N A
b2.2 Has the MRP controller established contact with supplier?			
b2.3 Are details of main supplier contacts known (Name, Tel, Cell, Fax, e-mail, emergency tel nr.)?			

	Name	Tel Nr.	Emergency Nr.	N A
a. Customer service / Dispatch / Supply				
b. Stand-in				
c. Logistics Manager				

	Yes	No	N A
b2.4 Has an in-plant representative for JIT / JIS supplier been defined? (Name, Tel nr.) (DAF)			

	Contact	Tel Nr	Manager	Extension
b2.5 DCSA Procurement & Exports contacts known?				
b2.6 DCSA Accounting contacts known?				

b3. IT connectivity and communication

	Yes	No	N A
b3.1 Has the supplier / part been switched on for EDI transmission (in SAP / MQ Series) by DCSA IT?			
b3.2 Has the vendor been set up with CX and the vondor been notified with user name & password (ExW)?			
b3.3 Does the user(s) at the supplier know how to read releases on the CX system (ExW)?			
b3.4 Can the vendor receive releases error-free into the ERP system via EDI (DAF)?			
b3.5 Does the vendor know the purpose of each EDI message and can the supply be planned accordingly? (DAF JIS)			
b3.6 Has an emergency concept for communication of release / demand data been defined (DAF)?			
b3.7 Does the in-house representative of the JIS/JIT supplier have sufficient means for communicating with the base plant in East London on a day-to-day basis? (DAF)			

b4. Customer service, Supply KPI's and problem solving processes

	Yes	No	N A
b4.1 Has the C&D schedule been explained and agreed with the supplier? (ExW)			
a Is the delivery lead time (supplier to DCSA) known?			
b. Does supplier know how to interpret release correctly (deliveries on in-plant-dates)?			
c. Does supplier know how and when to send RFTs?			
d. Does supplier know how and when to send ASNs?			
b4.2 Has the MRP Controller "customised" the releases to reflect the desired C&D pattern? (only where applicable) (ExW)			
b4.3 Have all problem management and supplier performance measurement processes been explained to the supplier (3-step report, 8-step report, 5-why report, works order process and implications, EBSC metrics, etc.)?			

b5. Physical Part Identification (where applicable)

	Remarks	Yes	No	N A
b5.1 Is the part marked / barcoded correctly for?				
a. Production number				
b. Serial number				
c. Batch / Traceability Nr.				
d. Q-Level / ZGS				

b6. Availability of Planning Data

				Yes	No	N A
b6.1 Does the supplier have the latest Production Calendar for ...?	2020	2021	2022			
b6.2 Does the supplier have the latest Production program for … ?	2020	2021	2022			
b6.3 Does supplier know the expected volumes (minimum, average, maximum) per part to supply in the series phase?						
	Min	Avg	Max			
b6.4 Does the supplier already have releases / forecasts available for the next 10 months?						
b6.5 Does the supplier have the latest Run-In Timeline for the w206 model?						
b6.6 Does the supplier have the latest information on the planned volumes, models and dates for Production Trials 1, 2, 3 (RHD):						
	# of units - Pro1 (RHD)	# of units -Pro2 (RHD)	# of units - Pro3 (RHD)			
b6.7 Does the supplier have the latest information on the planned volumes, models and dates for Production Trials 1, 2, 3 (LHD):						
	# of units - Pro1 (LHD)	# of units -Pro2 (LHD)	# of units - Pro3 (LHD)			
b6.8 Does the supplier have the latest information for Ramp-up Staffel 1?						
b6.9 Does the supplier have the latest information for Ramp-up Staffel 2 and 3?						

b7. Availability of Capacity

			Yes	No	N A
b7.1 Has the supplier designed the capacity of the production to fulfill the required demand levels in series phase?					
a. Can average demands in the series phase be covered by the planned normal shift model?					
b. Have any bottlenecks / constraints in the supply chain that could influence supply negatively been considered?					
c. Is machine / assembly cycle time / capacity sufficient to cover average demands during normal shift?					
d. Is sufficient extra capacity (people and time / shifts) available to cover estimated maximum demand?					
	people	time / shifts			
	Y/N	Y/N			
e. Is it ensured that the supplier can react flexibly to changes in demand, i.e. organise overtime or additional shifts?					
b7.2 Does supplier have capacity to supply the required volumes during:					
a. Production trials I to 3 (Pro1, Pro2 Pro 3)? (RHD)					
b. Production trials I to 3 (Pro1, Pro2 Pro 3)? (LHD)					
c. Ramp-up A (RHD) - 1 July 2007 - October 2007?					
d. Ramp-up B (LHD) - October 2007?					

b8. Proof of Capacity: Run-at Rate

	Yes	No	N A
b8.1 Is a run-at rate study required / applicable?			
b8.2 Has a run-at-rate study been completed at the supplier?			
b8.3 Has the run-at rate study shown that required capacity for supply will be fulfilled?			

b9. Have all DCSA MRP Paramaters been (1) defined and agreed with supplier and (2) maintained on SAP?

				Defined & agreed		Maintained?		
				Yes	No	Yes	No	N A
b9.1 All Lead time(s) – (ordering to delivery, transport time, etc.) (ExW, DAF)								
b9.2 Time from last call-off (fixed chute) to fitment (minutes / hours) (JIS)								
b9.3 Minimum Order Quantities and rounding factors set?								
b. - has lineside space, delivery lead time and packaging / transport factors been considered in setting lot size?								
b9.4 Min, Avg, Max stock **at DCSA** (Finished Goods)	Min	Avg	Max					
b9.5 Target safety stock **at supplier** (Finished Goods)	Min	Avg	Max					
b9.6 Part Classification								
b9.7 Delivery Frequencies								
b9.8 Other?								

b10. Have MRP Paramaters for all 2nd tier suppliers been (1) defined and agreed and (2) maintained in ERP system / planning environment?

				Defined & agreed?		Maintained?		
				Yes	No	Yes	No	N A
b10.1 Average Lead time(s) – (manufacturing, transport, etc.) - Import								
b10.2 Average Lead time(s) – (manufacturing, transport, etc.) - Local								
b10.3 Minimum Order Quantity and rounding factor								
b10.4 Min, Avg, Max stock at Supplier (Finished Goods)	Min	Avg	Max					
b10.5 Target safety stock at supplier (Raw Material)	Min	Avg	Max					
b10.6 Delivery Frequency								
b10.7 Other?								

b11. Logistics service providers (LSPs) — Yes | No | N A

			Yes	No	N A
b11.1 Has local service provider (CMH) been informed of new supplier / new parts by DCSA? (ExW)		Name			
Tel Nr					
b11.2 Has the local transporter (CFN) been informed of the new supplier / part (ExW) by DCSA?		Name			
Tel Nr					

b12. DCSA entry point and delivery point

			Yes	No	N A
b12.1 Has the gate entrance to DCSA been defined (DAF only)?	entry				
b12.2 Has the delivery point at DCSA been defined (DAF / ExW)?	delivery point				
b12.3 Has the line station been defined and is know by supplier?	fitment point				
b12.4 Is the available space at the delivery point known?	space (m^2)				
b12.5 Has the line-side stock been defined? (DAF)	Number of pallets				
	Lot size per pallet / trolley				
Further info					
b12.6 Has the marshalling area stock been defined? (DAF)	Number of pallets				
	Lot size per pallet / trolley				
Further info					

b13. Supply route

	Yes	No	N A
b13.1 Has the supply route from gate to delivery point been defined (DAF)?			
b13.2 Is the entire supply method until actual part fitment clearly defined?			
a. Responsibilities defined?			
b. Timing parameters defined?			
c. potential bottlenecks in supply route considered (from leaving till consumption)?			
d. All contacts in supply chain to DCSA and escalation procedures known?			

b14. Packaging

			Yes	No	N A
b14.1 Has packaging been designed on the basis of miniumum order quantity, lineside space and lead time (ExW / DAF)?					
b14.2 Has the packaging spec been defined by DCSA, and did supplier review and sign the "Packaging Specification" document (ExW)?					
DCSA packaging Engineer		Tel Nr.			
b14.3 Is enough packaging capacity (Chep / custom spec) available? (ExW)					
b14.4 Has the packaging return-concept been defined (custom packaging)? (ExW)					
b14.5 Has a packaging trial been conducted successfully and signed off with packging engineer (ExW), and does it prove the concept?					
b14.6 Has the packaging (trolleys / stillages / protection etc.) been defined / designed by the supplier and signed off? (DAF)					
b14.7 Have the trolleys been procured and tested for space, handling, roadworthiness etc. (DAF)?					
b14.8 Is enough capacity and also back-up packaging (trolleys, protections etc.) available (DAF)?					
b14.9 Have the trolleys / stillages been properly marked and labelled (barcoded?) according to requirements (DAF)?					
b14.10 Has the packaging spec been provided to the local transporter in the correct format (ExW / DAF)?		Transporter			
Contact Name					
Tel Nr					
b14.11 Has a maintenance concept (content), capacity and timing been put into place for the trolleys / stillages (DAF)?					

b15. Transportation and material handling

			Yes	No	N A
b15.1 Have the supplier and LSP been introduced and do they have contact details mutually (ExW)?					
Supplier		Tel Nr.			
LSP (Transporter)		Tel Nr.			
b15.2 Has the transportation means (vehicles) been procured / is it available (DAF)?					
b15.3 Has enough capacity on transport been considered (back-up vehicle, maintenance cycles and requirements) (DAF)?					
b15.4 Is contingency transport available on short notice in case of emergencies (DAF)?					
b15.5 Do all transportation media correspond to the plant requirements (emission, dimensions etc.) (DAF)?					
b15.6 Have all transport vehicles been porperly designated for plant entry, e.g. barcoded (DAF, ExW)?					
b15.7 Have all material handling equipments been defined / designed? (DAF)					
b15.8 Have all material handling equipments been procured and is enough capacity ensured (DAF)?					

b16. Transport documentation

	Yes	No	N A
b16.1 Can the supplier raise the correct transport documentation (ExW)?			
a. Delivery note, invoice, waybill, transport labels etc.			
b16.2 Has the Transport Label software (CD) been made available to the supplier (ExW)?			
b16.3 If supplier uses own software, does it conform to the DCSA specification? - (VDA format - spec available)? (ExW)			
b16.4 Has the Transport Label software (CD) been installed / configured correctly with all relevant master data (ExW)?			
b16.5 Has the user (dispatch clerk . Manager) been trained to use the sotware and know all requirements for the transport label? (ExW)?			
b16.6 Is all relevant delivery data for JIS / JIT supply available (barcodes, labels)?			

b17. Training requirements

	Yes	No	N A
b17.1 Have all employees been trained in the processes relating to supply (hardware, software, documentation, etc..)?			

b18. Payment terms and Invoicing

	Yes	No	N A
b18.1 Does the supplier know the payment terms and invoicing process, e.g. have DCSA VAT nr.?			

C. Internal Logistics at the supplier

Logistics Organisational Structure

	OK	Not OK
Are the major functions (and corresponding role-players) related to Logistics / supply defined at the supplier?		
Customer service / dispatch		
Production Planning and control		
Procurement		
Material Ordering		
Transportation and packaging		
Material Management / Inventory control and warehousing (RM / FG)		
Supplier management		

Supply Chain

	OK	Not OK
Has supplier got a succint understanding of its supply chain?		
Products and Customers (import / export)		
Raw Materials / Components and Suppliers		
Major material flows, strategic partners, information and control links, capacities / bottle necks.		
Some performance statistics, future directions etc. evident / available?		

Customer Service, outbound Logistics and Performance Measurement (to OE)

	OK	Not OK
Release / Call-off processing		
Version, plausibility and Integrity checks		
Dispatch Planning (FG)		
Dispatch Plan available? How frequently done? Horison covered? Responsible for?		
Planning / coordination process for collection and delivery (C&D) with LSP (pick-up roster / RFT)		
Availability of packaging / coordination of containers at the right time?		
Packaging Engineering, Planning and management (FG)		
Packaging design.		
Contracts with packagin providers and processes for returnable packaging.		
Raw material ordering for packaging. Handling of packaging materials.		
FG Management (WH)		
Definition of SLOCS. WH Layout. Labelling and barcoding of WH. Material movement control?		
Stock targets and process for setting. Stock counts and maintenance of target levels. FG inventory accuracy		
Transportation planning (FG)		
Selection of transport media and LSP's. Transportation Routes.		
Contingency Supply / LSP contracts, Responsible persons and contact lists		
Capacity planning and Layout of shunting / trailer yard.		
Dispatch, Transportation and delivery (FG)		
Staging of FG's for dispatch – area.		
Final packaging / preparation for customer / containerisation.		
Call-off of LSP vehicle according to C&D schedule (phone call)		
Loading of vehicle and Dispatch.		
Sending of ASN.		
Supply performance measurement (KPI's)		
Which ones? How frequent? Recordrd where? Visually displayed? Known to and used by all?		

Engineering Change and Run-in Run-out Management

	OK	Not OK
Selection and maintenance of Product Documentation System (PDS)		
Maintaining the Engineering BOM		
Receiving and documenting Eng change notifications in (PDS)		
Define master data of new parts / part levels in all systems (WHM, ERP, PPC, etc).		
Maintaining the production BOM		
Engineering change date coordination (with customers, suppliers and internally) for intro in production		
Documenting when an EC will run-in in production (date setting)		
Set dates for setting up of new contracts, date first orders to be placed, first line supply etc.		
EC Run-In management		
Monitor run-in dates, action contracts, first orders and first line supply and production.		
Perpetual Inventory (not necessarily here)		
Ensure stock integrity by correct material movements, adjustments and stock counts where needed –		
Refer RM and FG stock management functions		

Production planning and Control to fulfill FG	OK	Not OK
Production planning		
Demand Capacity planning based on Sales figures		
Medium range planning		
Consider bottlenecks / capacity constraints?		
Consider flexibility constraints?		
Short range planning		
Consider bottlenecks / capacity constraints?		
Consider flexibility constraints?		
Material Movement Planning and factory layout		
Definition of SLOCs physically and logically (system)		
Demarcation and labelling		
Creation and maintenance of Master Production Schedule		
Production job sequencing		
Creating Master Production Schedule (MPS) on FG level		
MRP		
Creating MPS on Material Level (MRP runs)		
Production Control		
Visual display of daily production targets on shopfloor		
Issuing of jobs for production		
Job card creation and issue		
Issuing of raw materials for production from RM warehouse		
FIFO principle		
Daily production action centre meeting		

Material / component Ordering and Mgmt to fulfill production	OK	Not OK
RM Management (Part of Material Handling function) – (WH)		
Setting of RM stock target. Ensuring RM stock integrity (stock counts), Defining RM SLOCs,		
Layout and labelling of RM storage area,		
Planning for RM / component Ordering (MRP)		
Planning horizon, Frequency of ordering, freeze period on orders, lead times, maintaining all MRP parameters		
Issuing of Orders (RM)		
Method of ordering, Communication media, exception reports and expediting,		

Supplier Management	OK	Not OK
Supplier Selection and monitoring		
Technology aspects and global scouting for competent suppliers..		
Sourcing decisions (also see EC & Run-in / Out Mgmgt) and contracting		
Supplier performacne target setting		
Supplier Performance Monitoring		
Supplier Development		

Inbound Logistics (RM)	OK	Not OK
Transportation planning (inbound)		

Design Approval Checklist

No. 01	Prerequisites / approval criteria for "design approval"	Responsible	Verification submitted
01.01	Technical specifications in the form of the project standard and protocol decisions incorporated into design.	AN	
01.02	Process simulation and the cycle times and buffer sizes needed for output are available.	AN	
01.03	Rough function sequence plans are available.	AN	
01.04	Static calculations of the forces and loads applied by the components to the building/shop are available. Statics approved by purchaser.	AN	
01.05	The agreed-upon logistics concept including the material flow is implemented in the layout.	AN	
01.06	Emergency strategies are available. Procedures in the event of technology OK – not OK failure and reject concept plus places of rework are described and agreed upon.	AN	
01.07	First robot change concept is included in layout.	AN	
01.08	The requirements for design approval from the robot simulation guideline (**ECM Volume 3, Chapter 041, Phase Plan**) are fulfilled (e.g. accessibility and feasibility analysis available, machinery and equipment kinematically analyzed, layout confirmed) Distance from gripper to load carrier when loading and unloading at least 50 mm.	AN	
01.09	Clamping and mounting concept plus geometric points have been tested and verified on 3D constructions. Changes have been reported by to the SFK team and documented in the vehicle data records. The joint sequence has been implemented and verified. A complete set of implement data has been presented to the purchaser	AN	
01.10	The system color concept has been presented to Installation Planning for approval. The documentation is realized via the minutes of the Design Meetings.	AN	
01.11	Quantity structure for control engineering available with current design status.	AN	
01.12	Calculations are available for all components approved by the client (part approvals are permissible) e.g.: drives, robots, hydraulic units, digital IR pay load (Kuka Load) are available in full and OK … .	AN	
01.13	Supplied parts are listed and specified	AN	
01.14	Configuration of media supplies (water, compressed air, technical gases, energy supplies, updated plant information sheet) as per **ECM Volume 3.070.012, -013 and -014** is available. Further information can also be found in Volume 2, Chapter 211.	AN	
01.15	Waste disposal concept for hazardous materials (gases, vapors, smoke, fluids,…) to be identified by the contractor with a risk assessment and presented to the purchaser.	AN	

No. 01	Prerequisites / approval criteria for "design approval"	Responsible	Verification submitted
01.16	Sensor and station layout for in-line measurement technology is created (for ReUse areas). Measurability of measurement points is digitally validated.	AN	
01.17	For each contractor, there is one electrical circuit diagram including F-matrix and a-network message list.	AN	
01.18	Plant layout with PLC zones and hazard areas is available.	AN	
01.19	Safety concept, including risk assessment, as per "Checklist for Technical Documentation" ergonomics and maintenance concept (risk of falling, accessibility) is available. The Work Safety GL was taken into account in the design.	AN	
01.20	The designation system for the plant layout is defined in accordance with the specifications of the purchaser.	AN	
01.21	The plant layout is signed by the purchaser and the contractor.	AN/AG	
01.22	Layout is coordinated with local conditions (local fittings, e.g. ground gradient, expansion joints, drain covers. Lighting conditions, piping, ventilation,[…). CAD data shall be applicable if the building is absent.	AN	
01.23	The concerns of the German Federal Immissions Protection Act (specific requirements for state and project concerned) are observed and agreed upon in the project (approval available at the time required).	AG	
01.24	The noise emissions agreed upon in the invitation to tender (specific requirements for state and project concerned) shall not be exceeded (**GL Work Safety ECM Volume 3.007**). These are to be approved by Work Safety	AN/AG	
	Virtual commissioning		
01.25	Acceptance criteria fulfilled in accordance with "Acceptance Checklist for Virtual Commissioning" (**ECM 3.028.01.02**).-	AN	
	Documentation		
01.26	The documentation has been checked in accordance with the "Checklist of Technical Documentation" (**ECM Volume 3.009.10**) and is available in full.	AN/AG	
	Approval (written document)		
01.27	The approval is logged and jointly signed by: - Planning (L4): Bodyshell planning, materials handling technology planning and electrical planning - Production (L4) - Maintenance (L4) - Specialist responsible for work safety This approval does not relieve the contractor of its overall responsibility to deliver a functioning complete system. The supplier shall document all defects, as well as schedule and monitor them via planning.	AN/AG	

No. 02	Prerequisites / approval criteria for system setup/commissioning (white buyoff)	Responsible	Verification submitted
02.01	If release for dispatch has been agreed upon in the project, the jointly defined criteria are to be fulfilled	AN/AG	
02.02	The components are finished in accordance with the sample cell or master piece. The processes agreed upon in Volume 2 are applicable as the basis	AN	
02.03	Virtual commissioning has been performed for the defined PLC ranges in accordance with the invitation to tender and acceptance checklist **ECM Volume 3.028.01.02**. An acceptance protocol is available.	AN	
02.04	A sample software PLC-is available for each contractor, programmed according to the requirements of the PLC / safety checklist.	AN	
	Prerequisites, systems		
02.05	All defects from the system acceptance – design approval have been removed or appropriate measures scheduled.	AN	
02.06	All components in accordance with the quantity schedule (current assignment) are fully installed at the construction site and are functional as individual components. All movement functions can be operated in manual mode via the relevant motion switches	AN	
02.07	Media such as compressed air, cooling water, electrical power supply for welding network, etc. are to be made available by the client in accordance with the interfaces agreed upon in Volume 3 Chapter 70.	AG	
02.08	Media installations and air extraction technology as of the handover point are installed and operational.	AN	
02.09	All stations or components are fully assembled; valves, actuators, sensors and terminal boxes are installed and identified/documented in accordance with the designation system.	AN	
02.10	The checklists are finished in accordance with Volume 3, Chapter 9	AG	
02.11	All safety facilities are fully available and active. The operational readiness of the safety facilities is attested to by the contractor in the “Cutout Matrix” form. Protective equipment that is not yet active shall not be recognized as protective equipment. Shopfloor visit performed with Work Safety	AN	
02.12	For the hazardous materials used by the contractor and required for the process, handling approvals are either available or defined with schedule (including hazardous materials required for setting up)	AG	
02.13	The client’s employees required for trial operation have received suitable instruction and verification has been submitted to the client. (Trial operation agreement **ECM Volume 3.002.04.27**) The work safety briefing has been carried out.	AN	
02.14	All robots are installed and ready to run; commissioning has been carried out and documented. Load data identification verified locally (e.g. oscillating)	AN	

No. 02	Prerequisites / approval criteria for system setup/commissioning (white buyoff)	Responsible	Verification submitted
02.15	Requirements for simulation acceptance from robot simulation guideline (**ECM Volume 3 Chapter 041, Phase Plan**) are fulfilled to the extent commissioned. (E.g. station sequence simulated, cycle time confirmed, robot locks set, motion parameters created, etc.). An inspection of all simulation cells was conducted as part of a simulation acceptance.	AN	
02.16	Current joint plans for the thermal and non-thermal joining methods are available. (Resistance welding, projection welding, Weldfast, laser applications, clinching, bolted connections, adhesive joints, etc.) For joining methods included in the RDS, the joint plans shall be generated from the RDS.	AN	
02.17	System sequence plan [time-path diagrams/functional diagram] is available. (**ECM Volume 3.002.04.13**)	AN	
02.18	"Measurement holes for calibrating the jigs and fixtures have been made in accordance with the specifications.	AN	
02.19	Clamping kinematics ("interference contours") and clamping designations checked in accordance with the clamping and mounting concept including shim technology and are OK. The documentation is realized via the minutes of the Design Meetings	AN	
02.20	Current documentation hardware for the assembly stand (~~Ruplan~~ E-CAD electric circuit diagram, fluid power systems) available at the construction site (available to purchaser).	AN	
02.21	Certificates of competence for programmers and certificate of responsibility (**ECM Volume 3.008**) are available before the start of programming activities. (An obligation to update applies in the event of personnel changes)	AN	
	Spare parts and gauges		
02.22	Complete parts lists are available. (**ECM Volume 1.020.01**)	AN	
02.23	Component gauges approved by the purchaser for the detachable parts are available and ready for use.	AN	
	Measurements		
02.24	System measured according to product data record. Documentation of measurements is available and harmonized with OLP simulation and clamping and mounting concept (laser tracker measurement / photogrametry,…)	AN	
02.25	Hemming nests and hem steels are aligned, documentation is available as a measurement report.	AN	
	Documentation		
02.26	The documentation has been checked in accordance with the "Checklist of Technical Documentation" (**ECM Volume 3.009.10**) and is available in full.	AG	

	Intermediate trials before automatic mode		
02.27	Schedule for testing functional readiness of all technologies is agreed upon and verified.		
02.28	Schedule for testing all joining elements (spot welding, laser, bolts, etc.) and bolts available on the component. The joining quality is not decisive. Adhesive application without adhesive delivery.		
02.29	~~Schedule for testing software checklists (offline programe), overall control engineering: "PLC, safety PLC" are randomly inspected by the purchaser and have an adequate status. (1st check)~~		
	Approval (written document), part payment		
02.30	The approval is logged and jointly signed by: - Planning (L4): bodyshell planning, materials handling technology planning and electrical planning - Production (L4) - Maintenance (L4) - Specialist responsible for work safety This approval does not relieve the contractor of its overall responsibility to deliver a functioning complete system. The supplier shall document all defects, as well as schedule and monitor them via planning.	AN/AG	

Production Trial 1 Checklist

No. 04	Prerequisites / approval criteria for "production trial 1"	Responsible	Verification submitted
	Prerequisites, system		
04.01	Robots and drives operate 100% at the planned speed.	AN	
	Plant testing		
04.02	All defects from the automatic mode acceptance have been removed or appropriate measures scheduled.	AN	
04.03	The operating functions are implemented as per **ECM Volume 3.026.14.01.01** and confirmed using the corresponding checklist. All emergency strategies are incorporated and implemented in the plant structure. Example: Adhesive application not OK: Seam preview program outflow/inflow and rectification concepts are implemented.	AN	
04.04	Process control engineering (e.g. switchboard, body control system (plus), IntergraView, [delivery scope of the purchaser]) are fully implemented.	AN	
04.05	Fault and malfunction simulations have been performed before PRO 1.	AG	
04.06	The diagnostic display in the automation systems displays the original errors correctly in the event of a plant malfunction.	AN	
04.07	All quality monitoring systems are active (e.g. monitoring systems for bonding, laser, …)	AN	
04.08	In-line measurement technology is fully operational. Static, dynamic and adjustment tests have been passed.	AN	
04.09	The functionality of testing and measuring instruments was conducted and verified as per the Certificates of Proficiency criteria (**ECM Volume 3.009.00.01**).	AN	
04.10	The cycle time derived from simulation +20% (without Q stop) is also achieved in mix mode (vehicle 1 x N). Measures are assigned for all cycle time exceedances. The cycle time is identified in each performance test before the production trial.	AN	
	Archiving		
04.11	Archiving concept/server is functioning and is available for connection to the plants.	AG	
04.12	Archiving of the software (user programs PLC and robots and technology control) on the server is available as per the archiving concept. (**ECM Volume 3.020.04.01 "Network connection for technology control**") the current data is stored in an archive	AN	
	Gauges		
04.13	All master parts are available and up to date.	AN	
	Documentation		

No. 04	Prerequisites / approval criteria for "production trial 1"	Responsible	Verification submitted
04.14	The documentation has been checked in accordance with the "Checklist of Technical Documentation" (**ECM Volume 3.009.10**) and is available in full.	AG	
	Approval (written document)	AG	
04.15	The approval is logged and jointly signed by: - Planning (L4): Bodyshell planning, materials handling technology planning and electrical planning - Production (L4) - Maintenance (E4)-specialist responsible for work safety This approval does not relieve the contractor of its overall responsibility to deliver a functioning complete system. The supplier shall document all defects, as well as schedule and monitor them via planning.	AN / AG	