FEASIBILITY REPORT

LOCALISATION OF COLLISION PREVENTION SYSTEM COMPONENTS FOR TRACKLESS MOBILE MACHINERY

REVISION 1.0

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EXECUTIVE SUMMARY

Globally, more than 30% of mining industry deaths are caused by failures of vehicle interaction controls. To reduce mining fatalities due to vehicle interactions, the global mining industry is increasing the adoption of safety-related technologies, resulting in a substantial increase in the number of mines investing in collision prevention technology.

In response to the high proportion of TMM-related fatalities, in December 2022 sub-regulations 8.10.1.2b and 8.10.2.1b in Chapter 8 of the regulations to the Mine Health and Safety Act (MHSA) was gazetted. These sub-regulations, which came into effect immediately, compel the mining industry to provide collision prevention systems and devices that will automatically slow down and stop TMMs so that collisions between them and pedestrians, and other machines, are prevented.

The Minerals Council South Africa (Minerals Council) is committed to Zero-Harm, balancing saving lives and livelihoods, and creating new livelihoods where possible. It is against this backdrop that the Minerals Council continues to assist mines on their journey to compliance with the TMM regulations.

The Minerals Council commissioned the Technology Localisation Implementation Unit (TLIU) to investigate the feasibility of localising collision prevention system components that are used in the manufacture of trackless mobile machines and collision warning and avoidance devices. Such localisation could include component manufacture, assembly and/or insourcing or outsourcing.

To this end, a comprehensive Request for Proposals was provided stipulating the key elements of the project scope as follows:

- Desktop/literature review
- Categorisation correctness
- Stakeholder mapping
- Supplier development
- Market valuation
- Local manufacture, assembly, insource or outsource capability
- CPS testing capability
- Case studies
- Other opportunities

Localisation has been a central tenet of South Africa’s economic development strategies for many decades, and its success will consolidate and grow the economy. Most of the master plans have a strong focus on expanding local production, downstream beneficiation, and localisation. In addition, the recently finalised Industrial Policy Action Plan (IPAP) provides a framework for growth through the focus on four key areas, namely localisation, industrialisation, digitisation, and decarbonisation. To promote localisation, the focus has been on the establishment of state procurement measures to boost local industries, initiatives to increase local content, capacitation of local firms, and improved access to domestic and export markets.

South Africa is one of the top 10 mining countries in the world and is a major producer of platinum group metals, coal, iron, manganese, chrome, and nickel. The country also has large deposits of rare-earth metals and related specialty refining infrastructure. The South African mining sector contributes about 8% to the GDP of the country.

With the gazetting of the Chapter 8 MHSA sub-regulations, South Africa is the only country in the world to make it mandatory for mining companies to comply with TMM collision prevention controls. This development has led to the establishment of several companies and stimulated the development of new technology and products to meet the need for Level 9 compliance. South African mines have become pioneers in the adoption of CPS systems.

The global TMM collision prevention system (CPS) market size was valued at U$66.80bn in 2022 and is expected to expand at a compound annual growth rate (CAGR) of 11.4% from 2023 to 2030. The global mining sector CPS market was U$5,3 bn in 2022, and was projected to grow at a rate of 10.2% per annum from 2023 to 2030. North and South America account for the biggest market demand. Africa is the fastest growing market for CPS, with South Africa being a leader from a regulatory, technology development, manufacture, and testing and certification perspective.

The mining CPS market can be segmented into:
- Collison Warning and Avoidance Device Original Technology Manufacturer (CxD OTM)
- Trackless Mobile Machinery Original Equipment Manufacturer (TMM OEM)
- Third-party Integrators.

In South Africa, there is a mix of international and local CxD OTMs in the country, with some local companies having merged with international players. Many of the local CxD OTMs have developed their own components and systems, which have typically been certified and configured for fitment to a range of TMMs. It is understood that these systems are well suited to local conditions and in most cases provide the customers with a cost advantage, as well as strong local support.

South African companies have been shown to be more willing to comply with local requirements and adopt the ISO standards. There are now 12 such systems that have passed the ISO certification standards for surface operations. The testing for underground systems is in progress with six systems having passed some of the required tests.

The key **conclusions** from the study conducted to assess the feasibility of localising collision prevention system components for trackless mobile machinery are provided below:
- South Africa's TMM regulations has stimulated the related technology and product developments as well as the establishment of several companies competing in the market.
- The CPS industry is in a volatile growth phase, and there are many companies active in the market. It is likely that not all companies will survive, and local consolidation will take place through mergers and acquisitions.
- Most of the CPS products and components are already being localised and this has warranted significant investment of own resources by the companies, with very little non-financial and financial support provided by government.
- There is a need to assist the CPS ecosystem to develop, manufacture, test, certify and deploy their products and systems. Such support could be provided by both local and international, public and private sector players.
- As with all technology-based products, development is not a once-off event, but rather an ongoing activity to stay ahead of the competition. There will be a continuous need to invest in research and development to develop the next-generation CPS.
- The CPS ecosystem has made significant investments to train employees in product development, and the integration and installation of CPS systems.
- Some form of local collaborative approach and centralised support would assist South Africa to maintain and even expand its current lead.
- The local automotive and electronics sectors have strong technological and manufacturing expertise that could be harnessed to assist CxD OTMs.
- South Africa's lead in this field does provide international market opportunities as other countries adopt similar regulations. Exploiting this opportunity will entail significant marketing efforts and associated costs.
- TMM population data requires further validation and verification as some data is missing from the submission.
- South Africa has the capacity and capability to conduct testing according to MOSH guidelines. Technology Readiness Level 7 testing needs to be augmented by technology to mitigate against risks associated with real-environment testing.
- Assessments were conducted on the 12 CPS opportunities identified for local manufacture and assembly. The following opportunities warranted more detailed investigation for localisation:

CPS-ready cap lamp test station, control system wiring, back-up battery assembly, and enclosures.
- Five new potential localisation opportunities were identified through consultations with CPS companies, namely pedestrian tags, batteries and cells, printed circuit board (PCB) material, enclosures and cabling. These opportunities were investigated.

Flowing from the work done during the project, the following key **recommendations** are made:
- To support the local CPS ecosystem, and the South African mining industry (SAMI) to achieve TMM regulations compliance, it is recommended that two Sector-Wide Technology Assistance Packages (SWTAPs) be established, namely the CPS Product Design and Manufacture SWTAP and the CPS Testing and Certification SWTAP.
- Whilst recognising that the CPS market is a competitive environment, the formation of a CPS industry body or forum (possibly under the Mandela Mining Precinct) should be considered with a view to strengthening the sector by addressing common problems and issues.
- It is recommended that an initiative to provide international market development assistance to the CPS ecosystem be investigated and developed with the dtic. This could include support for international market development including trade missions and exhibitions.
- It is recommended that CPS orientated auto electrician training be provided to ease the pressures regarding installation and maintenance.
- The TLIU should continue with discussions with the multi-national OEM to localise the manufacture of the pedestrian tag and cap lamp. These discussions should also include the potential localisation of repair and maintenance services related to CPS systems.
- The opportunities to localise CPS-ready cap lamp test station, batteries and cells, PCB material, enclosures and cabling should be investigated further through joint engagements with the CPS ecosystem.
- The opportunity to use a digital tool such as digital twins to support the demonstration of CPS system performance in a representative environment should be investigated.
- The potential to access an independent mock or test mine facility should be investigated. This will enable the testing of TMMs in a representative environment without impacting negatively on operations and safety.
- It is recommended that the TMM population data be further validated and verified, especially regarding the classification of “legacy, intelligent” and “legacy, unintelligent”, and a determination of which machines can be retrofitted with CPS systems.

The remainder of this document covers the work done towards achieving the objectives of this project.

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GLOSSARY OF TERMS

ADAS	-	Advanced Driver-Assistance Systems
AEB	-	Automated Emergency Braking
AfCFTA	-	African Continental Free Trade Area
AI	-	Artificial Intelligence
AMM	-	Autonomous Mine Machines
B-BBEE	-	Broad-Based Black Economic Empowerment
BEM	-	Brake Effectiveness Management
BIS	-	Black Industrialist Scheme
BRICS	-	Brazil, Russia, India, China, and South Africa
CAD	-	Computer-Aided Design
CAGR	-	Compound Annual Growth Rate
CAN	-	Controller Area Network
CAS	-	Collision Avoidance System
CCTV	-	Closed Circuit Television
CCU	-	Central Control Unit
CIP	-	Critical Infrastructure Programme
CIP and HIP	-	Cold and Hot Isostatic Pressing
CMS	-	Collision Management System
CNC	-	Computer Numerical Control
CONMESA	-	Construction and Mining Equipment Suppliers Association
COP	-	Code of Practice
CPFP	-	Capital Projects Feasibility Programme
CPS	-	Collision Prevention System
CSIR	-	Council for Scientific and Industrial Research
CUT	-	Central University of Technology
CWAS	-	Collision Warning and Avoidance Device
CxD	-	Collision Warning and Avoidance Device
CxDC	-	CxD Controller
CxDI	-	CxD Machine Interface
CxDLK	-	CxD Log Keeper
DAQ	-	Data Acquisition Unit
DATMO	-	Detect and Track Moving Objects
DMPR	-	Department of Mineral and Petroleum Resources
DMRE	-	Department of Mineral Resources
DPR	-	Direct Powder Rolling
DSTI	-	Department of Science, Technology and Innovation
DTS	-	Detection and Tracking System
ECUs	-	Electronic Control Units
EMC	-	Electromagnetic Compatibility
EMESRT	-	Earth Moving Equipment Safety Round Table
EWS	-	Effective Warning System
FDM	-	Fleet Data Management
FMS	-	Fleet Management Systems
FTAP	-	Firm Technology Assistance Package
FTS	-	Fail to Safe

GBS	-	Global Business Services
GDP	-	Gross Domestic Product
GDU	-	Graphical Display Unit
GNSS	-	Global Navigation Satellite System
GPS	-	Global Positioning System
GUI	-	Graphic User Interface
GVA	-	Gross Value Added
HMI	-	Human Machine Interface
HP GNSS	-	High Precision Global Navigation Satellite System
ICMM	-	International Council on Mining and Metals
ICs	-	Integrated Circuits
ICT	-	Information and Communication Technology
IFPTI	-	Intsimbi Future Production Technologies Initiative
IoT	-	Internet of Things
IPAP	-	Industrial Policy Action Plan
ISO	-	International Standards Organisation
ISS	-	Intelligent Safety System
LCD	-	Liquid Crystal Display
LED	-	Light-Emitting Diode
LiDAR	-	Light, Detection and Ranging
LO	-	Local Object
MBS	-	Machine Braking System
MC	-	Machine Control
MCEP	-	Manufacturing Competitiveness Enhancement Programme
MCI	-	Machine to CxD Interface
MCSA	-	Minerals Council South Africa
MCxDI	-	Machine CxD Interface
MEMSA	-	Mining Equipment Manufacturers of South Africa
MHSA	-	Mine Health and Safety Act
MHSC	-	Mine Health and Safety Council
MIASA	-	Mining Industry Association of Southern Africa
MIM	-	Metal Injection Moulding
MLK	-	Machine Log Keeping
MMP	-	Mandela Mining Precinct
MOSH	-	Mining Industry Occupational Safety and Health
MS	-	Machine Sensing
NAACAM	-	National Association of Automotive Component and Allied Manufacturers
naamsa	-	National Association of Automobile Manufacturers South Africa
NTIP	-	National Technologies Implementation Platform
OEM	-	Original Equipment Manufacturer
OLED	-	Organic Light-Emitting Diode
OTM	-	Original Technology Manufacturer
OWS	-	Operator Warning System
PCB	-	Printed Circuit Board
PDS	-	Proximity Detection System
PGM	-	Platinum Group Metals

PPPFA	-	Preferential Procurement Policy Framework Act
PWS	-	Pedestrian Warning System
R&D	-	Research and Development
RCM	-	Radio Control Module
RDI	-	Research, Development and Innovation
RF	-	Radio Frequency
RFID	-	Radio Frequency Identification
RO	-	Remote Object
RTD	-	Real-Time Detection
RTLS	-	Real-Time Location System
S	-	Surface
SA	-	South Africa
SABS	-	South African Bureau of Standards
SACEEC	-	South African Capital Equipment Export Council
SADC	-	Southern African Development Community
SAMERDI	-	South African Mining Extraction Research, Development and Innovation
SAMES	-	South African Micro-Electronics Systems
SAMI	-	South African Mining Industry
SAMPEC	-	South African Mineral Processing Equipment Cluster
SCM	-	Speed Control Management
SIC	-	Standard Industrial Classification
SIMAC	-	Short Internal Monitoring and Control
SLAM	-	Simultaneous Localisation and Mapping
SMT	-	Surface Mount Technology
SP GNSS	-	Standard Precision GNSS
SPII	-	Support Programme for Industrial Innovation
SWTAP	-	Sector-Wide Technology Assistance Package
TFT	-	Thin Film Transistor
The DTIC	-	Department of Trade, Industry and Competition
THRIP	-	Technology and Human Resources for Industry Programme
TIA	-	Technology Innovation Agency
TIPS	-	Trade and Industrial Policy Strategies
TLIU	-	Technology Localisation Implementation Unit
TMM(s)	-	Trackless Mobile Machinery/Machines
TMMP	-	Trackless Mobile Machinery CPS Product
TMP	-	Traffic Management Plan
ToF	-	Time-of-Flight
ToR	-	Terms of Reference
TRL	-	Technology Readiness Level
UG	-	Underground
UJ	-	University of Johannesburg
UP	-	University of Pretoria
V2X	-	Vehicle-to-everything
V2XI	-	V2X Interface
VD	-	Vicinity Detection
VDG	-	Vehicle Dynamics Group

VUT	-	Vaal University of Technology
WMI	-	Wits Mining Institute

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1 INTRODUCTION

1.1 Project Background

Transport accidents, including those caused by trackless mobile machines, remain one of the top three causes of death and injury in the SAMI. Achieving zero-harm production in the mining industry requires the continuous development and implementation of innovative solutions to ensure that production targets are met without causing injury, death, and illness to workers, including damage to equipment and infrastructure.

Some of the key factors that can potentially lead to TMM safety-related incidents such as fatalities, injuries, and damage to property (equipment and infrastructure) are:
- Undesired or unwanted vehicle interactions.
- Driver non-compliance to the Traffic Management Plan.
- Non-compliance to TMM safety-related regulations, particularly sub-regulation 8.10 of the Mine Health and Safety Act.
- Inadequate implementation of the vehicle interaction defensive control models developed by the Earth Moving Equipment Safety Round Table (EMESRT).

In terms of Section 21 of the Mine Health and Safety Act (MHSA), original equipment manufacturers (OEMs) that supply products and machines to mines have specific statutory health and safety obligations. OEMs therefore have a critical role to play to design and develop machines that comply with the new sub-regulations. This will necessitate the addition of collision prevention devices and telecommunication systems to work in tandem with the trackless mobile machines. Compliance will invariably lead to an associated increase in costs.

To remain competitive, comply with the regulations of the MHSA, and provide a safe working environment (zero harm), there is a concerted drive towards the modernisation of mining operations and the adoption of new technology, especially fourth industrial revolution technologies.

The Minerals Council South Africa commissioned the Technology Localisation Implementation Unit to investigate the feasibility of localising collision prevention system components that are used in the manufacture of trackless mobile machinery and collision warning and avoidance devices.

1.2 Approach and Methodology

To effectively address the customer requirements, this feasibility assessment was undertaken in five phases:
- Phase 0: Project Inception
- Phase 1: Data Gathering
- Phase 2: Data Analysis and Synthesis
- Phase 3: Case Study Development
- Phase 4: Reporting.

The approach and methodology that was adopted to execute this project is presented in Figure 1 below:

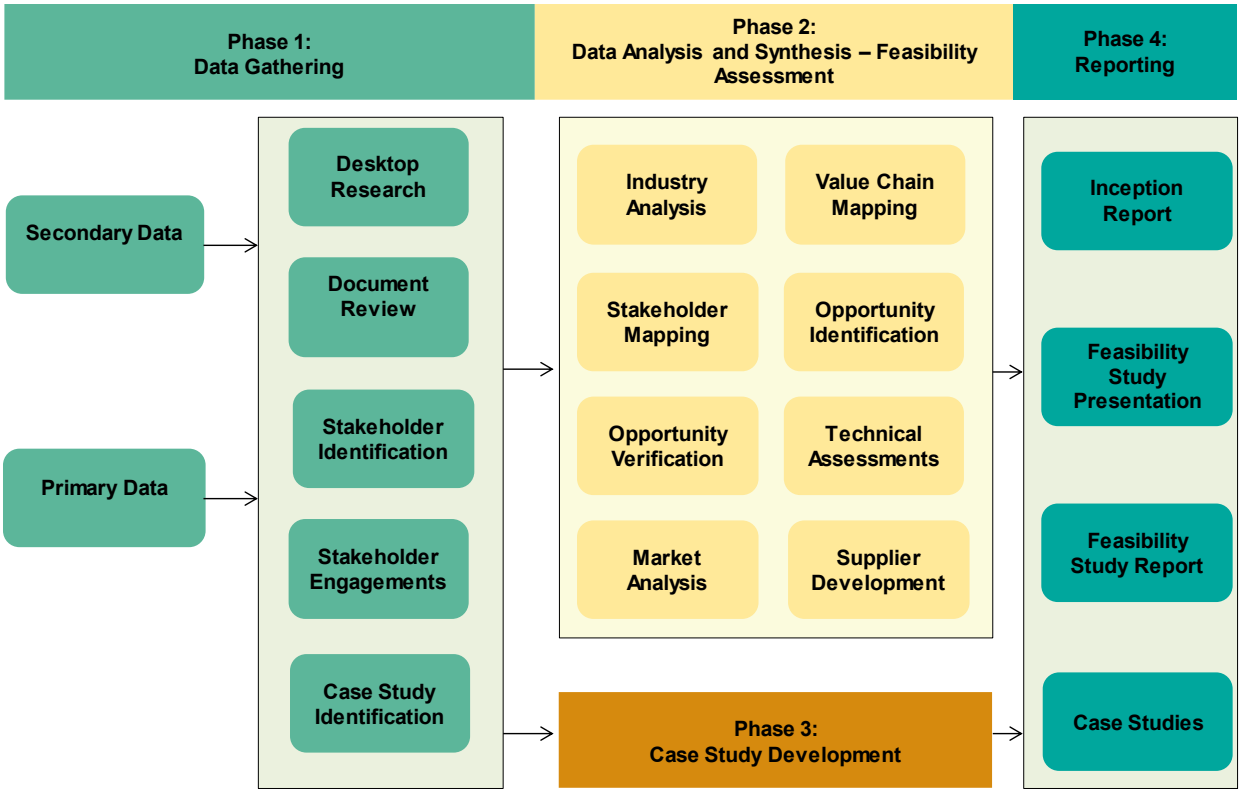

Figure 1: Project Approach and Methodology

A brief description of the work that was undertaken during each project phase is given below:

- **Phase 0: Project Inception**
  Prior to the commencement of the project, inception work was undertaken to ensure a common understanding of the brief, the establishment of reporting and communication lines, the development of a detailed project plan and reaching agreement on the proposed methodology. An inception report was prepared.

- **Phase 1: Data Gathering**
  This entailed the gathering and review of both primary (stakeholder engagements) and secondary data (desktop research). Potential case studies were identified and information on these projects was gathered and reviewed. Relevant outputs from the preliminary work conducted by the Minerals Council South Africa, University of Pretoria, and the National Association of Automobile Manufacturers (naamsa) of South Africa were also gathered and reviewed. These outputs provided valuable baseline information to structure and launch the feasibility assessment.

- **Phase 2: Data Analysis and Synthesis**
  The data gathered in Phase 1 was analysed and synthesised to address the key project requirements such as an industry analysis, value chain mapping, stakeholder mapping, opportunity identification, opportunity verification, technical assessments, market analysis, and supplier development.

- **Phase 3: Case Study Development**
  The data gathered in Phase 1 was used to prepare seven case studies on projects that are successful examples of localisation in terms of manufacture, assembly and insource or outsource. The case studies were selected from each of the following categories: (a) Original Technology Manufacturers, (b) Third Party Suppliers, and (c) Original Equipment Manufacturers.

A case study report was prepared as a separate document with each case included as an appendix to the report. The case studies have also been included in the final feasibility report.

- **Phase 4: Reporting**
  All the reporting requirements of the project were addressed during this phase of the project. This included: (a) inception presentation and report, (b) feasibility study presentation and report, and (c) case studies. The results of the work conducted in Phases 1 to 3 have been used to prepare a feasibility report that covers, amongst others, the aspects listed in the Minerals Council South Africa Request for Proposals.

1.3 Report Preview

The remainder of this document covers the work done towards achieving the objectives of this project.

- *Chapter 2* provides the global and South African strategic context as this relates to developments in the mining industry.
- In *Chapter 3*, a comprehensive industry analysis is presented covering information on the global and South African TMM and CPS industry, and a value chain and stakeholder analysis. In addition, an assessment of the TMM population is presented together with a CPS tooling and testing capability assessment, and an evaluation of the local manufacturing, assembly, and insource or outsource capabilities.
- *Chapter 4* provides an examination of the CPS localisation opportunities identified in the Minerals Council's Terms of Reference for the project. Potential new CPS localisation opportunities are presented together with an approach for supplier development.
- *Chapter 5* contains a detailed analysis of the CPS market, outlining the results of a market size assessment and local content analysis. A description of the market characteristics is also included.
- In *Chapter 6*, a summary of the results of the seven case studies that were developed is provided. The case studies are included in *Appendices A to G*.
- The project conclusions and recommendations are outlined in *Chapter 7 and 8* respectively.

2 STRATEGIC CONTEXT

2.1 Global Context

The global mining industry plays a crucial role by providing the minerals and raw materials used to develop infrastructure and produce a variety of industrial and consumer products. The performance of the mining industry impacts on key downstream industrial sectors such as manufacturing, agriculture and agro-processing, food and beverage, construction, and renewable energy.

According to the *PwC Mine 2024: Preparing for Impact* report, in 2023 the global mining industry faced challenges such as falling commodity prices and rising costs resulting in a drop in revenue of more than 7% and a decrease in profits. A similar trend was forecast for 2024. In 2023, revenue of US$845bn and profit of US$90bn was achieved. These indicators were forecasted to decrease in 2024 to US$792bn and US$55bn respectively.

In 2024, *Mining Digital* reported that the top 10 mining countries are China, Australia, Russia, United States, Canada, Brazil, South Africa, Indonesia, India and Peru.

There are four key technologies that are disrupting the global mining industry namely drone technology, collision-avoidance systems, artificial intelligence, and digital twinning systems. These technologies improve productivity and efficiency and contribute to safer working environments.

The use of digital twinning in the mining industry has started to increase significantly and this has the potential to revolutionise mining processes. While being a nascent technology, several industrial applications have started to emerge including applications focused on improving the productivity of mining machinery, managing mining assets, using simulations for training purposes, and automating the ore extraction process.

Globally, more than 30% of mining industry deaths are caused by failures of vehicle interaction controls. To reduce mining fatalities due to vehicle interactions, the global mining industry is increasing the adoption of safety-related technologies. According to the *Mine-Site Technology Adoption Survey 2023* produced by GlobalData during the period 2018 to 2023, the number of mines that have invested in collision avoidance technology has increased from 62% to 72%.

The key international industry bodies that focus on collision avoidance systems are the Earth Moving Equipment Safety Round Table (EMESRT) and the International Council on Mining and Metals (ICMM). Both organisations are crucial to establishing industry-wide standards and best practices for CAS.

Africa is the fastest growing market for CAS, with South Africa being a leader from a regulatory, technology development and manufacture, and testing and certification perspective. The African Continental Free Trade Area (“AfCFTA”) is an agreement that allows duty-free trade in products and raw material between the 55 members of the African Union. This agreement presents opportunities to fast track the development and deployment of CAS technology on the continent through the establishment of regional value chains.

2.2 South African Context

In recent years, the key focus of South Africa’s industrialisation policy has been on:

- The promotion and development of economic infrastructure such as special economic zones, industrial parks, and incubators.
- The use of preferential procurement regulations to drive localisation by designating products for local manufacture.

- The development of incentives and funding instruments for specific sectors and geographic locations.
- The promotion of value chain development and industrial clustering approaches to economic development.
- The development and implementation of master plans for sectors that show high potential for growth, localisation, and job creation.

The South African government has embarked on a process of developing and implementing various sectoral master plans, in collaboration with various stakeholders including the private and public sector, and organised labour. Most of the master plans have a strong focus on expanding local production, downstream beneficiation, and localisation. Localisation has been a central tenet of South Africa's economic development strategies for many decades, and its success will consolidate and grow the economy. To promote localisation, the focus has been on the establishment of state procurement measures to boost local industries, initiatives to increase local content, capacitation of local firms, and improved access to domestic and export markets.

In addition, the Industrial Policy Action Plan (IPAP) was recently finalised by government and provides a framework for growth through the focus on four key areas, namely localisation, industrialisation, digitisation, and decarbonisation.

South Africa is one of the top 10 mining countries in the world and is a major producer of Platinum Group Metals (PGM), coal, iron, manganese, chrome, and nickel. The country also has large deposits of rare-earth metals and related specialty refining infrastructure.

According to the *International Trade Administration,* mining contributes about 8% to gross domestic product (GDP) but has been in decline for more than two decades due to policy uncertainty, lack of clarity on environmental issues such as the carbon tax, the regulatory framework, security issues, and infrastructure issues including electricity, ports, and railroads. Due to strong demand from world commodity markets, production and sales have recently shown year-on-year growth. The DMRE intends to catalyse exploration by streamlining the licensing regime. Recently, investment in new mining projects has been stagnant.

In 2021 and 2022, South African mines recorded total fatalities of 74 and 49 respectively. A high proportion of these were trackless mobile machinery (TMMs) related deaths, namely eight in 2021 and eight in 2022. Transport accidents, including those caused by TMMs, remain one of the top three causes of death and injury in the SAMI. Achieving Zero-Harm production in this industry requires the continuous development and implementation of innovative solutions to ensure that production targets are met without causing injury, death, and illness to workers, including damage to equipment and infrastructure.

TMMs refer to any self-propelled mobile machine used at a mine for surface or underground activities such as transport and mining. Mobility is achieved through mechanical shoes, skids, wheels, or other types of devices attached to the machine.

Some of the key factors that can potentially lead to TMM safety-related incidents such as fatalities, injuries, and damage to property (equipment and infrastructure) are:

- Undesired or unwanted vehicle interactions
- Non-compliance to the traffic management plan
- Non-compliance to TMM safety-related regulations, particularly sub-regulation 8.10 of the Mine Health and Safety Act Regulations
- Inadequate implementation of vehicle interaction defensive controls.

Regulation 8.10 of the Mine Health and Safety Act, 1996, (Act No. 29 of 1996) deals with collisions between TMMs and pedestrians. This regulation was promulgated in February 2015 with sub-regulations 8.10.1.2b and 8.10.2.1b being suspended at the time of promulgation. In response to the

high proportion of TMM-related fatalities, the suspension of these sub-regulations was lifted in December 2022. These sub-regulations (8.10.1.2b and 8.10.2.1b) compel the mining industry to provide collision prevention systems and devices that will automatically slow down and stop TMMs so that collisions between them and pedestrians, and other machines, are avoided. Given the emergency-like situation, the lifting of the suspension of the sub-regulations came into effect immediately, and no transition period to achieve compliance was allowed.

The Minerals Council South Africa (Minerals Council) is committed to Zero-Harm, balancing saving lives and livelihoods, and creating new livelihoods where possible. It is against this backdrop that the Minerals Council continues to assist mines on their journey to compliance with the TMM regulations, which were published on 21 December 2022 in Gazette No. 47790, Vol 690, Government Notice No. 2908.

This is done through a common member-differentiated and holistic risk-based approach for Collision Prevention Systems (CPS) ecosystem readiness, including investigating the potential impact and opportunities presented by the implementation of these regulations from operational readiness, technology readiness, skills readiness, and enabling cross-cutting issues such as local component manufacture, assembly and/or insourcing-outsourcing capability perspectives.

In addition, to support the SAMI's compliance with the new TMM regulations, the Minerals Council has published a few documents, including the User Requirements Specification for Collision Prevention Systems document. All the documents produced for this purpose are collectively known as the MOSH CPS Guideline and can be found at https://www.mosh.co.za/transport-and-machinery/documents.

The user requirements document provides an important definition for CPS products, which is shown in the CPS Functional Breakdown Structure depicted below (see Figure 2):

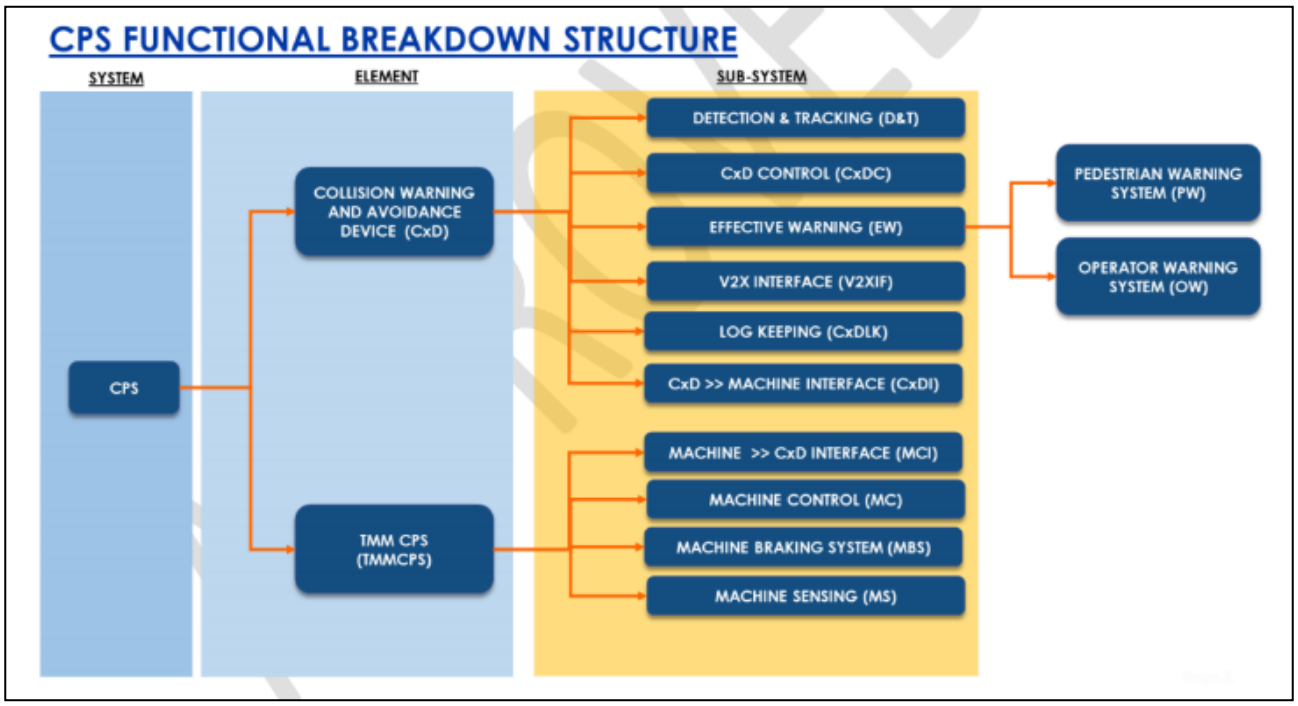

Figure 2: CPS Functional Breakdown Structure

Chapter 8 of the MHSA provides the regulatory impetus for the widespread adoption of CPS in the SAMI, where there is a significant risk of collision. In support, the following initiatives from the Minerals Council provide critical enablers toward the achievement of Zero-Harm: (a) Development of the MOSH CPS Guideline, (b) Special project on "Industry Alignment on TMM Regulations", and (c) Establishment of a testing capability at the University of Pretoria's Vehicle Dynamics Group.

3 INDUSTRY ANALYSIS

3.1 Overview of Global TMM and CPS Industry

The global collision avoidance system (CAS) market size was valued at U$66.80bn in 2022 and is expected to expand at a compound annual growth rate (CAGR) of 11.4% from 2023 to 2030.

The mining CPS market can be segmented into:
- Collison Warning and Avoidance Device Original Technology Manufacturers
- Trackless Mobile Machinery Original Equipment Suppliers
- Third-party Integrators.

The global mining sector CAS market was U$5,3 bn in 2022, and was projected to grow at a rate of 10.2% per annum from 2023 to 2030. North and South America account for the biggest market demand, whilst Africa is the fastest growing market.

The following international industry bodies are influential drivers of this growth:
- Earth Moving Equipment Safety Round Table
- International Council on Mining and Metals

The key future CAS technologies include LiDAR, AI cameras, radar and ultrasonics.

3.2 Overview of South African TMM and CPS Industry

Local mining equipment manufacturers play a crucial role in supplying the SAMI with world-class and innovative equipment. Being close to the raw material used in the production of mining equipment is a competitive advantage for local manufacturers. Notwithstanding this, equipment manufacturers are heavily dependent on the growth of the mining industry and face fierce competition from low-priced imports which impede local production.

Figure 3 shows the total market size for mining equipment in South Africa for the period 2018 to 20304.

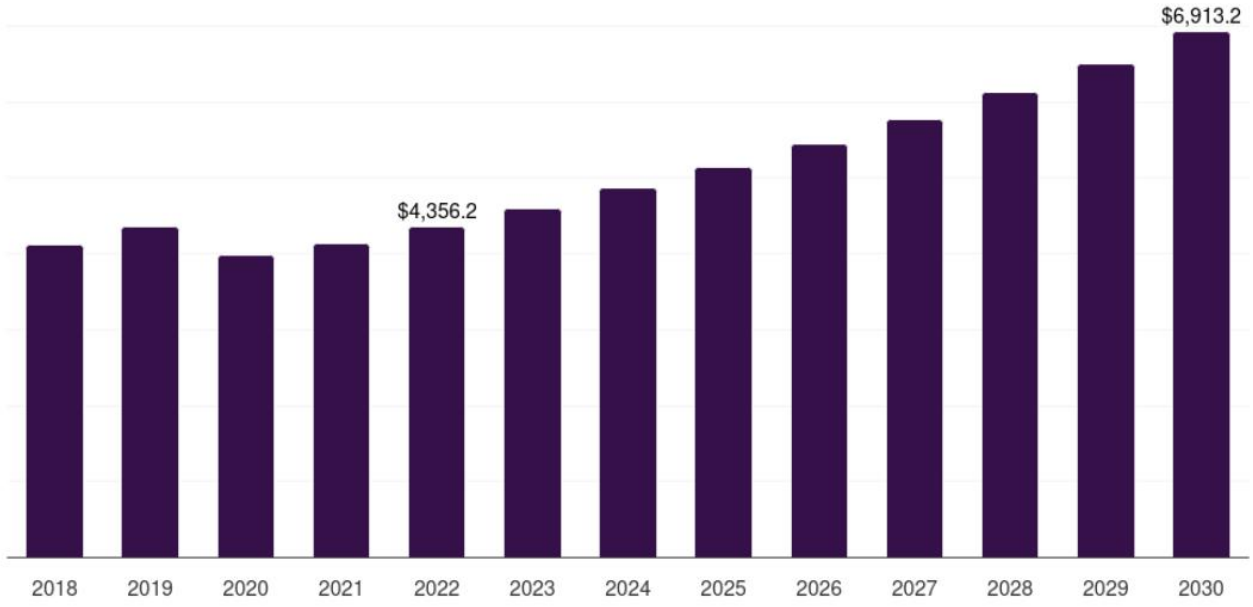

Figure 3: South Africa Mining Equipment Market, 2018 - 2030 (US$M)

Source: https://www.grandviewresearch.com/horizon/outlook/mining-equipment-market/south-africa

In 2022, the SA mining equipment market achieved revenue of USD 4 356.2 million, with surface mining equipment achieving a revenue share of 42.15% and machinery for underground mining applications being the most lucrative and fastest growing market segment. The country's mining equipment market is expected to grow to USD 6 913.2 million by 2030, achieving a CAGR of 5.9% between 2023 to 2030.

The African Continental Free Trade Area offers South African mining equipment manufacturers a huge opportunity to export their well-developed equipment to other countries on the continent. Africa is the fastest growing market for CAS. By collaborating with local CxD OTMs and third-party integrators, mining equipment manufacturers could penetrate the African market with comprehensive, integrated and locally developed solutions.

Safety regulations have driven the development of an active CPS sector in South Africa and given South Africa a reputation as a world leader in this sector. Several companies active in the South African CPS sector. There is a mix of international and local CxD OTMs in the country, with some local companies having merged with international players. A number of these companies have in some way acquired a South African CxD OTM or accessed their technology.

Many of the local CxD OTMs have developed their own components and systems, which have typically been certified and configured for fitment to a range of TMMs. As with the CxD products there has been a rapid growth in ISO compliance, with 11 products now certified. There is growing interest from international TMM OEMs in attaining ISO certification for their systems.

The demand for systems, and the lack of readiness by TMM OEMs, has seen the emergence of third-party integrators, with the products of seven such integrators being in various stages of certification. The use of third-party integrators introduces a more complex risk management scenario, as the performance responsibility is typically shared between three parties.

3.3 Value Chain Analysis

To achieve TMM regulatory compliance, CPS products need to be installed on TMMs that operate where there are significant risks of collision, the mine site and the people that are in the vicinity of TMMs. These products need to be integrated so that they operate as a fully functional CPS system that will prevent collisions, injury and fatalities. Figure 4 shows the various CPS sub-systems that are installed on TMMs, the mine site and people.

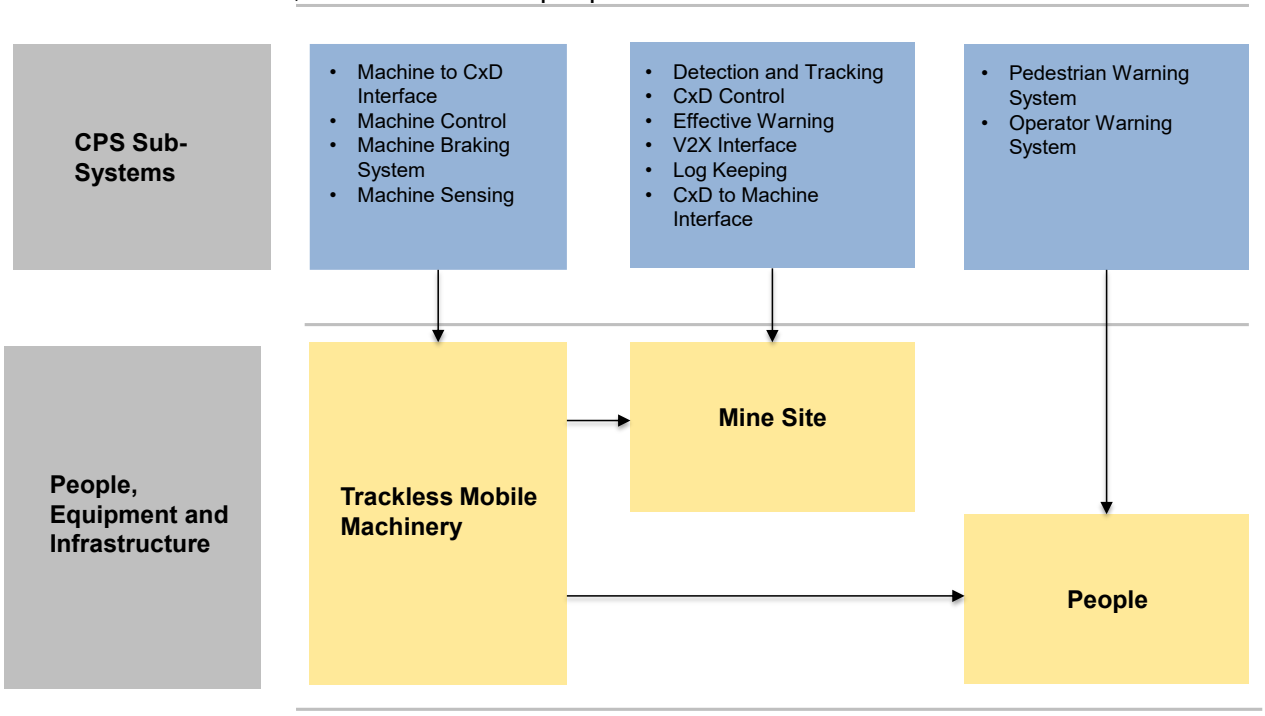

Figure 4: TMM and CPS Value Chain Overview

The typical value chain for trackless mobile machinery is depicted in Figure 5.

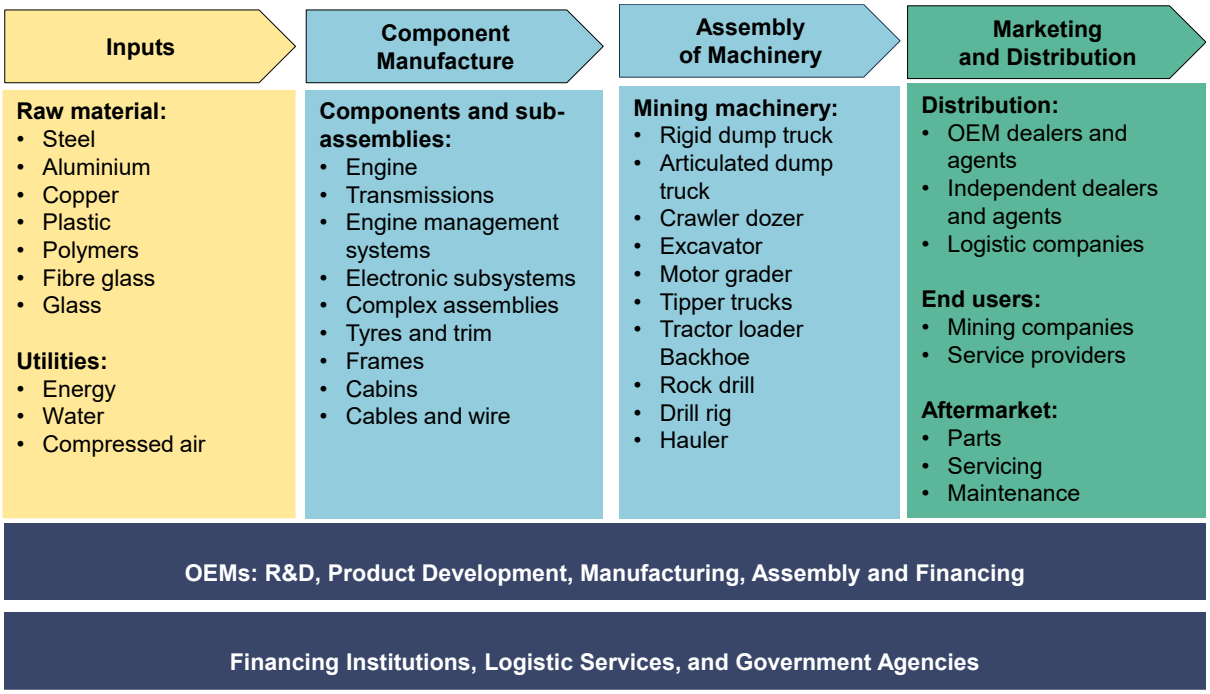

Figure 5: Value chain for trackless mobile machinery

The value chain consists of four stages, namely inputs, component manufacture, assembly of machinery, and marketing and distribution.

- Inputs consist of various raw materials and utilities. The typical raw materials used for the manufacture of TMMs, and their various components include steel, aluminium, copper, plastic, polymers, fibre glass and glass. The utilities used are energy, water and compressed air.
- Component manufacture involves the production of components and sub-assemblies such as engines, transmissions, engine management systems, electronic sub-systems, complex assemblies, tyres and trim, frames, cabins, and cables and wires. Some of these components will be manufactured in-house by OEMs, while others will be sourced from tier one suppliers.
- Assembly of machinery involves assembly of the various components and sub-systems to produce the different types of mining equipment such as rigid dump trucks, articulated dump trucks, excavators, haulers, etc.
- Marketing and distribution could take the form of distribution of TMMs through channels such as dealers, agents and logistics companies. In addition, OEMs make direct sales to mining houses and service providers. The aftermarket offering covers the supply of spare parts and providing servicing and maintenance services.
- Key value chain processes conducted by OEMs include research and development, product development, manufacturing, assembly and financing.
- Key support entities include financing institutions, logistics companies and government departments and agencies.

To enable the functioning of a TMM for CPS compliance, the vehicle needs to be fitted with various CPS sub-systems as shown in Figure 6.

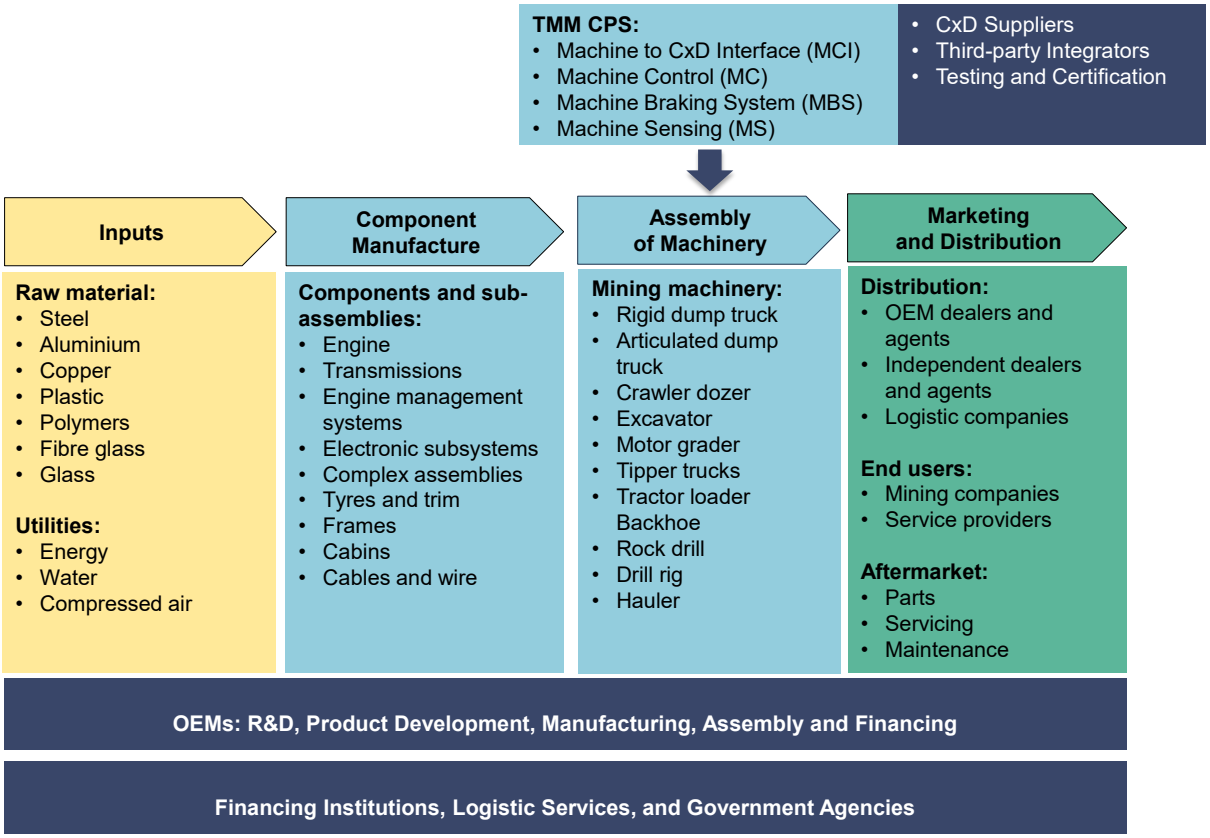

Figure 6: Value chain for TMM with CPS

The TMM CPS sub-systems include Machine to CxD Interface (MCI), Machine Control (MC), Machine Braking System (MBS), and Machine Sensing (MS). These sub-systems consist of a variety

of components and are developed and installed by TMM OEMs, CxD suppliers and/or third-party integrators. Before installation, the sub-systems undergo rigorous testing and need to be certified.

The value chain for collision prevention systems in mining encompasses various stages, from raw material suppliers to end-users. Figure 7 outlines the key components and processes involved in bringing CPS systems to market, highlighting the roles of different stakeholders and the flow of value.

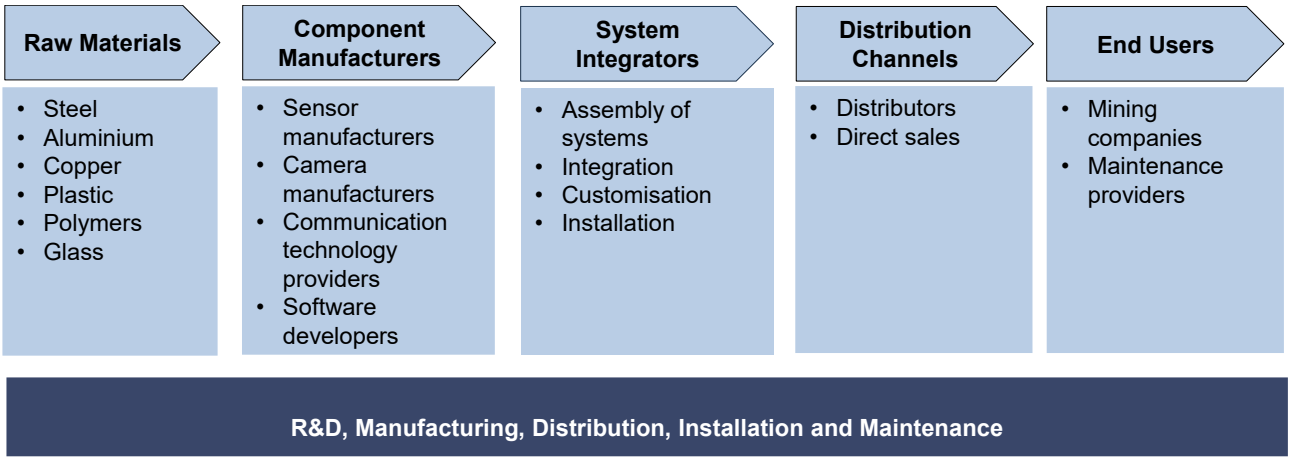

Figure 7: Generic CPS value chain

The main components of the value chain are described briefly below:

- *Raw Materials:*
  - Steel and Aluminium: Essential for manufacturing sensors and protective housings.
  - Semiconductors: Integral for sensor and communication technology.
  - Plastic and Rubber: Used in the construction of various system components.
- *Component Manufacturers:*
  - Sensor Manufacturers: Produce the sensors that detect potential collisions.
  - Communication Technology Providers: Develop wireless technologies for system integration.
  - Software Developers: Create predictive maintenance and monitoring software.
- *System Integrators:*
  - Integrating Firms: Assemble various components into complete collision prevention systems.
  - Customization: Modify systems to meet specific mining company needs.
- *Distribution Channels:*
  - Distributors: Facilitate the supply of systems to mining companies.
  - Direct Sales: Manufacturers sell directly to large mining companies.
- *End-Users:*
  - Mining Companies: Utilize collision prevention systems to enhance safety.
  - Maintenance Providers: Offer ongoing service and system upkeep.

The key value chain processes are outlined below:

- *Research and Development:*
  Innovation in sensor technology and communication systems is the backbone of collision prevention systems. Continuous R&D efforts ensure advanced, reliable solutions.
- *Manufacturing:*
  Component manufacturers produce high-quality sensors, communication devices, and protective housings. System integrators then assemble these components into functional safety systems.
- *Distribution:*
  Effective distribution channels are crucial for delivering systems to end-users in various regions.
- *Installation and Maintenance:*

Professional installation ensures proper integration with existing infrastructure, while specialised maintenance services maintain system functionality and efficiency.

Collision prevention systems are important to enhance safety and operational efficiency in mining environments. CPS systems involve various components designed to detect and automatically prevent potential collisions between machinery, vehicles, and personnel. The main components are:

- *Sensors*. Sensors are critical for detecting obstacles and monitoring the environment. They may include but are not limited to radar, LiDAR, ultrasonic sensors, and cameras. Each type of sensor has specific capabilities, such as detecting distance, speed, and direction of moving objects.
- *Control Units*. Control units process the data collected by sensors and make decisions to prevent collisions. They use algorithms to analyse the information and send commands to the actuators accordingly.
- *Actuators*: Actuators execute the commands from the control units, such as applying brakes or steering adjustments. They are essential for the timely response to detected hazards.
- *Communication Systems*: Communication systems enable real-time data exchange between various components and machinery. They ensure that the system operates cohesively and that any potential threats are addressed promptly.
- *Warning Devices*: Warning devices alert operators and personnel about imminent collisions. These can include visual signals like lights, auditory alarms, and haptic feedback systems.
- *Software*: Software plays a vital role in integrating all components and ensuring they work together efficiently. It includes the user interface, diagnostic tools, and update systems to keep the collision prevention system functioning optimally.

3.4 Stakeholder Analysis

There are a variety of stakeholders that operate in the CPS ecosystem in South Africa and who are critical to the successful implementation of these systems in the mining industry. In broad terms, these stakeholders include mining companies, technology providers, manufacturers, government departments and agencies, regulatory bodies, industry associations, and research and academic institutions.

Table 1 provides a list of the stakeholders and their roles in the CPS ecosystem..

Table 1: Stakeholders and Roles

Stakeholders	Roles
CxD Suppliers	These are companies that design, develop and manufacture collision warning and avoidance components and systems.
TMM OEMs	TMM OEMs are companies that produce trackless mobile machinery for the mining industry. These OEMs operate in the yellow metals sector and typically also produce machinery and equipment for the construction and agricultural sectors.
Third-Party Integrators	These companies integrate CxD components and systems with vehicles and reporting systems.
Local Manufacturers	There are a range of manufacturers that support the CPS ecosystem to produce CPS products and systems. Automotive and electronics manufacturers have the appropriate capabilities and facilities to assist in this regard.

Stakeholders	Roles
Mining Houses	The mining houses are the end users of the CPS systems, which they need to successfully implement to achieve TMM regulatory compliance.
Junior Miners	These are small, early-stage miners who play a significant role in the local mining industry. These companies are also required to successfully implement CPS systems to achieve TMM regulatory compliance.
Mining Service Providers	Mining service companies provide various services to mines. This could include the installation and maintenance of CPS systems.
Department of Mineral and Petroleum Resources (DMPR)	The DMPR promotes and regulates the minerals, mining and petroleum resources of South Africa. The department is responsible for mine health and safety, and for ensuring that the appropriate regulations are developed, gazetted, and complied with.
Department of Science, Technology and Innovation (DSTI)	The DSTI is responsible for research, development and innovation and has a focus on technology localisation, beneficiation and advanced manufacturing. The department funds the TLIU, Mandela Mining Precinct (MMP), and the South African Mining Extraction Research, Development and Innovation (SAMERDI) strategy.
Department of Trade, Industry and Competition (the DTIC)	DTIC provides several incentives that support industry and trade such as: • Support Programme for Industrial Innovation • Technology and Human Resources for Industry Programme • Manufacturing Competitiveness Enhancement Programme • Capital Projects Feasibility Programme • Global Business Services Incentive • Critical Infrastructure Programme • Black Industrialist scheme Some of these support measures could be relevant to the CPS companies. The department could also be approached to provide tailored support for the CPS ecosystem.
Mine Health and Safety Council (MHSC)	The MHSC is a public entity that advises the Minister of DMPR on occupational health and safety legislation, and research and innovation, for South African mines.
Council for Scientific and Industrial Research (CSIR)	The CSIR is a research, development and innovation (RDI) organisation that reports to the DSTI. The organisation also undertakes RDI for the mining, manufacturing and electronics sectors.
Mintek	Mintek is a national organisation that conducts RDI on minerals processing and extractive metallurgy. The organisation also has facilities that could be used to produce base material for rapid prototyping purposes, which could be of value to CPS companies.
Mandela Mining Precinct (MMP)	The MMP is a public-private partnership that focuses on mining RDI and is responsible for implementing SAMERDI. MMP is funded by the DSTI and Minerals Council.
Technology Localisation Implementation Unit (TLIU)	The TLIU is funded by the DSTI and is mandated to support localisation in the country through the following service offerings: • Firm Technology Assistance Package (FTAP) • Sector-Wide Technology Assistance Package (SWTAP) • Industry Profiling and Benchmarking

Stakeholders	Roles
South African Bureau of Standards (SABS)	SABS is a public entity that develops and promotes standards for products and services. The organisation has been appointed by the DTIC to provide local content verification services of designated products in alignment with SANS 1286, and the Preferential Procurement Policy Framework Act.
Technology Innovation Agency (TIA)	TIA is a DSTI funded agency that focuses on technology development and commercialisation. The agency provides funding and has the Technology Stations Programme, which could assist with CPS product design, development and manufacturing.
Intsimbi Future Production Technologies Initiative (IFPTI)	IFPTI is a programme established by DTIC and has an initiative called the National Technologies Implementation Platform (NTIP). This platform provides support to the local steel and plastics sectors, as well as tool, die and mould-making industries.
University of Pretoria (UP)	The Vehicle Dynamics Group (VDG) of UP have established facilities and procedures to test the performance of collision prevention systems for the local and international mining industry. VDG follows the Minerals Council's MOSH specifications on CPS testing protocols.
Wits Mining Institute (WMI)	WMI conducts research and skills development for the mining industry. The institute also has a partnership with MMP and is involved in the SAMERDI strategy.
University of Johannesburg (UJ)	UJ has a mock mine at the School of Mining Engineering that could be used for single machine testing CPS systems.
Vaal University of Technology (VUT)	VUT hosts the materials and processing technology station (TSMPT) that is funded by TIA. TSMPT assists manufacturers of metal-based products and composite-based products to improve their products and processes.
Central University of Technology (CUT)	CUT hosts the product development technology station that is funded by TIA. The technology station has access to rapid prototyping equipment that could assist with product development and manufacture.
Minerals Council South Africa	As a mining industry employers' organisation, the Minerals Council supports and promotes the SAMI. The Minerals Council has a strong focus on Zero-Harm, and in support of this goal, has undertaken the following initiatives: • Development of the MOSH CPS Guidelines • Special project on "Industry Alignment on TMM Regulations" • Establishment of a testing capability at the University of Pretoria's Vehicle Dynamics Group.
Mining Equipment Manufacturers of South Africa (MEMSA)	MEMSA is an industry organisation established by DTIC to promote the interests of the mining equipment manufacturers. The organisation facilitates market access and technological development.
South African Mineral Processing Equipment Cluster (SAMPEC)	SAMPEC is a cluster that is part of South African Capital Equipment Export Council (SACEEC) and is involved in assisting members with market access and industry sustainability.
Construction and Mining Equipment Suppliers Association (CONMESA)	CONMESA promotes the manufacture, assembly and distribution of construction and mining equipment in the country.

Stakeholders	Roles
South African Capital Equipment Export Council (SACEEC)	SACEEC is a public-private partnership between DTIC and the capital equipment industry. The council assists its members to access global markets.
National Association of Automotive Component and Allied Manufacturers (NAACAM)	NAACAM represents automotive component manufacturers and could provide access to member companies for the local manufacture of CPS products.
Naamsa	Naamsa is a trade association that represents the local automotive industry and could provide access to member companies for the local manufacture of CPS products.
Mining Industry Association of Southern Africa (MIASA)	MIASA consists of mining industry associations in the Southern African Development Community (SADC). The associations of various countries are part of this association, with the Minerals Council representing South Africa. This body could be used to promote mine safety and the adoption of CPS systems by mines in the region.
Earth Moving Equipment Safety Round Table (EMESRT)	EMESRT is an international initiative established by mining companies to work with OEMs to improve the safety of mining equipment and operations. The initiative has a strong focus on providing guidelines for collision avoidance systems.
International Council on Mining and Metals (ICMM)	ICMM is an international organisation that focuses on sustainable development and has a specific focus on “Eliminating fatalities and building a strong safety culture” in the mining and metals sector.

3.5 TMM Population Map

The scope of this section of work relates to mapping out the TMM population in terms of type, model, year of manufacture, mining processes and mine-type.

The objectives of the work were as follows:

- Verify available information and update where applicable
- Identify the number of TMMs that can be classified as old, unintelligent or legacy vehicles
- Propose technology solutions and localisation funding opportunities, including those at community level
- Demonstrate potential CPS technology demand per mine type, that is, surface operations and underground operations.

Methodology

To assess the mining landscape, a South African mining map was obtained from the Council of Geosciences, shown in Figure 8. This map highlights the locations and concentrations of commodities mined in South Africa, based on the geographic locations of each operation. South Africa boasts a large amount of mineral resources, which necessitates the use of TMMs for mining operations.

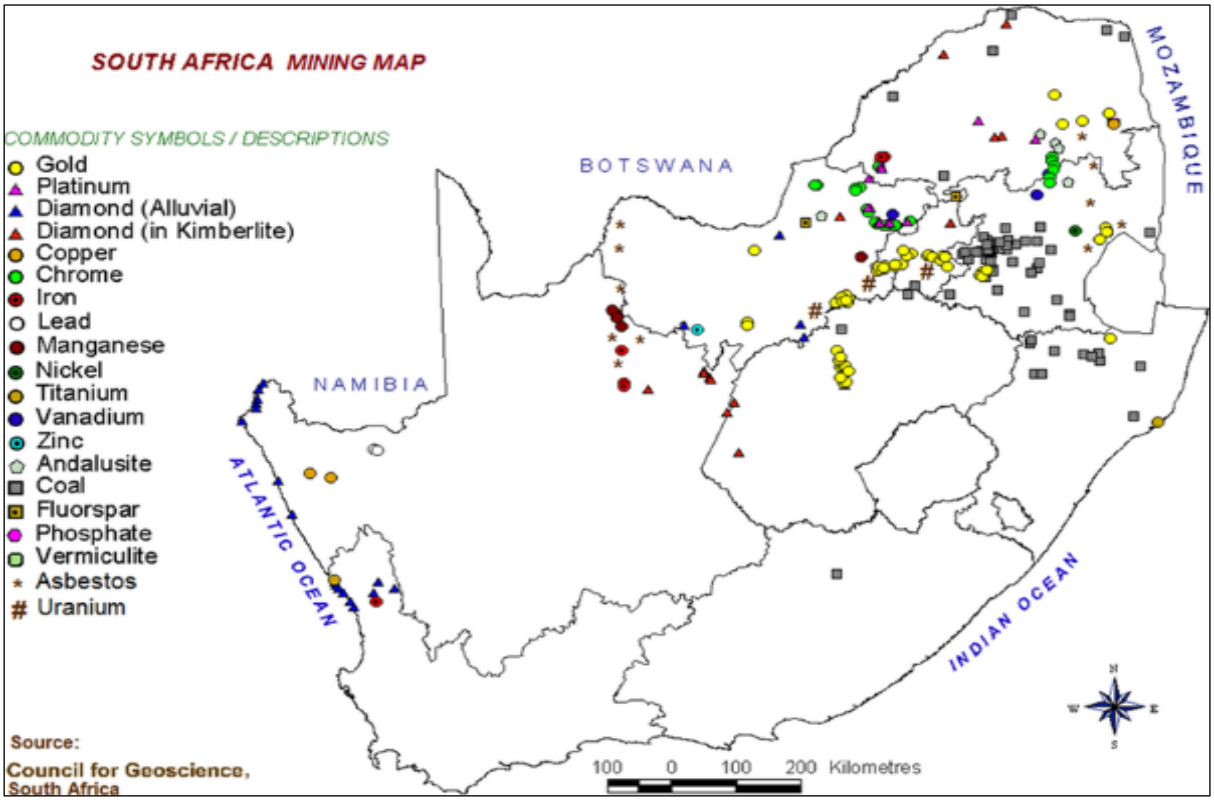

Figure 8: South African mining map (Source: Council for Geoscience)

A desktop study was undertaken to identify the data associated with TMMs within the SAMI. Existing TMM population estimate data was obtained for 2021 (CSIR Mining, 2021). The data was based on the information collected in 2017 by the then Department of Mineral Resources and Energy (DMRE), now known as the Department of Mineral and Petroleum Resources (DMPR). Preliminary analysis was conducted using historical data.

For validation, a market intelligence service provider (GlobalData) was appointed to source the equipment data. The data was sorted and interrogated to identify the required metrics; however, some of the information was not readily available. The data provided by GlobalData included 428 operating mines in South Africa. Other sources indicate that there are 561 mines operating in South Africa (MiningIQ, 2024). The current data reflects the number of holding operations rather than the individual operating shafts, providing a general overview of the country's mines.

The historical data also indicated many more mines operating in South Africa. Table 2 highlights the differences between the historic and currently sourced data.

Table 2: Comparison of data for number of mines in operation in South Africa

	Historical data (2021)	Current Data (2025)
Number of mines who responded	104	428
Total number of mines	919	428
Number of surface mines	743	311
Number of underground mines	176	117
Number of diesel-powered TMMs	16 224	11 279
Number of TMMs in surface mines	12 191 (approx.)	6 708
Number of TMMs in underground mines	4 033 (approx.)	4 571

To supplement the data with an additional layer of verification, the team developed a machine learning model that was trained and used to identify TMMs at all operating surface mines, estimated at 561, using Google images. The development is an ongoing exercise with continuous model enhancement through feeding a large dataset to the model. The machine learning model/tool was not part of the initial scope. However, the team developed and added it to the project to enhance the project deliverables. To validate the findings of the machine vision model, the South African mining map shown in Figure 8 will be used. The model will locate mines using artificial intelligence and identify the TMMs located at a particular mine. Thereafter, the TMMs will be classified and the numbers identified for each of the operations within the SAMI will be reported on.

3.5.1 Data Analysis

The information received from GlobalData was analysed and the results are depicted in Figure 9.

The data provided by GlobalData did not include specific descriptions that were contained in historical data, for example front-end loaders are classified as loaders in the current data. Some of the descriptions or vehicle types that were not accounted for, and that were included in the historical data, are cherry pickers, cranes and buses.

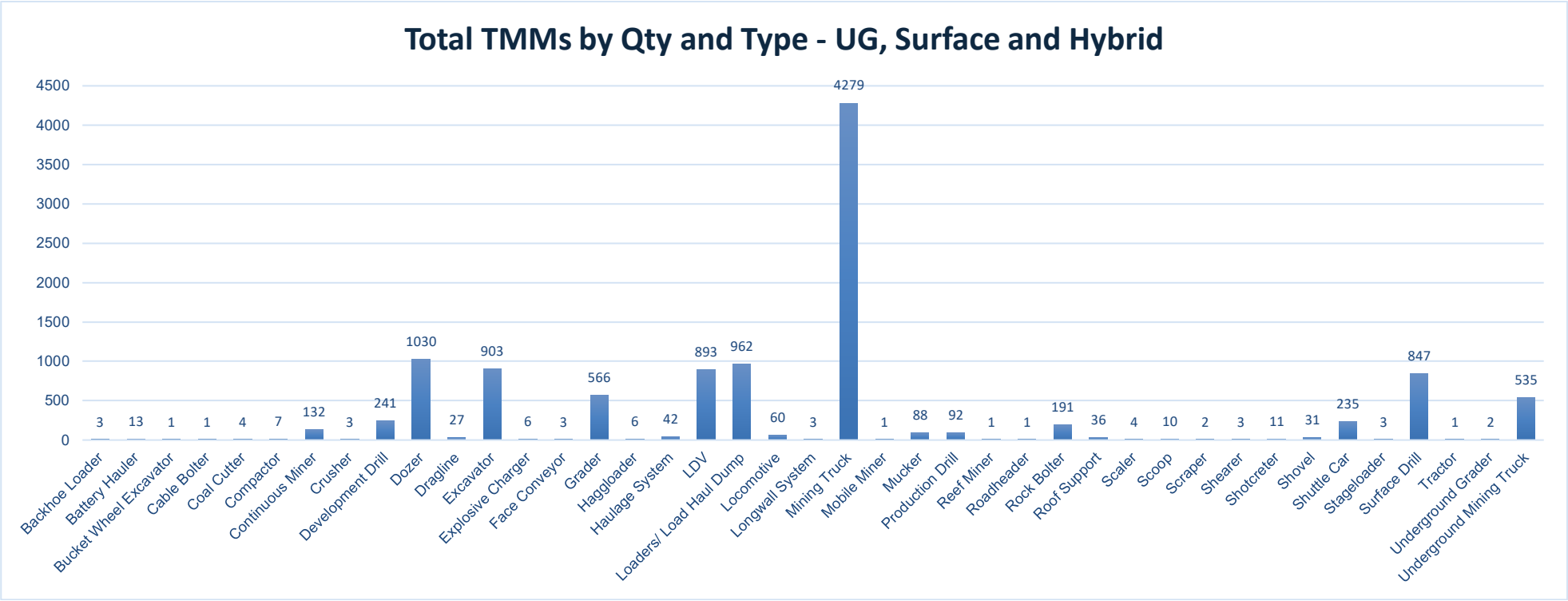

Figure 9: Types of TMMs in use

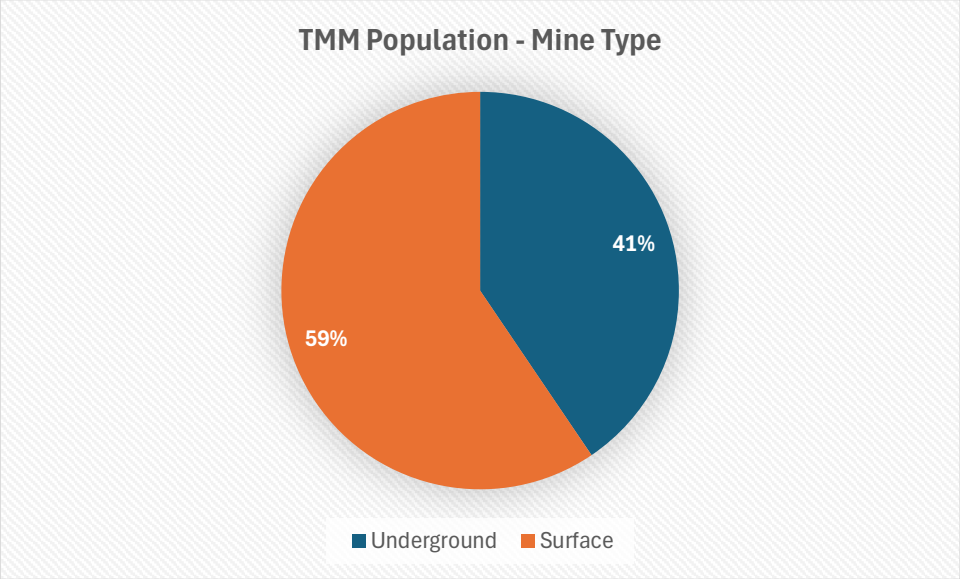

Figure 10: TMM Population per mine type

Figure 10 shows the split of the TMM population based on mine-type. The data indicates that 59% of TMMs are operated in surface mines, while 41% of the TMM population is operated in underground mines.

An analysis of the models of TMMs used in the different types of mines was undertaken and is depicted in Table 3. Highlighted in the table are the main equipment used in mining operations and where they are used, listed by supplier pseudonym.

Table 3: TMM Models for different mine types

Supplier/OEM	Surface	Underground (UG)	UG / Surface	Grand Total
A	-	70	-	70
B	82	183	4	269
C	20	-	-	20
D	85	31	2	118
E	-	2	-	2
F	3	4	2	9
G	515	365	55	935
H	4	-	-	4
I	-	22	-	22
J	12	29	-	41
K	-	7	-	7
L	-	81	5	86
M	1	-	-	1
N	-	6	1	7
O	-	60	-	60
P	61	16	5	82
Q	-	7	-	7
R	1	-	-	1
S	-	10	-	10
T	1	-	-	1
U	1	-	-	1
V	-	278	68	346
W	6	-	-	6
(blank)	6	-	-	6

Supplier/OEM	Surface	Underground (UG)	UG / Surface	Grand Total
X	328	35	7	370
Y	18	-	-	18
Z	36	20	1	57
AA	3	-	-	3
BB	-	1	-	1
CC	-	2	-	2
DD	-	4	-	4
EE	5	2	-	7
FF	-	1	-	1
GG	-	1	-	1
HH	12	-	-	12
P&H	12	17	-	29
II	2	-	-	2
JJ	-	12	-	12
KK	9	83	-	92
LL	-	4	-	4
MM	-	127	-	127
NN	60	757	7	824
OO	-	2	-	2
PP	6	-	-	6
QQ	1	-	-	1
TBC	1558	617	187	2362
TBC (Estimated)	3238	1154	656	5048
RR	29	5	-	34
SS	14	-	-	14
TT	71	45	21	137
UU	4	-	-	4
Grand Total	**6198**	**4060**	**1021**	**11279**

3.5.2 TMM Classification

The TMMs were classified as intelligent and unintelligent, and split per mine-type. Intelligent TMMs refer to vehicles fitted with CAN bus, braking system, sensors and other intelligent communication systems that will enable ease of CxD component integration. Unintelligent TMMs are classified as vehicles that will require retrofitting of intelligent systems to convert them into vehicles that can be integrated with CxD technologies, for example fitting GPS sensors on legacy equipment to enable tracking and geofencing. Several approximation methods were considered for classification of TMMs into the two categories, and two were ultimately selected and used. Chronological age and assumed effective age based on mine operation type were used for the approximation. Chronological age refers to the number of years since equipment manufacture, while effective age refers to the age of the asset based on its condition, which may be affected by inter-alia handling, wear and maintenance history (ART, 2024). Table 3 summarises the data that was used for the approximation. The following assumptions on mine type data and vehicle model were used to support the approximation.

- All equipment is used optimally based on typical operating hours for each TMM type, e.g. haul trucks often run 18–24 hours on a surface mine
- All equipment is maintained in the same way
- Most of the equipment manufactured before 2016 is assumed to be unintelligent
- Most junior miners operate unintelligent TMMs.

Figure 11 indicates a percentage split according to the classification of intelligent vs unintelligent fleet in operation in South African mines. Of the total fleet, 78% are considered to be intelligent, and 22% are unintelligent.

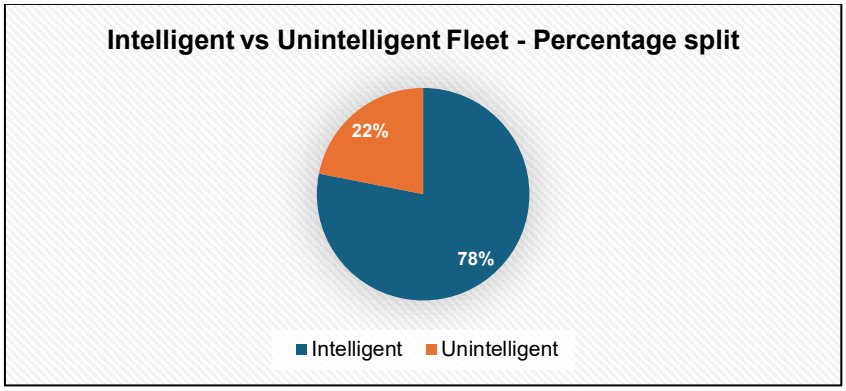

Figure 11: Intelligent vs unintelligent TMM classification

Figure 12 indicates a spread of intelligent TMMs in South African mining operations per mine-type. Intelligent TMMs are most prevalent in surface mines (52%), while 30% of the fleet operates in underground mines and 10% are in operations that employ both surface and underground mining methods.

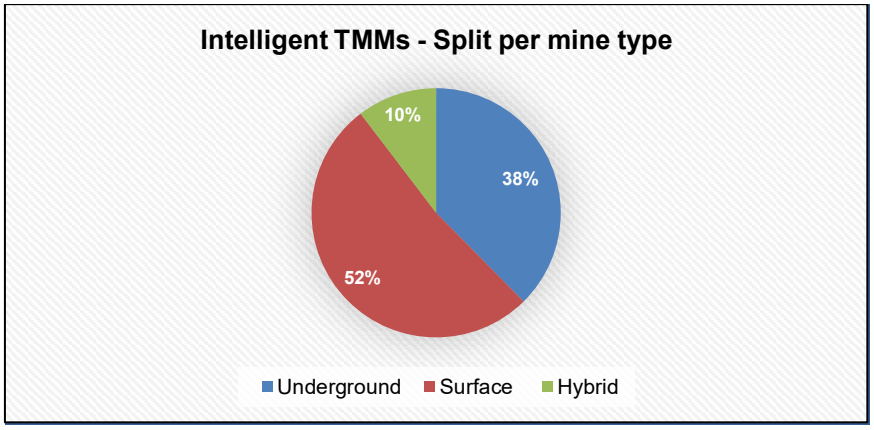

Figure 12: Intelligent TMM split per mine type

Figure 13 indicates that 66% of unintelligent TMMs are found in surface mines, 30% in underground mines, and 4% in hybrid mines. Unintelligent TMMs will require retrofitting of CAN bus, braking systems and sensors to convert them into intelligent systems, which can then be fitted with CxD systems to achieve automatic slowdown and stop capabilities.

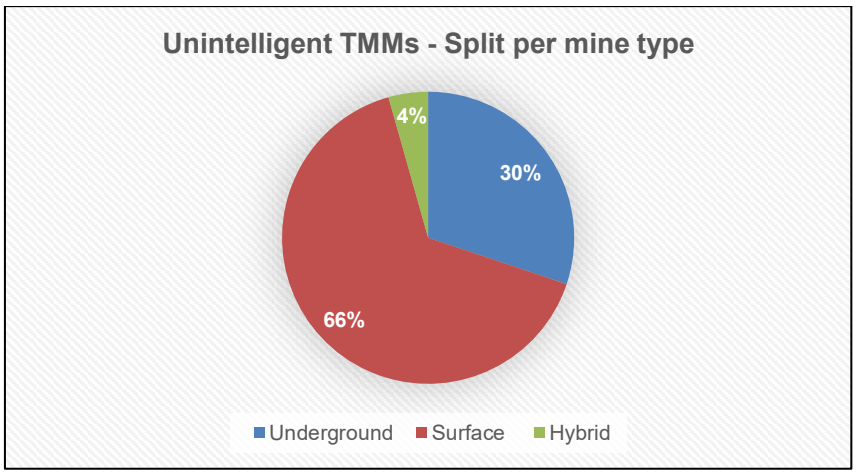

Figure 13: Unintelligent TMM split per mine type

Table 4 provides the total number of intelligent and unintelligent TMMs per mine-type.

Table 4: Total number of intelligent and unintelligent TMMs per mine type

Row Labels	Intelligent	Unintelligent	Grand Total
Surface	4 584	1 614	6 198
UG	3 313	747	4 060
UG / Surface	913	108	1 021
Grand Total	**8 810**	**2 469**	**11 279**

There are 8 810 intelligent TMMs that can be fitted with CxD systems to achieve automatic slowdown and stop capability, while 2 469 vehicles can be upgraded to achieve other metrics based on individual mines' objectives.

The focus of the study is to identify the potential market for the development of CPS manufacture and assembly within South Africa, notwithstanding that only TMMs operating in mines where there is a significant risk of collision should be fitted with CPS. For surface mines, 4 584 TMMs can be fitted with CxD, while 3 313 TMMs that operate underground can also be fitted. A small portion of TMMs operate in hybrid mining environments where surface and underground mining methods are employed.

More stakeholder engagement in the form of workshops and focus groups must be considered to validate the classification as well as the viability for fitting systems onto the TMMs. As highlighted above, the TMM population data can be validated using the machine learning model and focused stakeholder engagements.

3.6 CPS Tooling and Testing Capability

The scope of this section of work relates to determining the CPS tooling and testing and independent verification capacity and capability in South Africa.

The objectives of the work were to:

- Identify other CPS components not listed in the request for proposal
- Identify technology providers for different systems
- Highlight local content based on local manufacturing capacity

3.6.1 Methodology

A desktop study was conducted to identify other CPS components not listed as localisation opportunities in the Terms of Reference (ToR) provided by the Minerals Council. Technology providers were identified for different systems including their capacity and capability to manufacture and assemble CxD systems. An indication of local content was also included. Figure 14 shows the high-level approach undertaken to gather data and achieve the objectives of this work package.

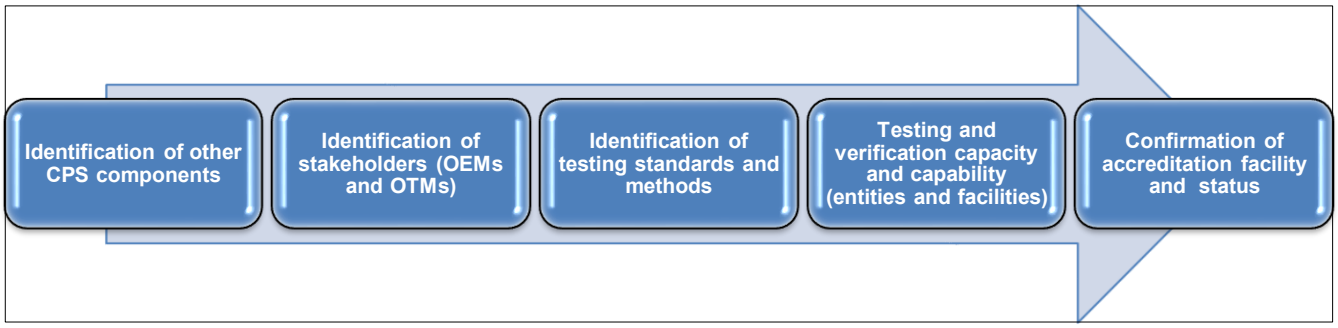

Figure 14: Methodology used to identify tooling and testing capacity

3.6.2 Tooling capability

Component tooling typically refers to the moulds, patterns, jigs and fixtures that are used to design, develop and manufacture components. South Africa has a plethora of engineering workshops that can produce the required patterns, jigs and fixtures.

CPS suppliers source moulds and enclosures from China due to low cost, fast turnaround times and product quality. While there are local companies that can produce moulds and enclosures, they are currently unable to compete with their Chinese counterparts who have lower production costs and economies of scale.

Clearly, there is a need to assist local companies to be able to produce moulds and enclosures that can compete with international companies. The Intsimbi Future Production Technologies Initiative (IFPTI) is a programme established by the DTIC and has an initiative called the National Technologies Implementation Platform (NTIP). This platform provides support to the local steel and plastics sectors, as well as tool, die and mould-making industries. NTIP should be approached to provide targeted assistance to enable local companies to produce competitive moulds and enclosures.

In addition, the use of advanced rapid prototyping processes should be explored as new options to produce moulds, components and enclosures for CPS. Some of these advanced processes are:

- Additive manufacturing (metal 3D printing)
- Metal injection moulding (MIM)
- Cold or hot isostatic pressing (CIP or HIP)
- Direct powder rolling (DPR)
- Forging
- Gravity sintering

These processes are suitable for producing one prototype, and small batches of products.

3.6.3 Independent testing and verification

Figure 15 shows the different types of tests and testing facilities that conduct testing at various technology readiness levels (TRLs).

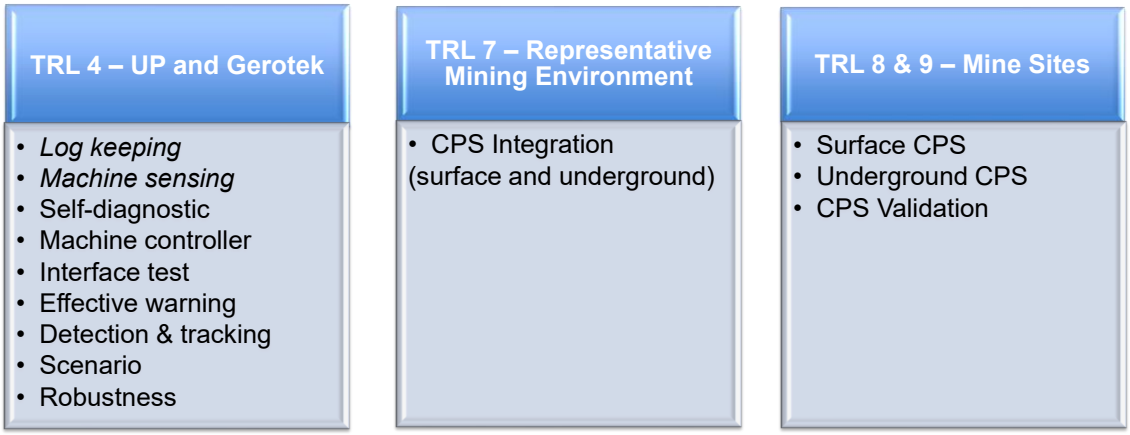

Figure 15: List of CPS tests and associated TRL level testing requirements

TRL 4 testing is conducted in a controlled environment at the University of Pretoria's testing facility and in collaboration with Gerotek testing facility. This is followed by testing in a representative mine environment at TRL 7, which includes robustness testing. Real environment testing, at relevant mining operations, is undertaken to demonstrate TRL 8 and 9 compliance. Digital tools can be used to support testing.

Data on testing facilities and protocols associated with CPS testing was collated through a desktop study and is presented in Table 5, Table 6, Table 7 and Table 8. The data indicates technology readiness level testing protocol and objectives and gives an indication of testing facilities to undertake the testing.

Table 5: Underground hard rock CxD TRL4 tests

No.	Phase	Test protocol	Test objective	Test site
1	1	UGHR CxD Interface Test	Confirm that CxD can interface with TMM according to ISO 21815-2:2021	UP laboratory
2	1	UGHR CxD Log-keeping Test	Logs needed to: • Conduct investigations should an incident occur • Maximise benefit derived from CPS – improved site control, production • management, etc. • Record data at higher TRL testing	UP laboratory
3	1	UGHR CxD Self-diagnostics Test	CxD needs to be able to detect failure modes and fail to safe should a critical failure be present. CxD to continuously monitor system health.	UP laboratory
4	2	UGHR CxD Detection and Tracking Test	CxD must be able to accurately detect pedestrians within the specified detection range and maintain this detection and accuracy for the duration that the pedestrian is within the detection range. CxD logs essential to the successful performance of this test.	Proving ground
5	2	UGHR CxD Effective Warning Test	CxD must warn the operator and pedestrian(s) effectively prior to initiating an automatic slow and stop event	Proving ground
6	2	UGHR CxD Controller Test	CxD algorithm tested by performing choreographed interaction scenarios. Stop gaps, system repeatability and consistency assessed.	Proving ground

Table 6: Underground hard rock TMM CPS TRL4 tests

No.	Phase	Test protocol	Test objective	Test site
1	1	UGHR TMM CPS Interface Test	Confirm that TMM CPS can interface with CxD according to ISO 21815-2:2021	UP laboratory/ OEM site/mine site
2	1	UGHR TMM CPS Log-keeping Test	Logs needed to: • Conduct investigations should an incident occur • Maximise benefit derived from CPS –improved site control, production • management, etc. • Record data at higher TRL testing	UP laboratory/ OEM site/mine site
3	1	UGHR TMM CPS Self-diagnostics Test	TMM CPS needs to be able to detect failure modes and fail to safe should a critical failure be present. TMM CPS to continuously monitor system health.	UP laboratory/ OEM site/mine site
4	2	UGHR TMM CPS Machine Sensing Test	TMM CPS needs to share information with CxD to enhance CxD performance.	Proving ground/ OEM site/mine site
5	2	UGHR TMM CPS Machine Controller Test	TMM CPS needs to implement commands (such as SLOW_DOWN or CONTROLLED_STOP) sent by CxD. This test verifies that the TMM CPS can implement these instructions.	Proving ground/ OEM site/mine site

Table 7: Surface CxD TRL4 tests

No.	Phase	Test protocol	Test objective	Test site
1	1	Surface CxD Interface Test	Confirm that CxD can interface with TMM according to ISO 21815-2:2021	UP laboratory
2	1	Surface CxD Log-keeping Test	Logs needed to: • Conduct investigations should an incident occur • Maximise benefit derived from CPS –improved site control, production • management, etc. • Record data at higher TRL testing	UP laboratory
3	1	Surface CxD Self-diagnostics Test	CxD needs to be able to detect failure modes and fail to safe should a critical failure be present. CxD to continuously monitor system health.	UP laboratory
4	2	Surface CxD Detection and Tracking Test	CxD must be able to accurately detect other TMMs within the specified detection range and maintain this detection and accuracy for the duration that the	Proving ground

			TMMs are within the detection range. CxD logs essential to the successful performance of this test.	
5	2	Surface CxD Effective Warning Test	CxD must warn the operator effectively prior to initiating an automatic slow and stop event	Proving ground
6	2	Surface CxD Controller Test	CxD algorithm tested by performing choreographed interaction scenarios. Stop gaps, system repeatability and consistency assessed.	Proving ground

Table 8: Surface TMM CPS TRL4 tests

No.	Phase	Test protocol	Test objective	Test site
1	1	Surface TMM CPS Interface Test	Confirm that TMM CPS can interface with CxD according to ISO 21815-2:2021	UP laboratory/ OEM site/mine site
2	1	Surface TMM CPS Log-keeping Test	Logs needed to: • Conduct investigations should an incident occur • Maximise benefit derived from CPS –improved site control, production • management, etc. • Record data at higher TRL testing	UP laboratory/ OEM site/mine site
3	1	Surface TMM CPS Self-diagnostics Test	TMM CPS needs to be able to detect failure modes and fail to safe should a critical failure be present. TMM CPS to continuously monitor system health.	UP laboratory/ OEM site/mine site
4	2	Surface TMM CPS Machine Sensing Test	TMM CPS needs to share information with CxD to enhance CxD performance.	Proving ground/ OEM site/mine site
5	2	Surface TMM CPS Machine Controller Test	TMM CPS needs to implement commands (such as SLOW_DOWN or CONTROLLED_STOP) sent by CxD. This test verifies that the TMM CPS can implement these instructions.	Proving ground/ OEM site/mine site

The test protocol is based on the MOSH CPS Guideline testing protocol.

Vehicle Dynamics Group, University of Pretoria

The Vehicle Dynamics Group (VDG) at the University of Pretoria (UP) have established facilities and procedures to test the performance of collision avoidance systems for the local and international mining industry.

The project team engaged VDG which is the only facility in the world that undertakes full system testing. The facility focuses on conducting testing in a safe and controlled environment at TRL 4. VDG tests the entire CPS system functionality and collaborates with other facilities such as Gerotek. The facility has a customer base that covers 30% locally manufactured systems. Approximately 30% of the customers have the capability to rebuild and integrate CPS components.

While the facility provides a controlled testing environment, it also aims to develop protocols that will enable testing that is representative of the real environment. The objective is to gradually develop

capabilities and facilities that will support this endeavour. VDG follows the Minerals Council's MOSH specifications on CPS testing protocols.

The facility undertakes functional testing of CxD and TMM CPS kits from technology manufacturers and TMM OEMs. The testing is broken down into essential components that require testing, and each component is tested according to the test specification.

3.7 Local Manufacturing, Assembly, Insource, and Outsource Capability

This section explains and unpacks the process of identifying key components (and sub-components) associated with CPS technologies/ecosystems based on the current CPS landscape. The identified components are then used as a guide for mapping the capabilities of the automotive and electronics industries. The process is illustrated in Figure 16.

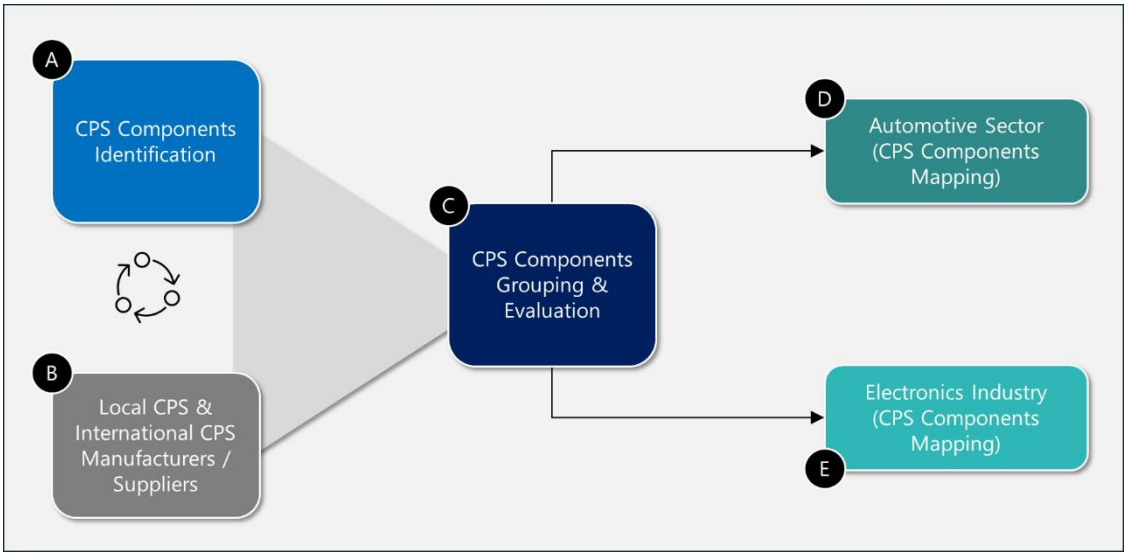

Figure 16: Mapping CPS key components for the automotive and electronic industries

The tasks and activities involved in each step are summarised in Table 9.

Table 9: Steps A-E – description

Process ID	Description
Step A	• Identification of CPS ecosystem components (*Iterative process with step B*) • Identify CPS system components according to the Minerals Council MOSH CPS Guidelines.
Step B	• Identify the various suppliers and manufacturers of CPS components, both local and international
Step C	• In Step C, by grouping together the key components of the CPS ecosystem, a system-of-systems view of the TMM ecosystem was created
Step D	• Application of the core component grouping identified in steps A-C to the automotive industry sector • Map the automotive capabilities to the CPS component ecosystem
Step E	• Application of the core component grouping identified in steps A-C to the electronics industry sector • Map the electronics capabilities to the CPS component ecosystem

STEP A:
The specifications developed by the Minerals Council South Africa (documents referenced: https://www.mosh.co.za/downloads/tm) related to the TMM sector were evaluated and all terms related to CPS components were extracted.

STEP B:
The various suppliers and manufacturers of CPS components were identified, both locally and internationally. The results of the study are presented in Table 10.

Table 10: Local and International CPS suppliers and manufacturers

Company Pseudonym	CPS Components	Description	Country
A	Motor Controllers, Communication Gateways	Electrical and control systems for mobile machine safety	Switzerland
B	CxD Controller, EMC Housing, Calibration Module	Electronic assemblies and integration-ready CPS parts	South Africa
C	Sensor Interface, Data Fusion Hub	Custom integration of sensors and central controllers	South Africa
D	Control Gateway, Test Harness	Specialized in automotive and mining control environments	Austria
E	Digital Twin Platform, Safety Overlay	Supports digital twin modeling for CPS testing	USA
F	Proximity Detection System, CxD Interface, Machine Braking Integration	South African developer offering fully integrated proximity systems for underground mining	South Africa
G	Radar Module, Display, Safety Controller	Advanced control electronics and sensing systems	Germany
H	CxD Interface, Display Systems, Emergency Stop Circuits	Global OEM supporting CPS integration with machine control units	USA
I	Vision Sensors, Machine Vision Analytics	Machine learning-based object detection	USA
J	Radar, Warning System, Power Supply	Specializes in object detection and alert systems for mines	Canada
K	Fleet Telemetry, Operator Alert, Proximity Detection	Offers integrated tracking and safety overlays	South Africa
L	Controller Units, CAN Bus Interfaces	Enables control logic integration for CPS-ready vehicles	Denmark
M	Collision Avoidance, V2X Interface, Operator Display	Provides intelligent solutions for machine-to-machine awareness and control	Sweden

Company Pseudonym	CPS Components	Description	Country
N	CxD Controller, Sensor Boards, Military-Grade Housings	Development of rugged CPS electronics and controllers	South Africa
O	Thermal Cameras, Visual Sensors	Nighttime or low-visibility detection add-ons	USA
P	V2X Communication Platform, Emergency Signaling	Critical communication infrastructure for fleet safety systems	Austria
Q	GNSS Module, Braking Response Integration	Precision GPS and control overlays for safe navigation	USA
R	Data Analytics Engine, Control Interface	Real-time diagnostics and response logic support	USA
S	UWB Tags, Real-time Tracking System	Provides active tracking tags and base stations for CPS	South Africa
T	CxD Controller, Proximity Sensors, Operator Warning System	Provides integrated CxD detection, proximity alert systems and in-cab operator feedback units	South Africa
U	CxD Platform, Sensor Fusion Engine	Merges inputs from multiple sensors for holistic detection	South Africa
V	Radar, Camera, Control Unit	Integrated collision sensing and avoidance modules for heavy machinery	Japan
W	Gas & Proximity Sensors, Operator Alerts	Industrial sensing and safety systems integration	USA
X	Ultrasonic Sensor, Braking Signal Interface	Provides robust sensing solutions for heavy-duty vehicles	Germany
Y	Radar, LiDAR, Sensor Fusion Hub	Advanced spatial detection and safety sensors	Germany
Z	Vision Systems, Camera Controllers	Machine vision and CPS integration electronics	Germany
AA	Machine Braking System, Proximity Sensor Suite	OEM equipment with native support for CPS modules	Japan
BB	EMC Laboratory Tools, Signal Analyzers	Component-level EMI/EMC test tools	India
CC	Cable Systems, EMI Shielded Harnesses	Cabling solutions for noise-sensitive CPS components	Germany
DD	Detection & Tracking, CxD Controller, Pedestrian Tags	Smart tag-based safety and awareness systems	USA
EE	Proximity Detection, Machine Controller, Onboard Displays	High-precision fleet management and collision detection	Australia
FF	CxD Log Keeper, Operator Display, Remote Data Sync	Integrated fleet and safety technology provider	USA

Company Pseudonym	CPS Components	Description	Country
GG	Communication Platform, Proximity Tags	Provides underground communication and CPS integration	Australia
HH	Wide Area Radar, Obstacle Detection	High-resolution radar solutions for harsh environments	UK
II	Sensor Fusion Core, Braking Decision Unit	Military-grade sensor integration tech adapted for mining	USA
JJ	Power Backup, Relay Systems, Telemetry	Redundant power and monitoring systems for CPS safety	UK
KK	Driver Alertness Detection, Interface Module	Fatigue risk management integrated into CPS	Australia
LL	Cameras, Video Displays, Alert Systems	Specialist in ruggedized vision solutions for mining equipment	Netherlands
MM	Radar, Camera, Emergency Control Interfaces	Electronic component supplier with integration-ready units	Japan
NN	Testing Platform, EMC Isolation Box	EMI/EMC testing and readiness platforms	South Africa
OO	Ultrasonic Detection Systems, Interface Modules	Sensing and automation provider for hazardous environments	Germany
PP	Radar Systems, CxD Interface	Heavy-duty radar-based detection solutions	USA
QQ	PDS, Safety Hubs	Dedicated CPS solution provider focused on South African mining	South Africa
RR	EMI Shielding Enclosures, Vibration-Resistant Controllers	Custom enclosures and ruggedized CPS hardware	USA
SS	Proximity Detection, Data Logger, Control Interface	Autonomous vehicle control and safety components	Australia
TT	Full CPS Platform, Training, Maintenance Tools	Provides complete CPS kits for underground and surface mining	South Africa
UU	Radar System, OWS, CxD Display	Compact CPS systems used globally in mining	Switzerland
VV	CxD System, Warning Systems, Brake Control	Automated detection and control subsystems for mining applications	Finland
WW	Proximity Detection Systems, Control Units	Underground mine safety and tracking systems	South Africa
XX	PLC, Safety Relay, Monitoring Interface	Automation and safety control for mining CPS applications	France
YY	Sensor Arrays, Proximity Switches	Supplies components for OEM and retrofit CPS systems	USA
ZZ	LiDAR, Proximity Sensors, Safety Controllers	Industrial sensing specialists with wide adoption in mining	Germany

Company Pseudonym	CPS Components	Description	Country
AAA	Industrial Controllers, Network Interfaces	PLC and fieldbus components for integrated safety	Germany
BBB	Operator Fatigue Monitoring, Data Logger	Physiological monitoring system integrated with CPS alerts	Australia
CCC	Emergency Pneumatic Stops, Logic Controllers	Mechanical fail-safe systems complementing CPS logic	Japan
DDD	Proximity Sensors, Smart Controllers	Advanced sensing solutions repurposed for industrial safety	UK
EEE	LiDAR, Radar, Machine Braking System	Offers advanced sensing and auto-braking integration solutions	USA
FFF	Proximity Control Modules, Brake Integration	Engineering giant offering mining equipment with integrated CPS options	Germany
GGG	GNSS Units, Calibration Tools	Precise positioning systems and diagnostics tools	Japan
HHH	Brake Testing Robot, V2X Module	Testing tools and communication modules for CPS readiness	South Africa
III	LiDAR, GNSS Interface, Braking Overlay	Combines precision GNSS and LiDAR for collision avoidance	USA
JJJ	LiDAR, Radar, Camera Modules	Supplier of smart vehicle environment sensors	France
LLL	RFID Tags, Sensor Fusion Engine	Real-time location and safety assurance systems	USA

The insights and results from the work in STEP B are listed in Table 11 and shown in Figure 17, Figure 18, Figure 19, Figure 20 and Figure 21.

Table 11: Results from study in STEP B

Diagram Description	Figure Reference
CPS Subsystems - Supplier Distribution: The diagram illustrates the CPS subsystem groupings in relation to the number of suppliers supporting the subsystems	Figure 17
Number of CPS Suppliers by Country (based on the subset in the study): The main suppliers and manufacturers by country are shown in this chart	Figure 18
CPS Suppliers by identified subsystem grouping: This chart shows the suppliers and manufacturers grouped by CPS subsystem combinations	Figure 19
Geographic distribution of CPS subsystems: This chart shows the suppliers and manufacturers grouped by CPS subsystem combinations	Figure 20
CPS Suppliers Heatmap by Subsystems:	Figure 21

This heatmap chart shows the suppliers and manufacturers related the subsystem combinations	

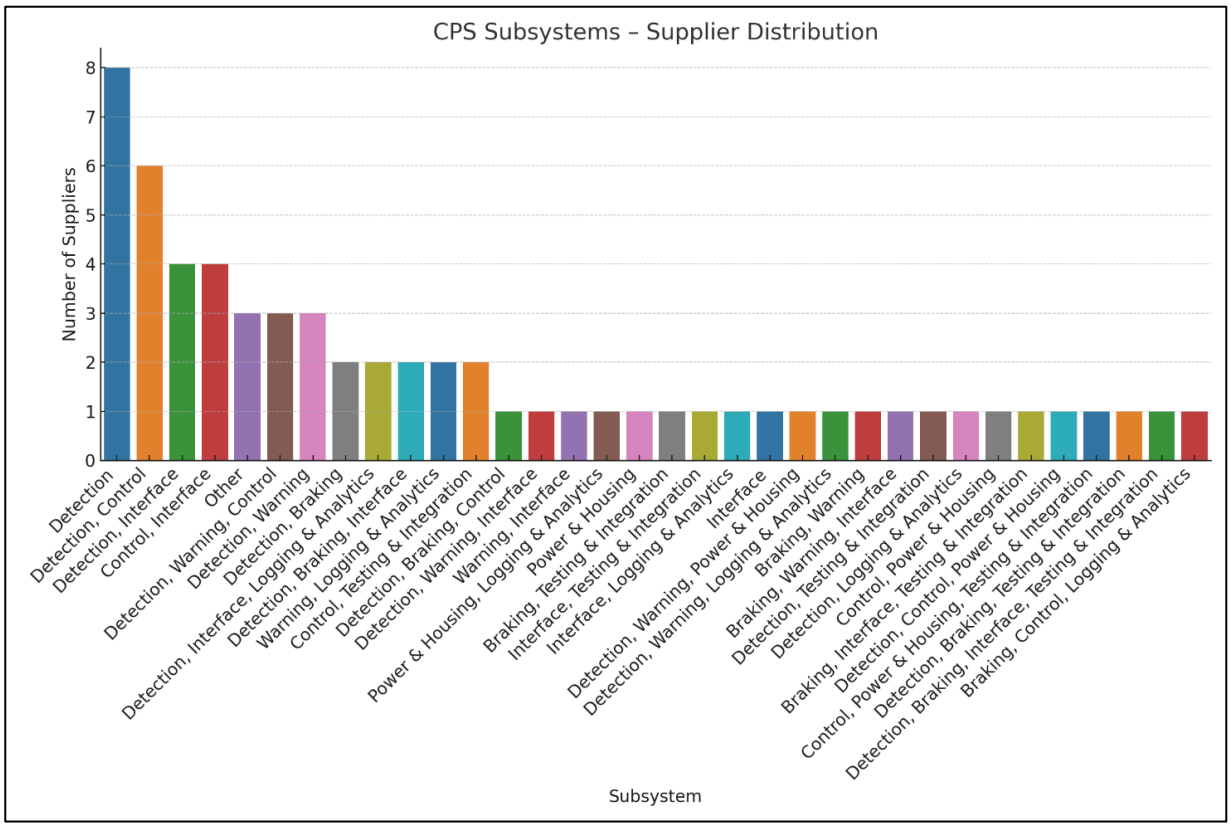

Figure 17: CPS Subsystems - Supplier Distribution

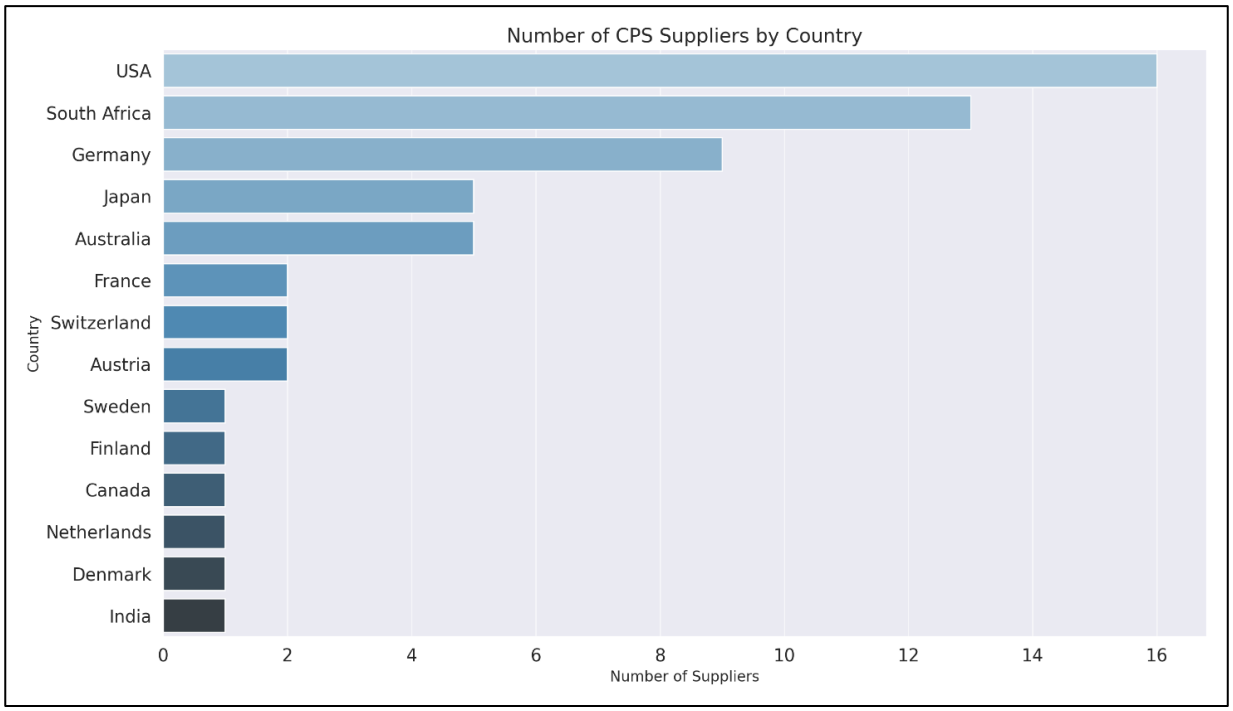

Figure 18: Number of CPS Suppliers by Country (based on the subset in the study)

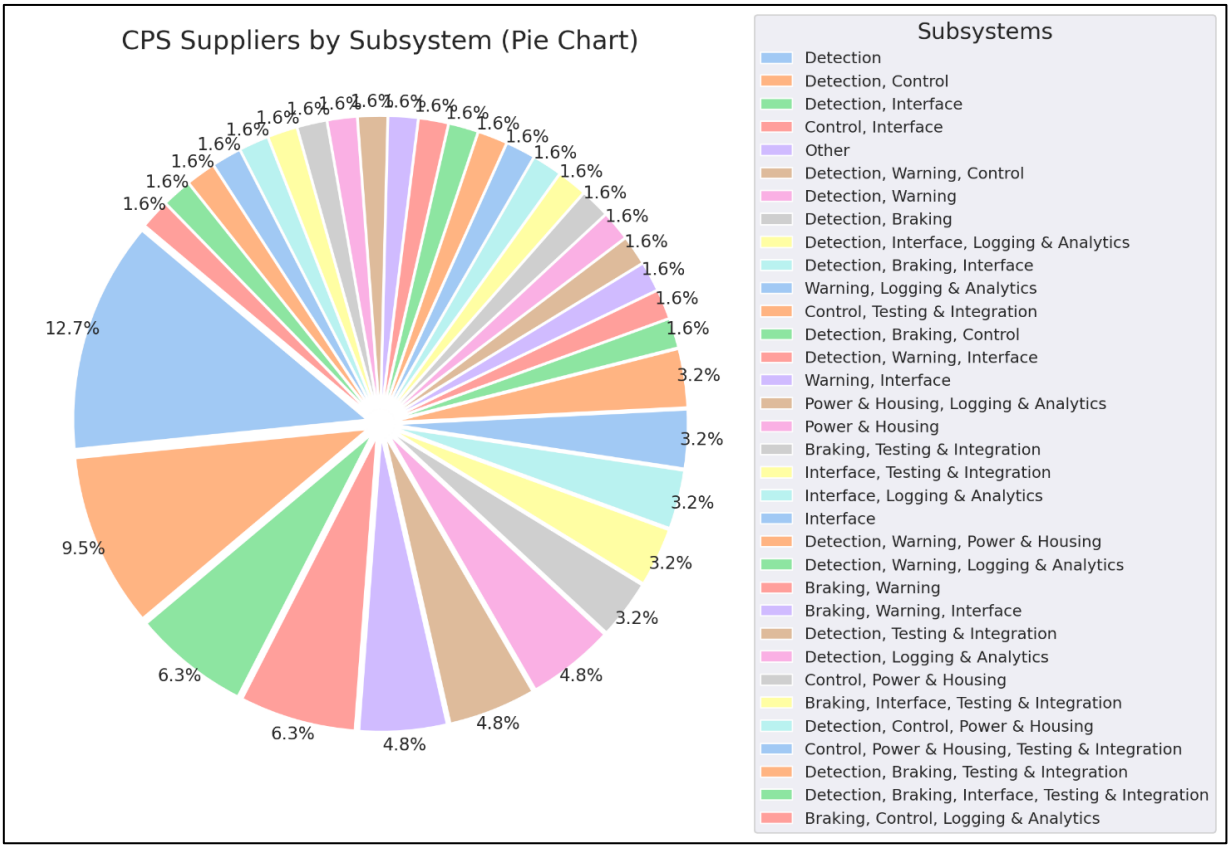

Figure 19: CPS Suppliers by identified subsystem grouping

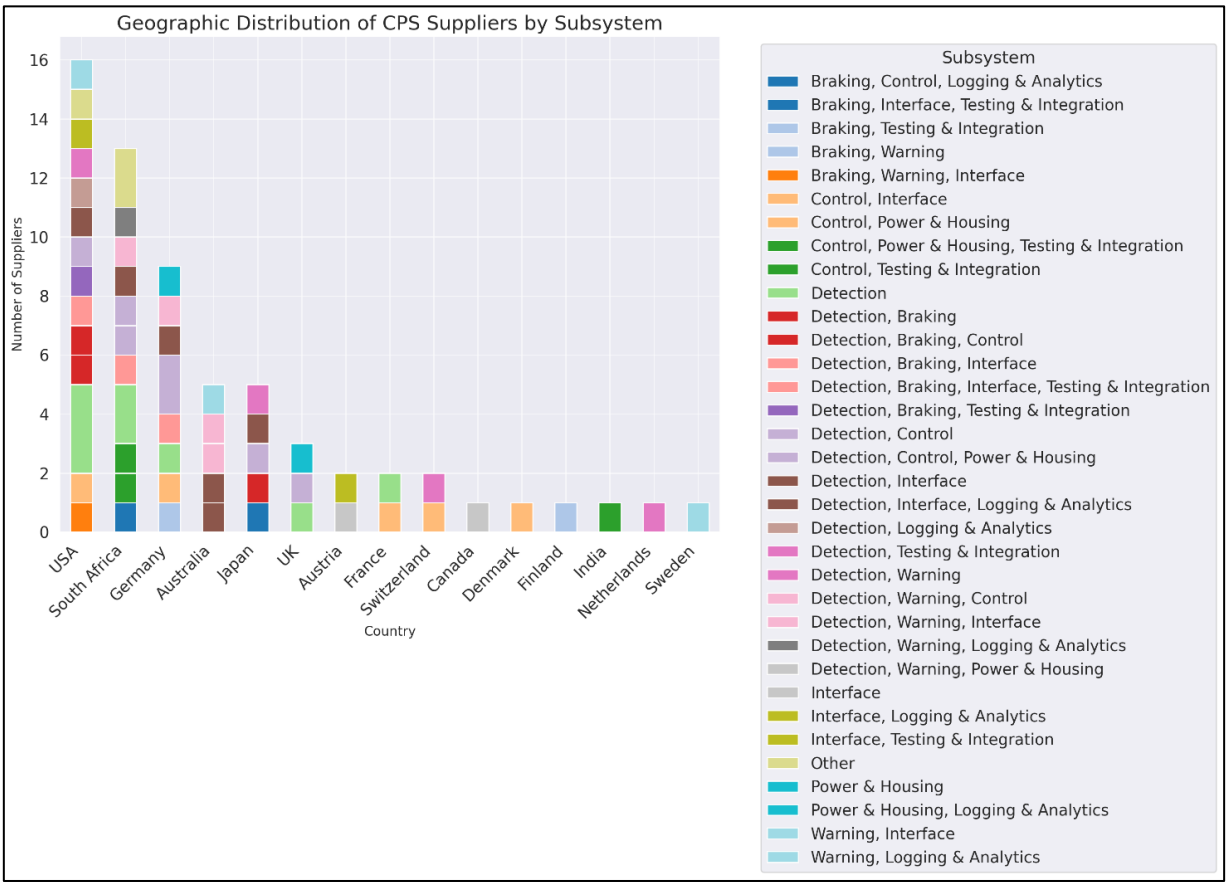

Figure 20: Geographic distribution of CPS subsystems

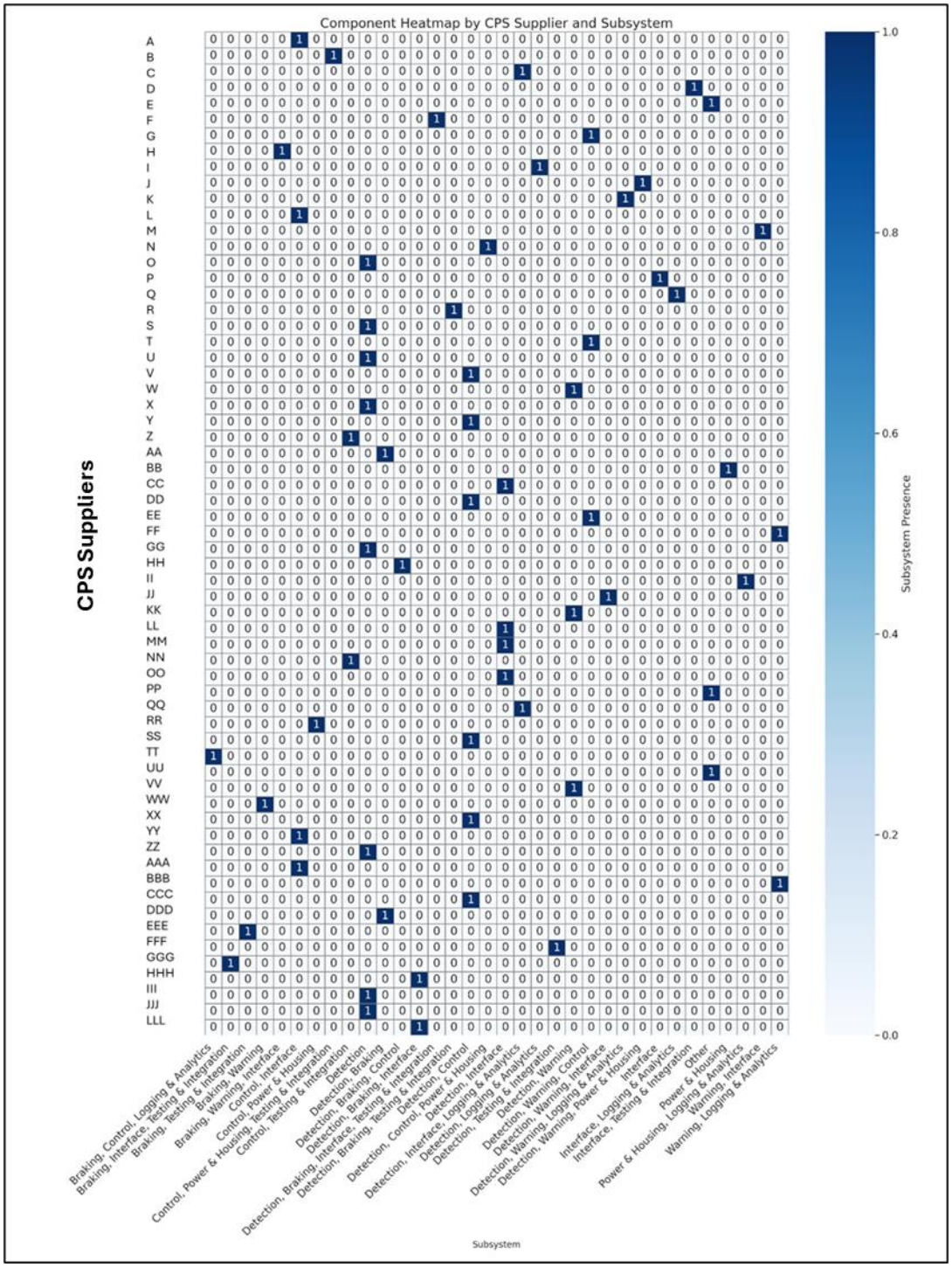

Figure 21: CPS Suppliers Heatmap by Subsystems

STEP C:

From the analysis carried out in STEP A and STEP B, the core CPS components and sub-components were identified and then grouped into a functional system-of-systems ecosystem. The CPS system-of-systems perspectives are shown in Figure 22, Figure 23 and Figure 24.

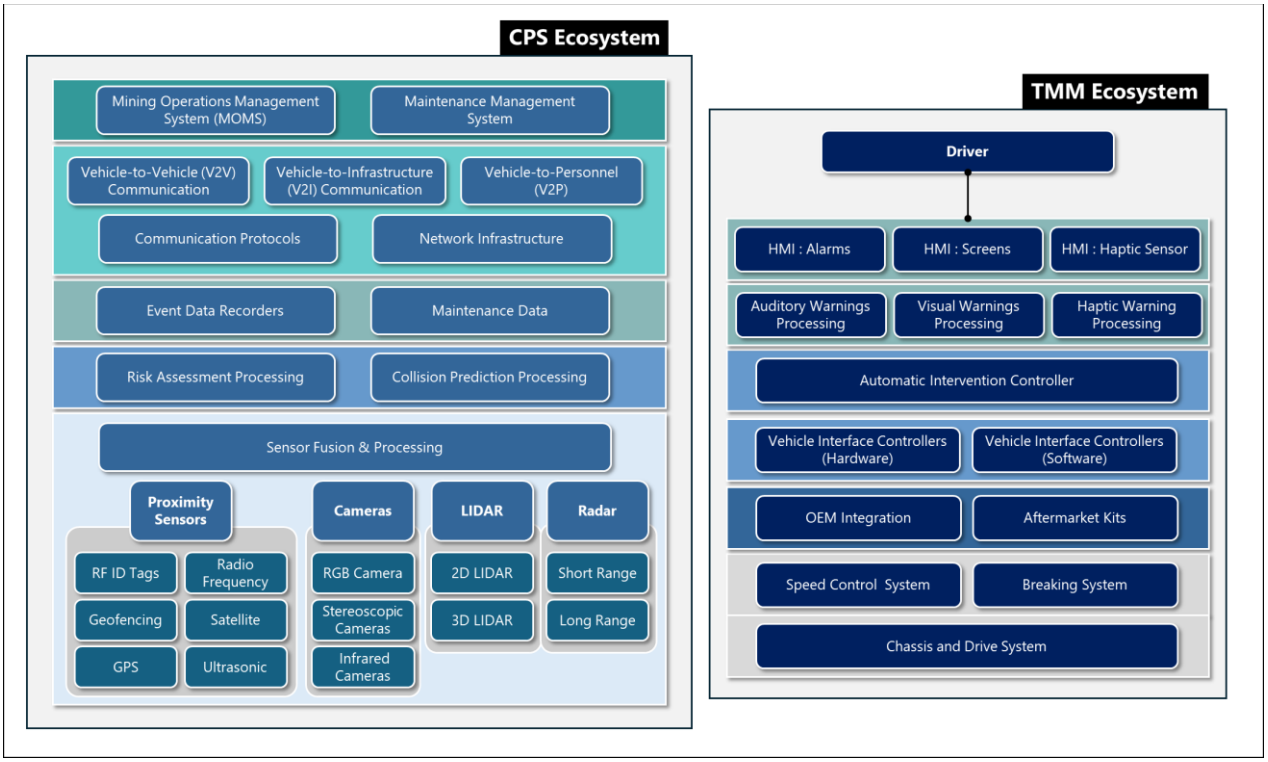

Figure 22: CPS Ecosystem & TMM Ecosystem (in terms of components)

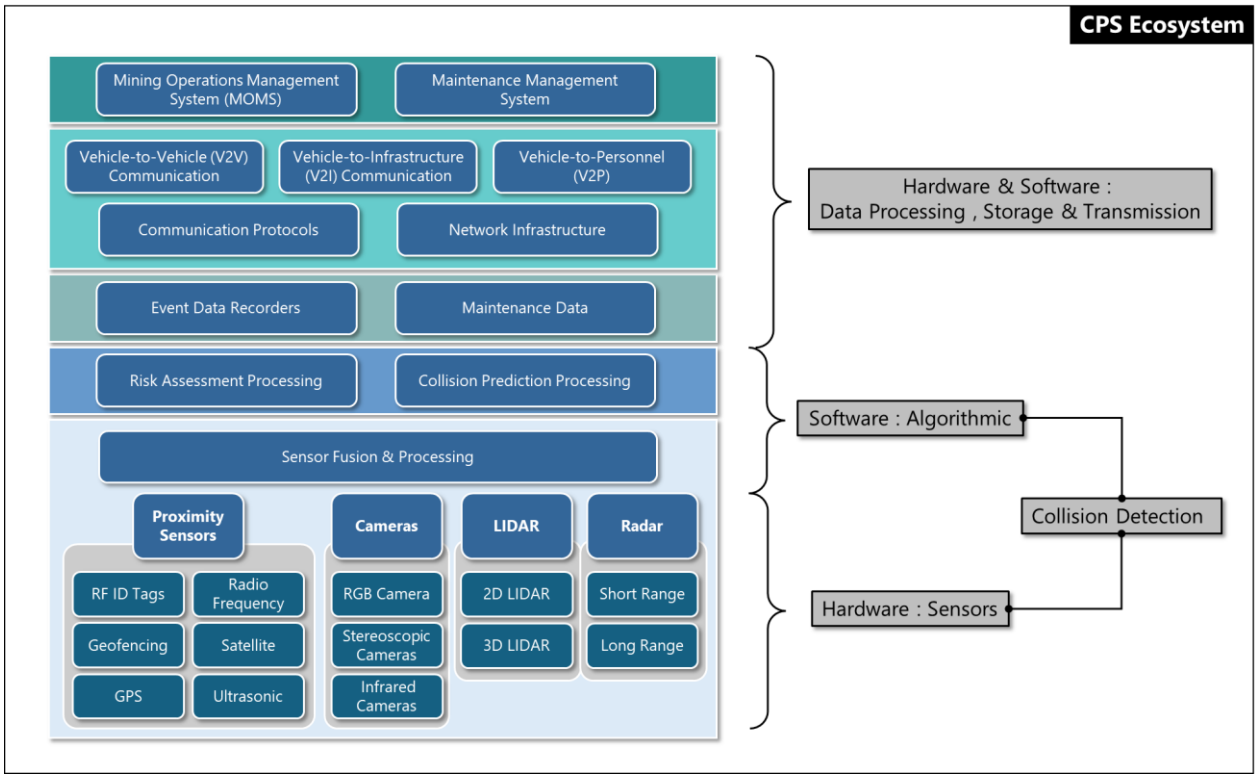

Figure 23: CPS Ecosystem - Hardware & Software Components

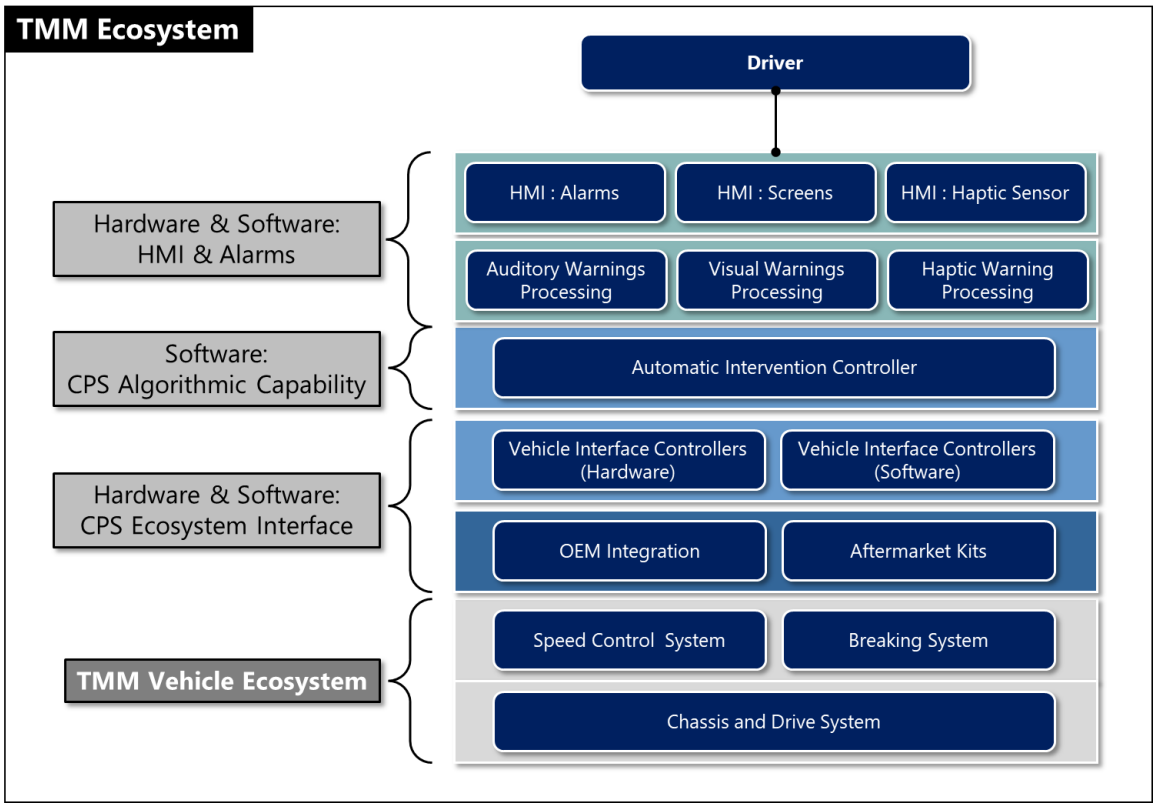

Figure 24: TMM Ecosystem - Hardware and Software Components

The following nine core CPS elements for use in STEP D and STEP E were then identified from the high-level CPS system-of-systems functional study listed in Table 12.

Table 12: Core CPS Components Identified to apply in STEPS D and E

Identified Core CPS Component	Function	Type/Feature
1) Proximity Detection Sensors	Detects objects or vehicles in proximity and generates alerts to prevent collisions	Ultrasonic, radar, LiDAR, GPS-based sensors
2) Radar Systems	Detects objects, measures distance, speed, and direction of obstacles	Short-range and long-range radar
3) LiDAR (Light Detection and Ranging)	Creates a 3D map by emitting laser pulses to identify objects and obstacles	Primarily used in dust-heavy areas
4) GPS Systems	Provides location-based tracking and mapping for spatial awareness	GPS receivers, antennas
5) Vehicle-to-Vehicle (V2V) Communication Modules	Enables vehicles to share real-time location and movement data	Wi-Fi Direct, DSRC
6) Control Unit and Processors	Central unit collects data, processes it, and triggers alerts	High-speed data processing

Identified Core CPS Component	Function	Type/Feature
7) Driver Interface and Alert Systems	Displays real-time alerts with visual and auditory signals	Screens, LEDs, speakers
8) Braking and Control Actuators	Engages brakes or adjusts speed based on CPS alerts	Pneumatic, hydraulic, electric actuators
9) System Software and Analytics Platform	Integrates CPS data, performs data logging, and provides optimisation insights	Cloud integration, real-time data visualisation

STEP D and E:
The section explored South Africa's local manufacturing, assembly, and supply chain capabilities for CPS components. The study identified nine critical CPS components for vehicle collision prevention, along with local companies that currently supply, partially supply, or have the potential to develop these components through targeted investment and capability-building initiatives.

The analysis was based on a refined evaluation of over 250 automotive and electronics companies from national industry databases, aiming to identify suppliers and manufacturers relevant to CPS localisation.

Relevant companies were assessed to determine their suitability to participate in a local CPS value chain. A multi-criteria framework was applied, with key evaluation factors spanning industry classification, business focus, manufacturing depth, quality certifications, and regional presence culminating in geographic mapping, capability profiling, and value-chain roles.

The research drew on multiple sources, including South Africa's automotive industry Original Equipment Manufacturers (OEMs), NAACAM, *Who Owns Whom* reports on the motor vehicle industry, Trade and Industrial Policy Strategies (TIPS) documents, and additional insights gathered through internet research.

3.7.1 Automotive Industry

3.7.1.1 CPS-relevant Automotive Component Manufacturers Geographic Representation

The map-based spatial distribution (Figure 25) illustrates the provincial locations of relevant automotive and component manufacturers with potential to participate in a local CPS value chain. The highest concentration of these companies is observed in Gauteng, followed by the Eastern Cape and KwaZulu-Natal.

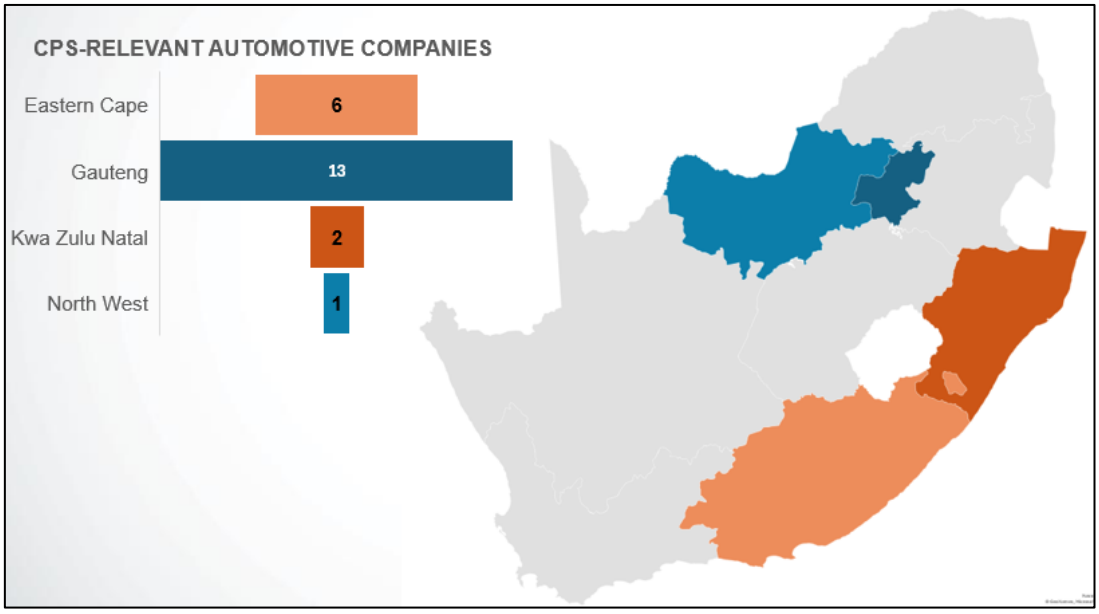

Figure 25: CPS-relevant Automotive Component Manufacturers Geographic Representation

These regions already host established OEM assembly plants and Tier 1 suppliers, making them key anchor points for local CPS component manufacturing ecosystems. Their regional proximity to South African mines reduces logistical complexity and supports the agile production of safety-critical systems.

3.7.1.2 CPS-relevant Automotive Component Manufacturers Value Add Distribution

The bar graph distribution in Figure 26 classifies companies based on their role in the automotive component value chain, spanning:

- OEMs: Companies that design and assemble complete vehicles
- Tier 1 Suppliers: Provide major components or systems directly to OEMs, such as engines, transmissions, and electronic control units
- Tier 2 Suppliers: Manufacture sub-components or specialised parts that are supplied to Tier 1 companies
- Tier 3 Suppliers: Provide raw materials or basic components used further up the supply chain
- Importers and Assemblers: Companies that import and assemble components or systems, often for local vehicle production.

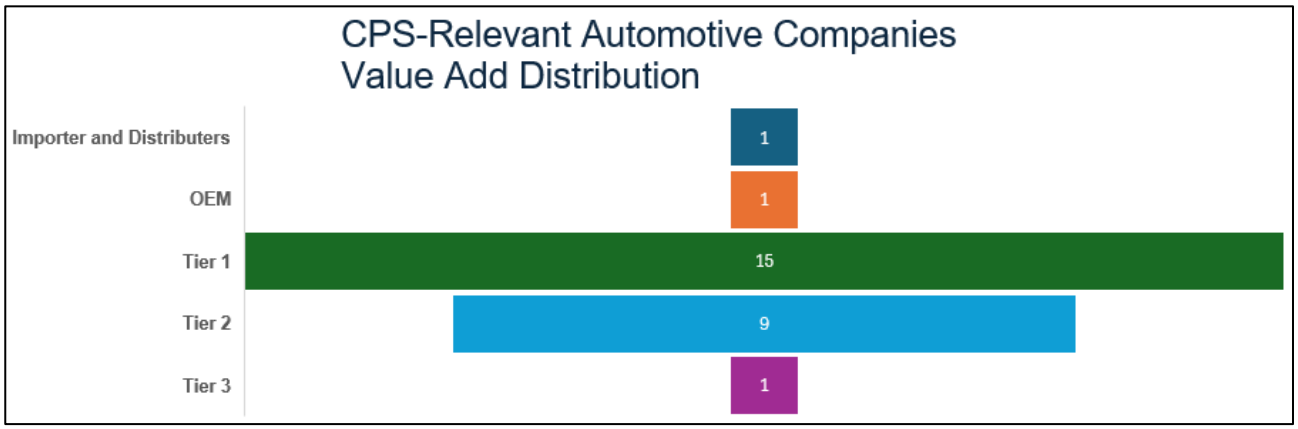

Figure 26: CPS-relevant Automotive Component Manufacturers Value Add Distribution

Approximately 57% of the select local automotive suppliers operate within Tier 1 and sub-assembly manufacturing. The focus was not on OEMs as they are multi-national companies assembling vehicles in South Africa but operating in line with sourcing directives from their foreign headquarters. Thus, while South Africa has a promising component manufacturing base, targeted investment or strategic partnerships may be needed to enhance capabilities in advanced system assembly and software integration.

3.7.1.3 CPS-relevant Automotive Component Manufacturers Categorisation

The bar graph distribution in Figure 27 categorises the identified companies based on their Standard Industrial Classification (SIC) codes (according to the business nature, and technical specialisation). The categories range from the auto salvage sector to service delivery.

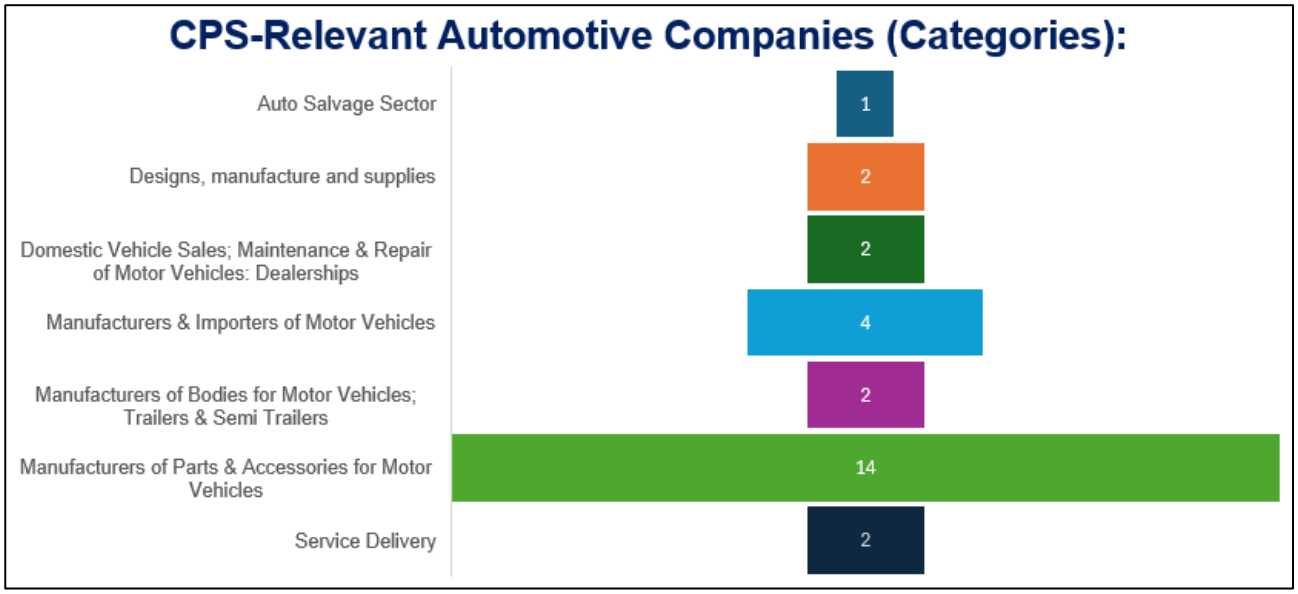

Figure 27: CPS-relevant Automotive Component Manufacturers Categorisation

Further accurate classification is essential for aligning local suppliers with specific CPS component opportunities (see section 3.7.1.5). Companies categorised under *"Manufacturers of Parts & Accessories for Motor Vehicles"* could be key candidates, for example, for localising brake actuation modules.

3.7.1.4 CPS-relevant Automotive Component Manufacturers Quality/Standards Certification

The bar graph distribution in Figure 28 lists companies that hold internationally recognised automotive standards, including but not limited to:

- ISO 9001 – Quality Management
- IATF 16949 – Automotive Quality Management
- ISO 14001 – Environmental Management.

Compliance with relevant standards is a key requirement for entry into global supply chains, especially for safety-critical systems such as CPS. The presence of these certifications indicates that a core group of companies are well-positioned for potential integration into the CPS value chain.

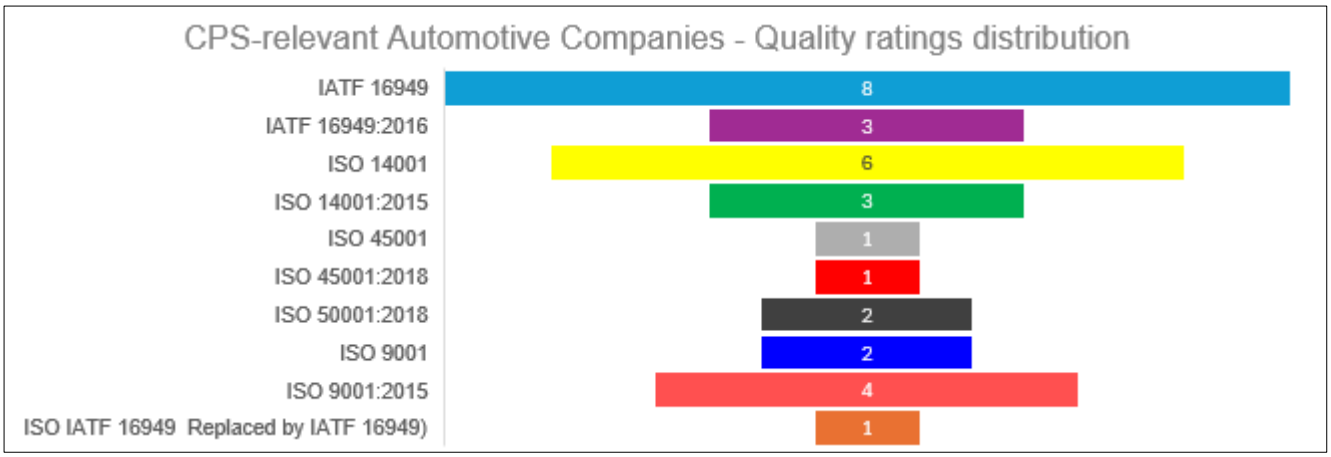

Figure 28: CPS-relevant Automotive Component Manufacturers Quality/Standards Certification

3.7.1.5 Automotive Companies with Potential CPS Components Relevance

Figure 29 features the nine CPS components identified in this work package (ranging from braking and control actuators to vehicle-to-vehicle communication modules) and allocates the relevant companies associated to each component.

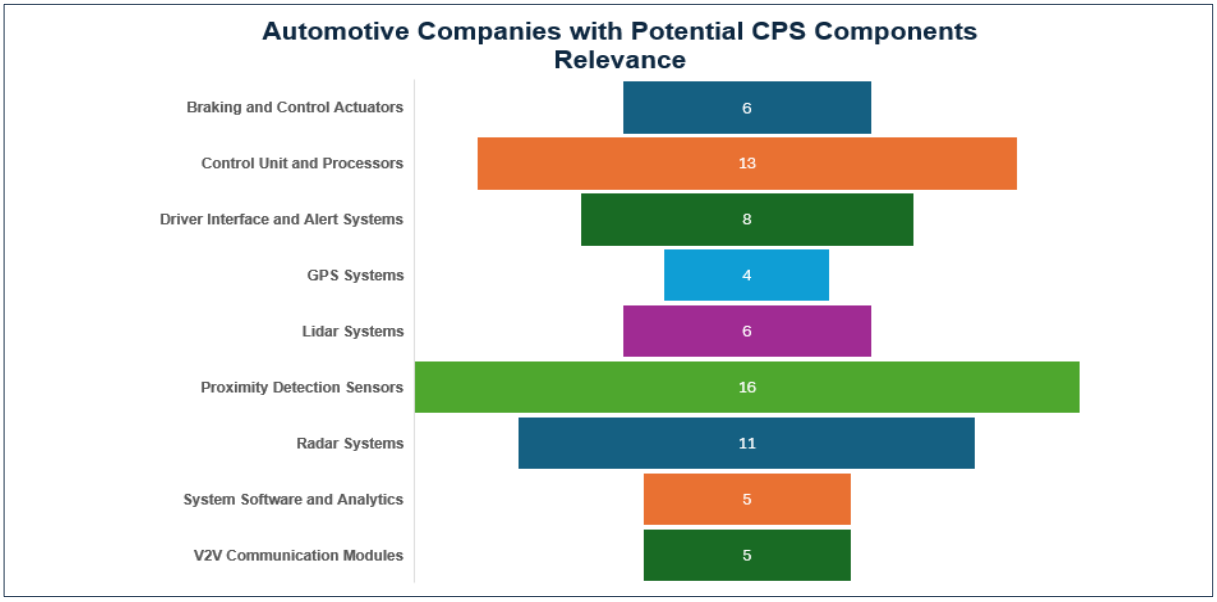

Figure 29: Automotive Companies with Potential CPS Components Relevance

The distribution provides insight into how local suppliers align with these CPS technologies, highlighting prospective manufacturing and integration opportunities. A more detailed table with company-specific information, including their potential CPS application, is presented in APPENDIX A -

3.7.2 Electronics Industry

The electronics industry plays a crucial role in supplying key sub-components for CPS, including radar systems, camera modules, electronic control units (ECUs), and power electronics.

3.7.2.1 CPS-relevant Electronics Component Manufacturers Geographic Representation

Electronic component manufacturers with potential CPS relevance are primarily concentrated in Gauteng as shown in Figure 30. This distribution aligns with South Africa's key ICT and high-tech corridors, focused on innovation and advanced manufacturing.

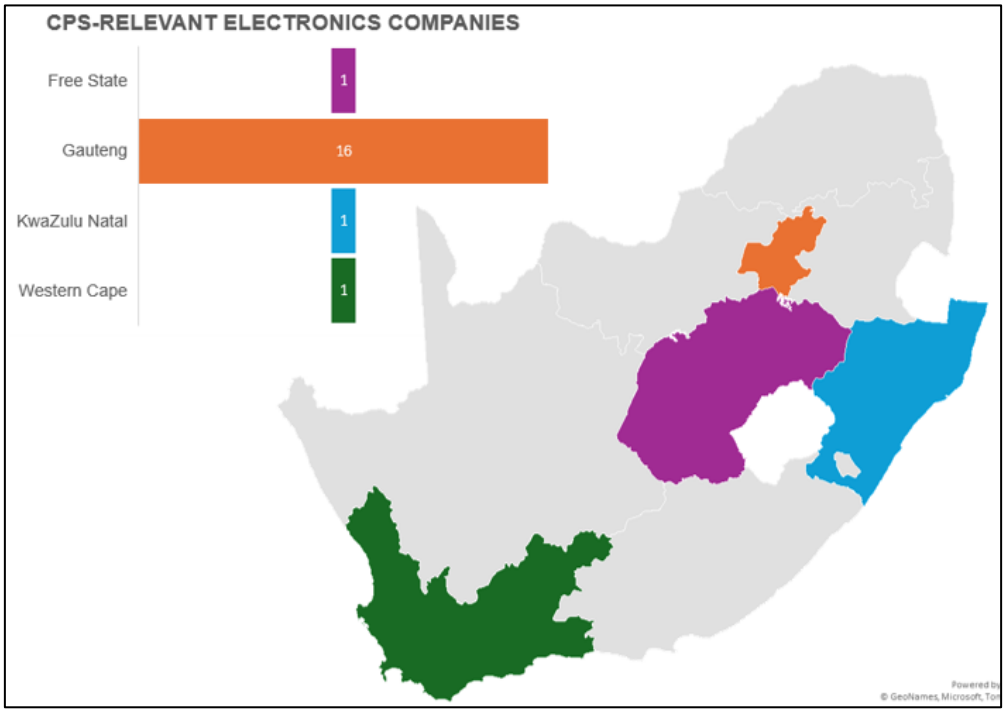

Figure 30: CPS-relevant Electronics Component Manufacturers Geographic Representation

The geographic clustering of these manufacturers supports collaboration and the integration of software and hardware development, enhancing the overall efficiency of the supply chain.

3.7.2.2 CPS-relevant Electronics Component Manufacturers Offerings Categorisation

The bar graph distribution in Figure 31 presents companies based on their electronic capabilities, that align with CPS component requirements. The offering categories range from prototyping and product development to custom electronics solutions.

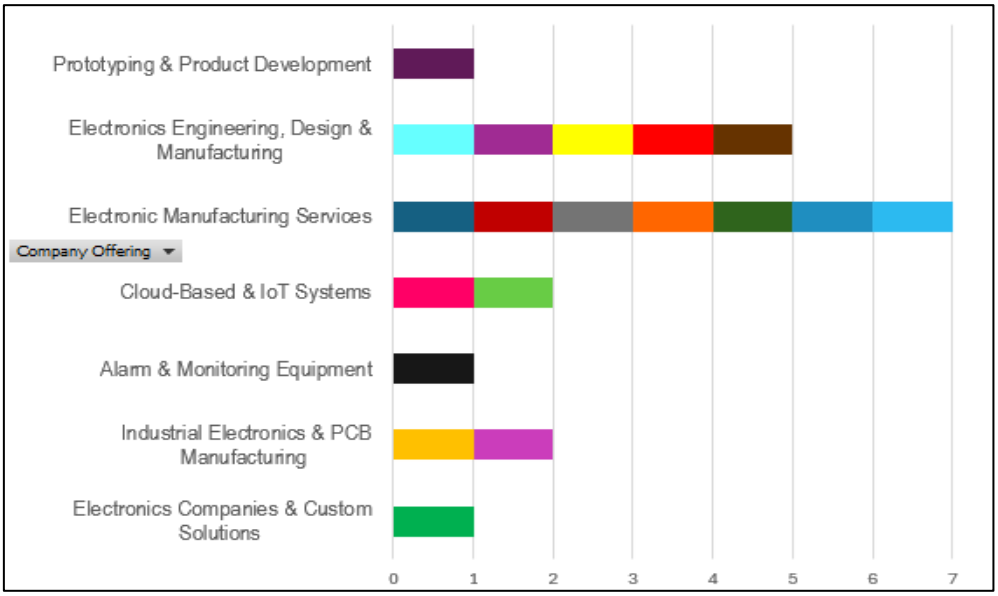

Figure 31: CPS-relevant Electronics Component Manufacturers Offerings Categorisation

This classification ensures that CPS component needs, such as real-time data processing, system integration, and monitoring capabilities, are accurately mapped to supplier expertise, which presents opportunities to explore advancement of local companies in aligned CPS technologies. Electronic design, engineering and manufacturing and related services are the most prevalent offerings across the identified companies.

3.7.2.3 CPS-relevant Electronics Component Manufacturers Product/Service Type Distribution

The bar graph distribution in Figure 32 presents electronics companies based on their product or service types, ranging from IoT and smart devices to sensors and industrial electronics.

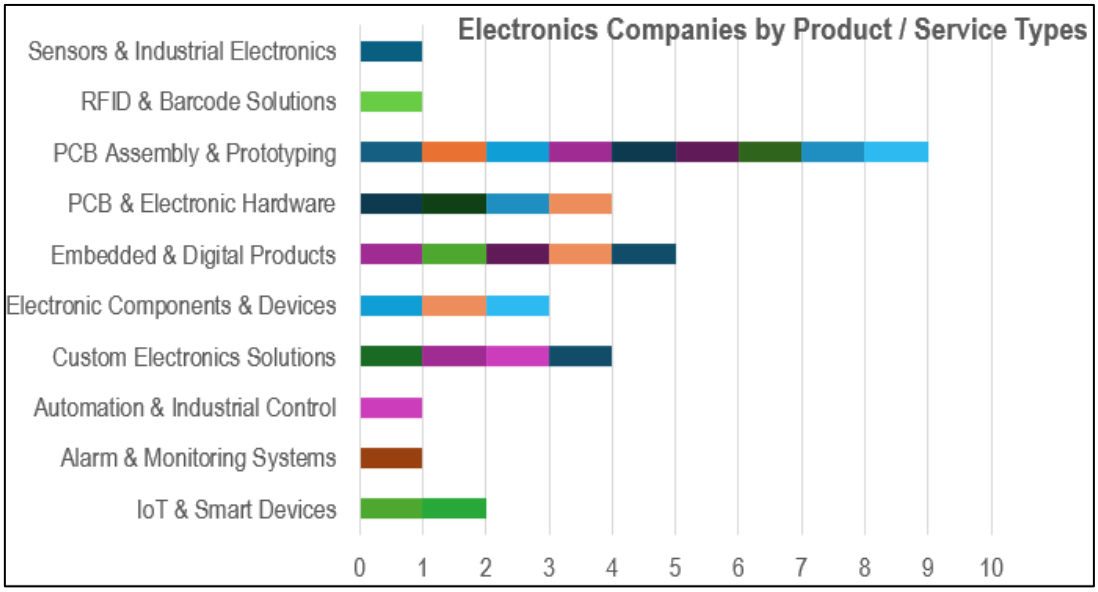

Figure 32: CPS-relevant Electronics Component Manufacturers Product/Service Distribution

From the identified electronics companies, many possess PCB prototyping, electronic hardware, assembly and prototyping, as well as embedded digital products or services. The ability to manufacture and test high-precision electronics locally is critical for CPS localisation.

3.7.2.4 CPS-relevant Electronics Component Manufacturers Quality/Standards Certification

The bar graph distribution in Figure 33 lists companies in the electronics sector based on their adherence to various industry-related standards, including but not limited to:

- ISO 9001: Quality Management Systems
- ISO 14001: Environmental Management Systems
- IPC-J-STD-001: Standard for Soldered Electrical and Electronic Assemblies.

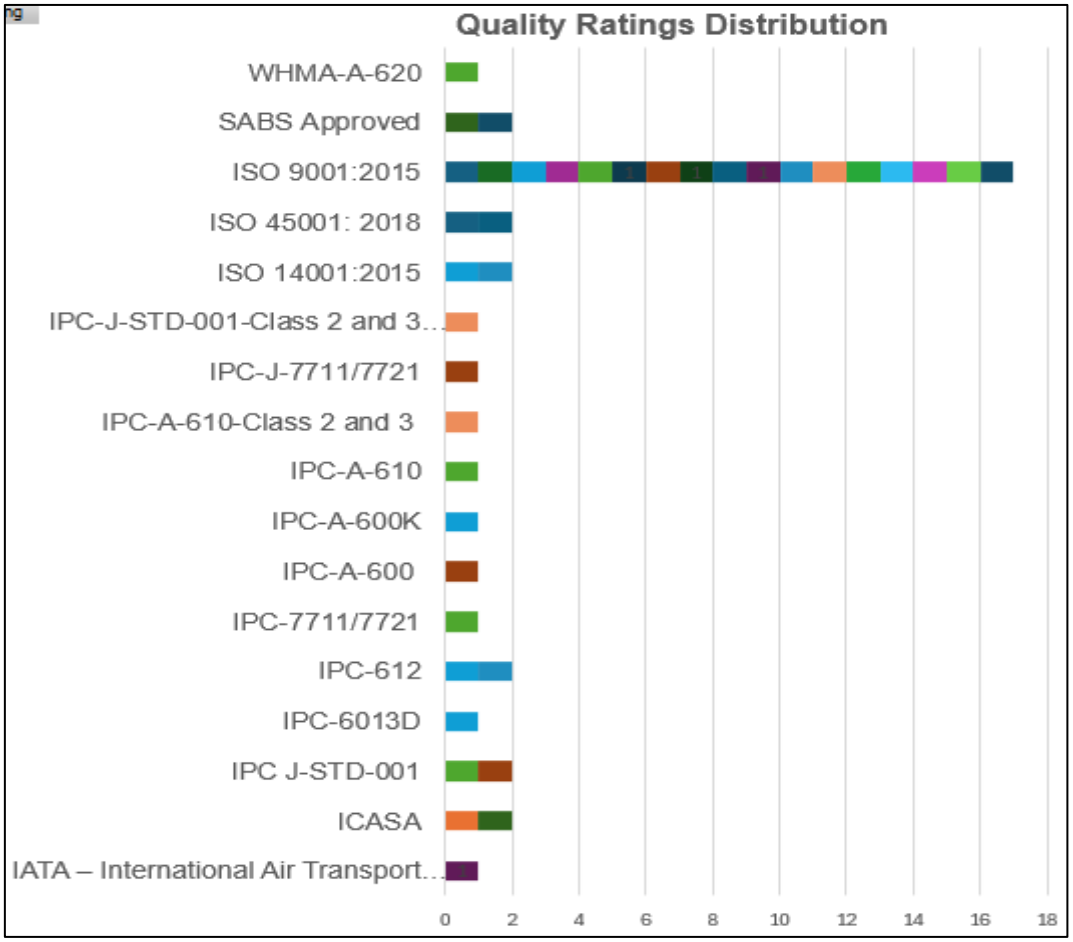

Figure 33: CPS-relevant Electronics Component Manufacturers Quality/Standards Certification

As CPS components are both safety-critical and data-intensive, compliance with relevant standards is essential for ensuring product quality, reliability, and cybersecurity. Adherence to standards positions local companies to meet the stringent requirements for CPS technologies and supports the development of a robust, trusted manufacturing ecosystem.

3.7.2.5 Electronics Companies with Potential CPS Component Relevance

Figure 34 features the nine CPS components and maps companies to the various components based on potential relevance.

This distribution offers insight into how electronics companies align with these CPS technologies, highlighting prospective development, production and integration opportunities. A more detailed table with company-specific information, potential CPS application, is presented in APPENDIX B -

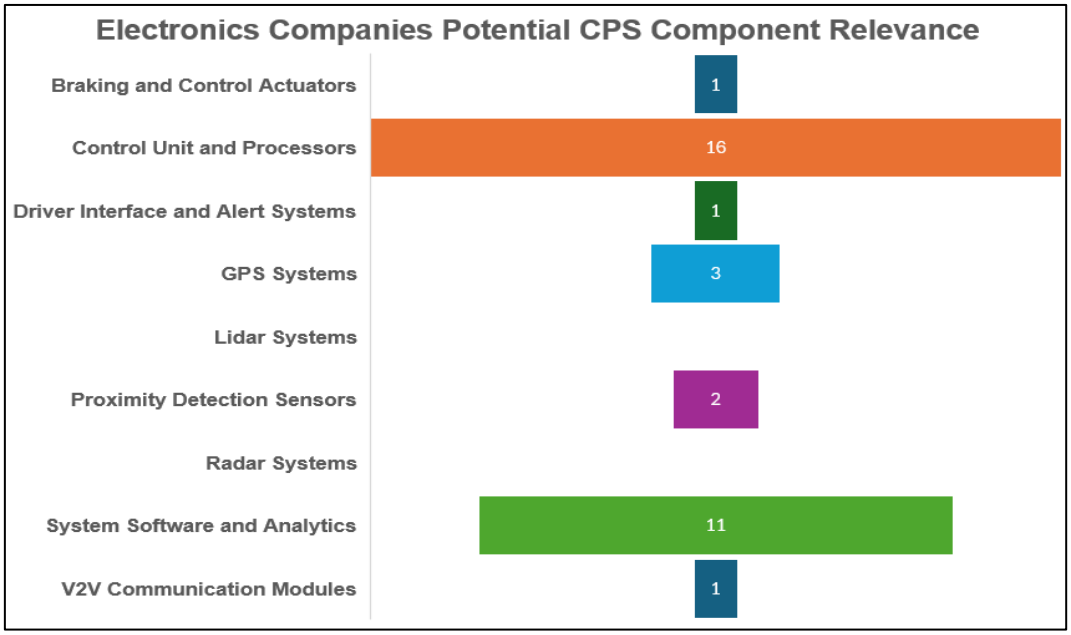

Figure 34: Electronics Companies Potential CPS Component Relevance

3.7.3 In summary

The analysis identified nine critical CPS components as priorities for localisation. Local strengths were found in mechanical and sub-assembly manufacturing, with emerging capabilities in embedded electronics, sensor packaging, and communications modules, whilst current capability in high-end system integration and embedded software development might be sparser. The findings highlight a clear opportunity to develop an insourcing and outsourcing strategy that leverages regional strengths, while addressing capability gaps through technology partnerships, skills development, or OEM support.

3.7.4 Conclusions

Findings from the automotive industry alignment analysis:

- *Technology Parity Exists*
  Core technologies such as LiDAR, radar, Vehicle-to-Everything (V2X) communication, and sensor fusion are already prevalent in the auto sector and directly applicable to TMM CPS systems
- *Common Control Architectures*
  Both domains leverage vehicle interface controllers, Human Machine Interfaces (HMIs), and intervention logic, enabling reuse of platforms and components
- *Opportunity for Product Diversification*
  CPS development in mining presents an added market for the automotive industry and Tier 1–2 suppliers
- *Scalable Supply Chains*
  Automotive suppliers offer established, scalable manufacturing and integration capabilities for sensors, embedded systems, and HMIs
- *Need for Harsh Environment Adaptation*
  Auto-grade components require modifications to withstand mining-specific challenges such as dust, vibration, and temperature extremes.

3.7.5 Recommendations

Suggested next steps should include engaging the automotive and electronics industries regarding:

- *Strategic Partnerships*
  Facilitate collaboration between mining OEMs and auto suppliers to co-develop ruggedised CPS solutions
- *Technology Transfer Programs*
  Leverage lessons from Advanced Driver-Assistance Systems (ADAS) and autonomous vehicle programs to accelerate mining CPS development
- *Standards Alignment*
  Work toward harmonising communication protocols (such as V2X, controller area network, and ethernet) and safety standards to reduce integration friction
- *Joint Innovation Platforms*
  Establish industry consortia and R&D initiatives focused on CPS for off-highway vehicles and mining use cases
- *Aftermarket Kit Development*
  Encourage auto suppliers to design modular retrofit CPS kits to support mixed-fleet mining operations

4 CPS LOCALISATION OPPORTUNITIES

4.1 Categorisation Correctness of CPS Localisation Opportunities

The Terms of Reference provided by the Minerals Council identified 12 CPS components for potential localisation, either through local manufacture, local assembly, or local outsource-insource. These opportunities were provided in two categories, namely local manufacture and local assembly.

A desktop review and unpacking of these opportunities was conducted in terms of localisation approaches, outsource supply chain issues, local manufacturing opportunities, and local outsource-insource opportunities.

Table 13 and Table 14 contain the results of this review for the manufacturing and assembly opportunities respectively.

Table 13: Review of CPS Local Manufacturing Opportunities

Technology	Localisation Approaches	Outsource Supply Chain Issues	Local Assembly Options	Local Outsource-Insource Opportunities
CxD Test Station	Enable decentralised local build of test platforms with plug-and-play features	Imported diagnostics boards and comm modules still required for advanced tests	1. Assemble test boards and UI panels at regional tech hubs 2. Integrate power units, switches, and test wiring locally 3. Pre-load diagnostic software and verify firmware in SA 4. Install plug-and-play components in local enclosures 5. Conduct local calibration, inspection, and certification	1. Outsource PCB fabrication and insource full unit assembly 2. Use third-party diagnostics sensors, integrate locally with power systems 3. Outsource interface touchscreen dev and insource housing integration 4. Work with contract manufacturers for wiring harnesses 5. Combine global protocol converters with local data loggers
Semiconductors	Promote SA-based system integration and component handling	Chips and analogue components imported with long lead times	1. Assemble sensor and control boards using local surface mount technology (SMT) services 2. Conduct local testing and validation of completed boards 3. Mount heat sinks and apply protective coatings in SA 4. Build modules combining sensors and embedded controllers 5. Apply localised firmware and labelling pre-delivery	1. Outsource chipsets, insource module and board integration 2. Use local PCB populators to reduce import assembly 3. Partner with microelectronics labs for test and validation 4. Outsource high-speed layout design, insource final board testing 5. Outsource enclosure design, insource semiconductor board casing
Control system wiring	Create SA-based wire shops for bundling, routing, and termination	Specialty wires and insulation materials sourced internationally	1. Cut, crimp, and label wires at local assembly shops 2. Bundle harnesses to standard lengths and formats 3. Mount terminal blocks and organise wiring looms 4. Conduct electrical integrity and insulation testing 5. Prepare installation kits with routing schematics	1. Outsource wire insulation and colour coding, insource final cut/crimp 2. Use third-party panel shops for base routing, insource PLC integration 3. Outsource wire design schematics, insource execution 4. Collaborate with OEMs for pre-cut stock, finish in SA 5. Joint ventures with vocational schools to build wire looms

Technology	Localisation Approaches	Outsource Supply Chain Issues	Local Assembly Options	Local Outsource-Insource Opportunities
Nuts and bolts	Local kitting and QA for fasteners, including customisation options	Corrosion-resistant alloys still imported	1. Sort and pack fasteners for machine-specific kits 2. Apply anti-rust or protective coatings in SA 3. Label and bag units per mining specifications 4. Customise torque specs and QA tags on-site 5. Integrate kits into broader mechanical assemblies	1. Outsource material sourcing, insource kitting and QA 2. Contract coating services while managing labelling locally 3. Outsource kit design and insource final assembly for dispatch 4. Partner with small hardware vendors for mixed-source kits 5. Use imported blanks and finalise in SA with packaging
Back-up battery	Focus on local battery management system (BMS) integration, pack casing, and wiring	Cells and fire-retardant wraps imported, slow delivery	1. Assemble battery packs and wire BMS units in SA 2. Mount and secure cells with vibration-proof support 3. Connect terminals and test charge/discharge performance 4. Encapsulate in locally made rugged enclosures 5. Apply compliance labelling and firmware updates locally	1. Outsource battery cells, insource assembly and BMS wiring 2. Partner with local firms for thermal packaging 3. Outsource firmware design, insource QA and load balancing 4. Use third-party cycle testers, insource verification 5. Import fireproof insulation, assemble packs in regional hubs
Enclosure	Enable local customisation and integration of electronics	Imported seals and locking mechanisms with quality variance	1. Drill and finish plastic or metal enclosures locally 2. Integrate internal electronics and wiring 3. Seal, label, and mark enclosure components 4. Conduct ingress testing and enclosure integrity check 5. Package and prepare units for mine-specific use	1. Outsource gasket and seal manufacturing, insource final assembly 2. Use third-party powder coaters, perform mounting in-house 3. Outsource CAD design, insource CNC/machine finishing 4. Work with enclosure shell suppliers, integrate tech locally 5. Mix imported locks with SA-made chassis and covers

Table 14: Review of CPS Local Assembly Opportunities

Technology	Localisation Approaches	Outsource Supply Chain Issues	Local Manufacturing Opportunities	Local Outsource-Insource Opportunities
Complete TMM Machine Controller	Design and manufacture controller units within SA to meet mining safety requirements	Dependence on imported microprocessors, sensors, and embedded modules	1. Fabricate controller chassis using local CNC and metal forming 2. Design and print PCBs using SA-based PCB facilities 3. Manufacture cable harnesses and panel mounts in SA 4. Produce ruggedised casing components and brackets locally 5. Localise firmware and safety interlocks for mine compliance	1. Outsource chipset procurement and insource PCB and housing manufacture 2. Partner with OEMs for high-level design, localise final builds 3. Outsource compliance testing to labs, insource firmware development 4. Import edge computing modules (microprocessors & other chipsets) locally integrate with CPS software 5. Use local harness makers while importing specialty connectors
CPS-ready Cap Lamp Test Station	Develop SA-specific testing platforms with modular architecture	IoT modules and high-accuracy sensors may be imported	1. Manufacture station frames and support locally 2. Develop switchboards and wiring panels in SA 3. Produce mounts and LED indicators via local suppliers 4. Print casings and control panels using 3D printing in SA 5. Build power regulation and status indicator boards locally	1. Import sensors and insource control panel production 2. Use global IoT platforms while assembling casings and displays locally 3. Outsource software logging design, insource hardware production 4. Partner with test labs to co-design but manufacture in SA 5. Outsource PCB layout, manufacture and populate locally
CxD Test Station	Focus on modular test infrastructure with locally built components	Import dependency for diagnostic integrated circuits (ICs), ports, and connectivity boards	1. Fabricate enclosures with modular access in SA workshops 2. Manufacture panel controls and overlays locally 3. Build switchgear and power distribution components 4. Print and populate interface PCBs for diagnostics 5. Develop protective packaging for mobile deployment	1. Outsource diagnostic chips, insource board production 2. Use imported rugged components but assemble enclosures in SA 3. Partner with test service providers for modular plug-in interface design 4. Insource all metalwork and outsource firmware for test diagnostics 5. Localise software dev and outsource advanced sensor sourcing

Technology	Localisation Approaches	Outsource Supply Chain Issues	Local Manufacturing Opportunities	Local Outsource-Insource Opportunities
Semiconductors	Enable basic semiconductor testing, and system-level integration		1. Test ICs in SA 2. Assemble embedded boards with logic controllers and filters 3. Manufacture auxiliary circuitry such as buffers and relays 4. Build test jigs and automated quality inspection tools	1. Outsource die fab, insource board-level integration 2. Partner with CSIR/MINTEK for design and outsource validation 3. Insource mixed-signal circuit design, outsource test automation
Display Screens	Integrate rugged displays with local support systems and protective interfaces	Lack of domestic thin film transistor (TFT) and organic light-emitting diode (OLED) production and controller ICs	1. Build display housings and sunshields in local workshops 2. Print and assemble interface PCBs for touch inputs and backlight control 3. Manufacture anti-glare protective coatings and screen filters locally 4. Localise display software interfaces and firmware logic 5. Fabricate brackets and adjustable mounts in SA	1. Import screen units, insource protective enclosure manufacture 2. Outsource UI theme design, embed and test locally 3. Use offshore screen drivers, integrate with SA control systems 4. License visual HMI tools and localise interface boards 5. Combine imported control ICs with locally fabricated PCBs
Sensor Integrated Closed Circuit Television (CCTV)	SA-assembled systems integrating commercial sensors into CPS	LiDAR, mm Wave, and IR sensors mostly imported with firmware locked	1. Manufacture rugged enclosures and sensor housings in SA 2. Design and print signal processing PCBs using local suppliers 3. Build local power management and filtering modules 4. Produce modular sensor mounts and interface brackets 5. Develop custom embedded software to unify sensor data	1. Outsource sensor chipsets, insource PCB and logic integration 2. Combine foreign sensing stacks with local algorithm development 3. Outsource calibration tools, insource all housing and power logic 4. Build regional test rigs and outsource global benchmarking 5. License AI models for signal processing, embed locally

Using the information produced during the review and unpacking process, and through direct engagement with players in the CPS ecosystem, assessments were conducted on the 12 CPS opportunities identified for local manufacture and assembly. These assessments are included in Table 15 and Table 16.

Table 15: Assessment of CPS Local Manufacture Opportunities

Local Manufacture Opportunity	Assessment
Complete TMM Machine Controller	The TMM machine controller is an electronic control system, that accepts inputs from the vehicle and the CxD, analyses the data to detect potential collisions and issues commands to the embedded TMM control systems via a CAN bus connection. The controller would typically include rugged enclosures, cables, cable connectors, printed circuit boards, battery, and display screen. A range of machine controllers are already being produced by local CxD companies in conjunction with local suppliers and contract manufacturers. This local production includes the following aspects. • Proprietary design printed circuit boards using imported PCB substrates • Printed board assembly using the above PCBs and locally sourced imported electronic and electro-mechanical componentry • Module production using the assembled PCBs, locally sourced imported enclosures, batteries, screens and other electromechanical parts.
CPS-ready Cap Lamp Test Station	The CPS-ready cap lamp test station can be used to test cap lamps at the end of production in the factory, and at the mines before taking the lamp into service and on returning from service. It can test the illumination output and modes, as well as any additional functionality assigned to the lamp. The test station would typically include a test station casing, cables, cable connectors, printed circuit board, indicators and power supply. Additional functionality could include data capture and reporting functions and display screen. The CPS-ready cap lamp test station could be locally designed and manufactured using locally made housings, PCBs and other locally available but imported components.
CxD Test Stations	The CxD test station offers the functionality of testing CxD modules, equipment and complete systems. The testing of complete systems would typically entail a dedicated industry test facility that would enable manufacturers, mines and certification bodies to test: • Functionality • Performance of the system against specifications and the regulations or manufacturers performance claims • Other aspects such as electromagnetic compatibility against international standards. Such a dedicated complete system test facility for the industry, possibly co-located with Gerotek, UP, or any other independent testing facility. A second approach is the deployment of manufacturer specific test stations for use at the mines. This would typically include test jigs and fixtures, purpose designed electronic interfaces and computerised test systems controllers. These could be used to test (go/no go) the functionality of individual system components such as machine controls, tags and sensors, to assist with site monitoring and maintenance.

Local Manufacture Opportunity	Assessment
Semiconductors	Semiconductors are the electronic circuits found on the assembled PCBs. These could include discrete components such as power transistors, commonly used integrated circuits, microprocessors and other programmable devices. In South Africa, South African Micro-Electronics Systems (SAMES) produced specialised semiconductors in the past, during the period 1979 - 2009. However, production has been moved to China. It is unlikely to be able to localise the semiconductors due to the wide variety of devices, the relatively small volumes, rapid technological development and high investment costs.
Display Screens	Display screens are used in many of the CPS devices and systems. These can also be classed as a special case of semiconductor, and the market is dominated by large global entities. Display screens are typically LED or LCD screens used for displaying in-cabin information, feedback and visual warnings, as well as computer monitors used in the centralised tracking and reporting systems. South Africa does not have a history of producing display screens. As for semiconductors, localising display screens are unlikely due to the wide variety of devices, the relatively small volumes, rapid technological development and high investment costs.
Sensor Integrated Circuits	Sensor integrated circuits could encompass a variety of sensors such as Radar, LiDAR, RFID, ultrasonic, cameras, etc. These are also semiconductors. As for semiconductors and display screens, localising sensor integrated circuits is unlikely due to the wide variety of devices, the relatively small volumes, rapid technological development and high investment costs.

Table 16: Assessment of CPS Local Assembly Opportunities

Local Assembly Opportunity	Assessment
Complete TMM Machine Controller	The TMM machine controller is an electronic control system, that accepts inputs from the vehicle and the CxD, analyses the data to detect potential collisions and issues commands to the embedded TMM control systems via a CAN bus connection. The controller would typically include rugged enclosures, cables, cable connectors, printed circuit boards, battery, and display screen. A range of machine controllers are already being manufactured and assembled by local CxD companies in conjunction with local suppliers and contract manufacturers. This local production and assembly include the following aspects. • Proprietary design printed circuit boards using imported PCB substrates • Printed board assembly using the above PCBs and locally sourced imported electronic and electromechanical componentry

Local Assembly Opportunity	Assessment
	• Module production using the assembled PCBs, locally sourced imported enclosures, batteries, screens and other electromechanical parts.
Semiconductors	This generally refers to thick film hybrid circuit assembly, where un-capsulated integrated circuits are directly bonded and connected to a thick film substrate. The links between components and some of the components are printed onto the substrate. This technology is suitable for high reliability and extreme environmental conditions and is often used in the production of sensors. There is one thick film producer in South Africa. It is unlikely to be able to localise the semiconductors due to the wide variety of devices, the relatively small volumes, rapid technological development and high investment costs.
Control System Wiring	The control system wiring is used to supply power and electrically connect control system modules as well as to connect sensors to the control system, and the control system to the TMM CAN bus. The cabling is equivalent to the vehicle nervous system, and extreme levels of reliability are required to ensure reliable CPS operation. Thick cables are used to connect power, whilst the rest of the connections could be classed as data connections requiring thinner cabling. Data connection may need to be shielded from electromagnetic interference. There are extensive design and engineering requirements due to the harsh environment (temperature, vibration, impact and moisture). This results in the selection of high specification cables, connectors, cable coverings and fixings. Assembly of automotive wiring harnesses already takes place in South Africa. It should be a relatively simple task to expand to include CPS wiring using the specified cabling and connectors.
Nuts and Bolts	Nuts and bolts are low value, non-critical, and readily available items, and many different variants are used in the production of CPS systems. There are local manufacturers and suppliers of nuts and bolts, from whom these items could be sourced.
Back-up Battery	A battery typically contains more than one cell. Various types of batteries are used in the different CPS systems and products, most of which use lithium-ion chemistry. There are several battery assemblers in South Africa that could be approached to undertake the assembly of specific batteries. There are no producers of lithium-ion cells in South Africa, probably due to the current relatively small market in relation to the investment costs. Notwithstanding this, the local production of lithium-ion cells, and the local assembly of lithium-ion batteries could be investigated considering the future demand relating to CPS products.
Enclosures	Each CPS system incorporates several enclosures to house the various modules such as pedestrian tags, mobile tags, machine controllers, fatigue monitors, display screens and sensors. In addition to the basic function of housing components, the enclosures also embody the style and appearance of the system.

Local Assembly Opportunity	Assessment
	Depending on the model, the enclosure could be some form of plastic, metal or composite material. There are extensive design and engineering requirements due to the harsh mining environment (temperature, vibration, impact and moisture) in which CPS systems need to operate. Off the shelf enclosures could be used in some instances. In this case, the circuit boards will be designed in line with the physical constraints associated with the enclosure. In more stringent areas, a customised enclosure could be selected giving the designer more control of all aspects of the product design. If local CxD manufacturers were to agree on a standardised range of enclosures, it would offer the opportunity of sharing tooling costs, but this would mean that all the local products would look similar.

4.2 Potential New CPS Localisation Opportunities

Through extensive engagement with various companies operating within the CPS ecosystem, it was found that most companies had already begun the journey of localising CPS products and systems and were far down the line in this journey. This included local design, development, manufacture, assembly and integration.

Further, most local companies indicated that they aspire to have 100% local content in their CPS systems. However, they recognise that this would be difficult to achieve due to economies of scale and affordability considerations. At this stage, it makes economic sense to import certain material and components.

The main barriers to localisation were cited as follows:
- The small local market size makes it difficult to achieve economies of scale.
- There are several players in the local market, each having their own product designs and range, with industry standardisation not being a top priority.
- Higher local production costs compared to other countries such as China.
- High investment costs are needed for product development, and equipment and tooling for local manufacture.

Notwithstanding this, five opportunities were identified for more detailed investigation. A brief discussion on these opportunities is provided in Table 17.

Table 17: Potential CPS Localisation Opportunities

Opportunity	Description
Pedestrian Tag	Pedestrian tags are used by TMM operators, miners and visitors in both underground and surface mining operations. In underground mining, pedestrian tags are used in conjunction with cap lamps, while in surface mining no cap lamps are used. Pedestrian tags typically consist of a transmitter, receiver, battery, LED, buzzer and enclosure. Based on the market size assessment prepared in Chapter 5 of this report, the South African market size for pedestrian tags has been estimated to be 95 400

Opportunity	Description
	units per annum. The average price per unit is R3 000, which gives an estimated market size of R286m per annum.
Batteries and Cells	A battery typically contains more than one cell. Various types of batteries are used in the different CPS systems and products, most of which use lithium-ion chemistry. These batteries are rechargeable. There are several battery assemblers in South Africa that could be approached to undertake the assembly of specific batteries. There are no producers of lithium-ion cells in the country, probably due to the current relatively small market in relation to the investment costs. In addition, lithium is not mined in South Africa but is available in the SADC region from Zimbabwe. Notwithstanding this, considering the potential future demand for batteries in CPS products, the local production of lithium-ion cells, and the local assembly of lithium-ion batteries could be investigated as a medium-to-long term opportunity.
PC Board Material	Most of the electronic components used in the various modules and sensors in the CPS system are mounted on a printed circuit board. The assembled printed circuit boards constitute the proprietary electronic hardware of each system. Most of the printed circuit boards used in the local CPS systems are produced locally using imported PCB materials. PCB production is a well-understood process that has been undertaken locally for more than 50 years. PCB materials consist of a substrate that is coated with a conductive material, typically copper. The pattern of the component connectors and the interconnections between the components is “printed” in a photo etching process that screens the pattern of the component connectors and the interconnections and removes the rest of the conductive material. PCBs can be single sided, double sided, or multilayered. Various substrates are used in line with performance requirements: • Phenolic resin for low cost, low performance applications, such as appliances and simple consumer electronic devices. • Fibre reinforced epoxy resin has become the standard for basic applications. • Polyimide is used for flexible PCBs and for higher operating temperatures. • Ceramics are used for high frequency applications. • Metal cores can also be used for mechanical strength and thermal conductivity, e.g. for power electronics applications. PCB material has traditionally been mass produced by large companies internationally. It should be noted that the local CPS systems could use a variety of different PCB materials, and the requirement is only a fraction of the local requirement which in turn is a very small fraction of the international consumption. However, it is possible that if the CxD companies rationalised the material, in combination with a very high market demand for CPS systems, the localisation of PCB materials could be considered in the future.
Enclosures	Mining operations in South Africa face extreme conditions, including dust, heat, vibration, and potential explosive atmospheres. CPS hardware must comply with South African mining regulations, and ISO and IEC standards, with enclosures designed for ruggedness and safety. Enclosures are used in various other sectors such as: • Automotive Industry: Enclosures protect sensors, cameras, and control units in autonomous vehicles, ensuring reliable operation in diverse driving conditions.

Opportunity	Description
	• Industrial Automation: Enclosures safeguard components in automated machinery and robotics, maintaining performance in demanding industrial environments. • Smart Cities: Enclosures house sensors and communication devices in smart infrastructure, contributing to efficient and resilient urban systems. The design of an enclosure must consider several factors: sealing and ingress protection ratings, thermal management, and mounting and accessibility. Certain applications may require specialised enclosures tailored to specific needs such as explosion-proof enclosures, shielded (protect against electromagnetic and radio-frequency interference) enclosures, and custom enclosures for unique applications. Depending on the application, enclosures are made from a variety of material and must comply with a range of standards. Typical material used in the manufacture of enclosures include steel, stainless steel, aluminium, polycarbonate, and fibre-reinforced polycarbonate. The typical standards are: • SANS 517, SANS 60529, SANS 1518, and SANS 10142 • MHSA Regulation 15.11 • ISO 21815-2 • IEC 60068-2-6 • IEEE 802 .11 There are numerous South African manufacturers that produce enclosures suitable for CPS in the mining industry. The manufacturing of enclosures for CPS creates a significant opportunity for local South African companies. There are already several manufacturers based in the country who could service the local market. The potential export of CPS systems could provide additional market opportunities for the current manufacturers of enclosures.
Cabling	A cable is insulated wires with a protective casing used for transmitting electricity or telecommunication signals. The manufacture of proximity detection systems or collision prevention systems requires use of cables for powering the equipment and transmitting messages, data and visual images. As such, a reliable and affordable supply of cables to the industry is important. There are several local cabling companies with the capability to design, develop and manufacture cables which comply with both local and international standards. Most of the companies are locally owned and have Level 1 B-BBEE status. However, as the demand for some of the required cabling is still low in South Africa, local companies are unable to produce these cables cost-effectively to the required specifications. Notwithstanding this situation, cabling is a potential localisation opportunity that could be investigated further. Such an investigation should cover the quantification of demand to justify localisation. In the meantime, one of the approaches could be to create SA-based wire shops for bundling, routing, repairing, and termination with specialty wires and insulation materials sourced internationally.

4.3 Supplier Development

South Africa's ground-breaking TMM regulations have led to the establishment of several companies and stimulated the development of new technology and products to meet the need for TMM

regulations compliance by mining companies. The CPS industry is in a volatile growth phase, and there are many companies active in the market. It is likely that not all companies will survive, and local consolidation will take place through mergers and acquisitions.

The process from product development to the final deployment of CPS systems is long and requires significant investment. While the local companies have invested heavily in new products and testing, very few CPS systems have received the required certification. It is also clear that the local CPS industry is still in its early stages of development, and that many companies need assistance to grow and become sustainable.

Based on the study that was conducted, the following supplier development initiatives should be considered:

- Support for product design, development and prototyping.
- Support for local manufacture.
- Support for testing, which is a long, iterative, and costly process.
- Skills development support, especially regarding auto electrician training.
- Market access support, especially regarding export markets.

The above initiatives could involve the provision of both financial and non-financial support measures. While there are some financial support measures in place for the broader manufacturing industry, these are difficult to access. Support measures that are targeted for the CPS sector are required.

Non-financial support measures should involve the participation of both local and international players. There should be a coordinated effort to bring together the relevant national system of innovation institutions to provide access to technical expertise and facilities. Academic and training institutions should design and offer appropriate education (engineering disciplines) and training (auto electricians and technicians) programmes for the CPS sector. Business to business linkages should be fostered to provide access to expertise from local and international private sector companies.

The TLIU has two support instruments that could potentially assist the CPS ecosystem, namely:

- Firm Technology Assistance Packages are support packages designed for firm-level interventions and are implemented to enhance the technological competitiveness of individual companies.
- The Sector-Wide Technology Assistance Package is an instrument that was designed to provide support towards the implementation of an intervention where high-end specialised technology services are made available for the benefit of a sector.

Further discussions with the TLIU would be necessary to unpack and reach agreement on the support that they could provide.

5 MARKET ANALYSIS

5.1 Market Size Assessment

The global collision avoidance system market size was valued at U$66.80bn in 2022 and is expected to expand at a compound annual growth rate of 11.4% from 2023 to 2030. The global mining sector CAS market was U$5.3bn in 2022 and was projected to grow 10.2% from 2023 to 2030. North and South America account for the biggest market demand, whilst Africa is the fastest growing market.

South African mines have been quick to adopt CPS systems to comply with safety regulations to prevent vehicle to pedestrian and vehicle-to-vehicle collisions. CPS, used in conjunction with fatigue monitoring systems, is seen as a high priority.

It is estimated that there are 8 810 intelligent TMMs suitable for retrofitting with CPS in 1 705 South African mines. Based on information from the mining industry, TMMs are on average replaced every 5 years.

Based on information gathered from the CPS ecosystem, and various assumptions, the current South African market size is estimated at R 828 million per annum. Table 18 lists the products considered, the average unit price, annual volumes, and estimated market size. As more accurate information is gathered, this market size estimation can be refined further.

Table 18: South African Market Size Estimation 2025

Products	Average Unit Price	Annual Volume	Estimated Market Size
Pedestrian tags	R 3 000	95 400	R 286 200 000
CPS-ready cap lamps	R 1 500	95 400	R 143 100 000
Mobile tags	R 4 000	51 150	R 204 600 000
CPS vehicle units	R 80 000	1 762	R 140 960 000
Tracking and reporting systems	R 120 000	341	R 40 920 000
Fatigue monitors	R 20 000	528	R 10 560 000
Machine monitors	R 10 000	176	R 1 760 000
Market Size Estimation			**R 828 100 000**

The assumptions used to prepare Table 18 are provided in Table 19.

Table 19: South African Market Size Estimation - Assumptions

Item	Assumption
Number of mining sites	1 705
Number of Intelligent TMMs	8 810
Number of mine workers	477 000
% of workers with cap lamps and tags	40
Number of visitor tags per mine	30
Number of reporting systems per mine	1
%vehicles fitted with fatigue monitors	30
% vehicles fitted with machine monitors	10
Controller replacement cycle	5 years
Pedestrian tag replacement cycle	2 years
Cap lamp replacement cycle	2 years

Mobile unit replacement cycle	3 years

Using the information in the above tables, and assuming a market growth rate of 10% per annum, the estimated local market (per volume) for the individual CPS components, for a five-year period, is given in Table 20 below.

Table 20: Estimated South African Market Size 2025-2029 (Volume)

Item	2025	2026	2027	2028	2029
	Number of Units				
Pedestrian tags	95 400	104 940	115 434	126 977	139 675
CPS ready cap lamps	95 400	104 940	115 434	126 977	139 675
Mobile tags	51 150	56 265	61 892	68 081	74 889
CPS vehicle units	1 762	1 938	2 132	2 345	2 580
Tracking and reporting systems	341	375	413	454	499
Fatigue monitors	528	581	639	703	773
Machine monitors	176	194	213	234	258

Assuming a market growth rate of 10% per annum, and a 4% year-on-year price increase, the estimated local market (in Rands) for the individual CPS components, for a five-year period, is given in Table 21.

Table 21: Estimated South African Market Size 2025-2029 (Rands)

Item	Estimated Market (million)				
	2025	2026	2027	2028	2029
Pedestrian tags	R 286.20	R 297.65	R 309.55	R 321.94	R 334.81
CPS ready cap lamps	R 143.10	R 148.82	R 154.78	R 160.97	R 167.41
Mobile tags	R 204.60	R 212.78	R 221.30	R 230.15	R 239.35
CPS vehicle units	R 140.96	R 146.60	R 152.46	R 158.56	R 164.90
Tracking and reporting system	R 40.92	R 42.56	R 44.26	R 46.03	R 47.87
Fatigue monitors	R 10.56	R 10.98	R 11.42	R 11.88	R 12.35
Machine monitors	R 1.76	R 1.83	R 1.90	R 1.98	R 2.06
Total	**R 828.10**	**861.22**	**R 895.67**	**R 931.50**	**R 968.76**

The above market size estimations have been prepared for the South African market only. Most CPS companies that were interviewed indicated that, due to the small local market size, they see the export market as the goal and route to ensure long term financial sustainability. In this regard, trade

agreements such as AfCFTA and BRICS, and the active participation in trade missions and events, could play a pivotal role to access export markets.

5.2 Local Content Analysis

This section outlines the work done to identify CPS systems and their local manufacturing, assembly and outsource/insource status. In addition, for each of the components, an assessment was conducted to estimate the local content composition. Both primary (stakeholder engagements) and secondary (desktop study) data methods were used to gather and analyse information.

For each of the components, an assessment was conducted to estimate the local content composition and identify the technology provider and country of manufacture and assembly. Table 22 contains the results of this assessment.

Table 22: Local Content Assessment

Component	Technology Provider	Country of Manufacture and Assembly	% Local Content (to be confirmed)
Proximity detection systems	One company	• Made in South Africa	• >90%
RADAR and LiDAR sensors	Four companies	• Made in South Africa • Made in Asia, Assembled in South Africa • Assembled in South Africa • No data	• >90% • <10% (to be confirmed) • >50% • No data
RFID Tags	Seven companies	• Assembled in South Africa • Made in Asia, Europe and USA • Made in Europe and USA • Made in Germany • Made in Europe and South America • Made in the UK • Made in China	• <35% • <10% • <10% • <10% • <10% • <10% • <10%
Cameras and vision systems	Five companies	• Made in South Africa • Assembled in South Africa • Made in China and North America • Made in the USA • Made in China	• >90% • <15% • <10% • <10% • <10%
Alert mechanisms and warning alarms	One company	• Made in South Africa	• >90%
GPS and geofencing	Four companies	• Assembled in South Africa • Made in Switzerland • Made in Asia, Europe and USA • Made in Germany	• <35% • <10% • <10% • <10%

Data logging and analysis	One company	• Assembled in South Africa	TBC

There are several local technology providers who can manufacture and install CPS components. The data highlights opportunities in the development of manufacturing capability to support the local manufacture and development of products such as RFID tags, GPS and geofencing systems, and LiDAR technologies. The development of local capability will enable economic development and growth within the manufacturing sector.

It is important to note that the information contained in Table 22 is a high-level assessment conducted through desktop study and engagement with some companies operating in the local CPS ecosystem. A comprehensive verification process of local content has not been undertaken by the project team. This is a complex process and relies on the willingness of companies to participate in such a process and share the relevant, and often commercially sensitive, information.

The local CPS ecosystem is still in the early stages of development when it comes to the development of CPS compliant systems. There is significant development, testing and certification work that still needs to be undertaken. The local CPS ecosystem is also highly competitive, with many players vying for a share of a relatively small local market. Therefore, it is highly unlikely that companies would be willing to share commercially sensitive information that would be needed to conduct a comprehensive local content assessment.

Notwithstanding this, local content verification should be conducted by a body such as the South African Bureau of Standards (SABS), who have been appointed by the Department of Trade, Industry and Competition (the dtic) to provide local content verification services. In accordance with the Preferential Procurement Policy Framework Act (PPPFA) regulation, SABS conducts local content verification of designated products in alignment with SANS 1286.

5.3 Market Characteristics

The Minerals Council's Terms of Reference for this project required an evaluation of numerous characteristics of the CPS market in South Africa. Due to the heterogeneous and developmental nature of the CPS ecosystem, it was difficult to obtain a generalised description for each characteristic. Notwithstanding this, some information on each characteristic is provided in Table 23.

Table 23: CPS Market Characteristics

Characteristic	Description
Timelines for supplier nominations and purchase order placements	Timelines vary significantly across the different companies and are probably dependent on the agreements reached between mining houses and OEMs, CxD OTMs and third-party integrators.
Availability of raw materials	The raw materials used to produce TMMs, and CPS products, are readily available in South Africa. However, it was found that printed circuit boards were imported into the country.
Inputs imports	Microelectronics, PCB material, moulds, enclosures and specialist components such as lenses were imported.
Investment costs	The deployment of CPS systems requires significant investment from mining houses. Such investments cover costs related to infrastructure, TMMs, hardware, software, system customisations, integration, testing, certification, installation, maintenance, spares, training, change management, and production downtime during testing and installation.

Characteristic	Description
	These costs are likely to be prohibitive for junior miners. The CxD OTMs incur significant design, development, integration, testing and certification, and training costs.
Barriers to localisation	The main barriers to localisation include: • The small local market size makes it difficult to achieve economies of scale. • There are several players in the local market, each having their own product designs and range, with industry standardisation not being a top priority. • Higher production costs compared to other countries such as China. • High investment costs are needed for product development, and equipment and tooling for local manufacture.
Technology licenses and agreements	Many local CPS companies collaborate with both local and international partners. These are either external (independent companies) or internal (other divisions and companies within the same group) collaborations. Issues relating to technology licenses would normally, where appropriate, be articulated in collaboration agreements.
IP issues	It was found that the protection of intellectual property was not a major, immediate, consideration for many of the CPS companies. The focus was on developing the CPS systems and products and deploying these as soon as possible into the market. Many companies felt that the software that was developed provided sufficient short-term protection, and that IP protection would be investigated in the future. It must be noted that IP protection is costly, especially for smaller companies.
Prevalence of exclusivity clauses for component design and manufacture	Many local CPS companies work with both local and international partners through either external (independent companies) or internal (other divisions and companies within the same group) contracts. It is unlikely that there are exclusive clauses, in contractual agreements, for component design and manufacture. If a manufacturer produces similar products for different OEMs or CxD OTMs, customers can capitalise on lower costs due to economies of scale. This is what happens globally in the automotive sector where first-tier manufacturers produce similar components for multiple OEMs. This practice is encouraged by OEMs because of the benefits of access to strong technical expertise and economies of scale.
Meeting OEM specifications and quality requirements	Thus far, CxD OTMs and third-party integrators have focused on retrofitting legacy machines that are being used at the various mines and there has been limited work done directly with OEMs to develop CPS systems for new TMMs. At any given mine, there are a variety of models and brands of legacy TMMs. Therefore, multiple customisations of CPS systems need to be developed, integrated and implemented. These CPS systems need to undergo the relevant testing (lab-scale, single machine, and in-situ) and be certified for deployment.
Subsidies by government	As far as can be determined, there are no subsidies that are specifically available for the CPS sector, and there may be a need to lobby government to provide appropriate support measures such as grants, subsidies and tax breaks. Notwithstanding this, the following are some of the funding instruments that may be relevant for the sector:

Characteristic	Description
	• Support Programme for Industrial Innovation (SPII) • Technology and Human Resources for Industry Programme (THRIP) • Manufacturing Competitiveness Enhancement Programme (MCEP) • Capital Projects Feasibility Programme (CPFP) • 12I Tax Allowance Incentive • Global Business Services (GBS) Incentive • Critical Infrastructure Programme (CIP) • Black Industrialist scheme (BIS).
Purchasing teams local content targets	Most companies indicated that they aspire to have 100% local content in their CPS systems. However, they recognise that this would be difficult to achieve due to economies of scale and affordability considerations. It makes economic sense to import certain material and components.
Start-ups and small volume suppliers	There are several local and international companies operating in the local CPS ecosystem. The small local market size, high investment costs, and time required to develop CPS systems and obtain certification, are significant barriers to entry for new start-up companies.
Potential demand, exports and applications in other sectors	Based on several assumptions, an assessment of the market size was prepared and is outlined in section 5.1 of this report. Most CPS companies intend to target the export market. Trade agreements such as AfCFTA and BRICS could be key enablers for accessing export markets. The automotive sector has advanced collision avoidance technology, and it is unlikely that CPS companies could penetrate this market. There may be opportunities to access technology and manufacturing capability from the automotive sector. The yellow metals sector, for construction and agricultural applications, is unlikely to be an additional market for CPS systems unless this is mandated through new regulations.

6 CPS LOCALISATION CASE STUDIES

The Minerals Council has commissioned a study to investigate the feasibility of localising CPS components that are used in the manufacture of TMM CPS and collision warning and avoidance devices (CxDs). Such localisation could include component manufacture, assembly and/or insourcing-outsourcing. Localisation has been a central tenet of South Africa's economic development strategies for many decades, and its success will consolidate and grow the economy. To promote localisation, the focus by government has been on the establishment of state procurement measures to boost local industries, initiatives to increase local content, capacitation of local firms, and improved access to domestic and export markets.

A key work package of this study is the development of case studies on successful examples of localisation in terms of manufacture, assembly and insource-outsource. The companies for case study development would need to be selected from the following categories:

- Collision Warning and Avoidance Devices Original Technology Manufacturer
- Trackless Mobile Machinery Collision Prevention System Original Equipment Manufacturer
- Third-party Integrator.

Extensive engagements, with 16 companies that operate within the South African TMM and CPS ecosystem, were conducted to identify potential localisation projects for case study development. This included engagements with eight CxD OTMs, seven TMM OEMs, and one third party integrator firm.

Seven case studies were prepared on the localisation initiatives, and these are included as a separate, confidential package issued to the Minerals Council. The typical areas covered in each case study are:

- A description of the project
- The process followed to identify, develop and implement the localisation opportunity
- The key stakeholders involved throughout the process
- The type of support that was provided by the different role players
- The status of the project
- Key socio-economic indicators (job creation, Gross Value Added, financial performance)
- Critical success factors
- Challenges experienced and pitfalls to avoid
- Lessons learnt
- General advice on localisation.

Based on the engagements with various companies involved in the local CPS domain, and specifically the detailed discussions with the seven companies selected for case study development, below is a summary of the key findings, critical success factors, challenges experienced, lessons learnt, and advice on localisation:

Key findings and insights

- South Africa is considered a global leader in the CPS domain. There is an opportunity to capitalise on this sentiment to capture a greater share of the global market. This can be achieved by showcasing South African CPS products and systems at international exhibitions and punting these proven technologies as the global benchmark.
- Some stakeholders perceive the incorporation of the MOSH CPS Guidelines as a hurdle in terms of the cost of implementation and possible misalignment with international standards, while others have praised the initiative. Notwithstanding this, the objective of achieving Zero-Harm in the SAMI received overwhelming support.
- All engagements have highlighted the need for a consolidated South Africa approach to leverage the pioneering work that has been conducted in the country as well as the proactive approach from a legislative and Minerals Council perspective.

- There are several good local suppliers that have focused on the full value chain. These companies have partnered with a range of stakeholders to design, manufacture, trial, test, certify and deploy their CPS technologies.
- A significant portion of production is local, with a mix of in-house assembly and third-party component production. However, specialised electronic components such as chips, screens, batteries and cabling are imported and have long lead times. Enclosures are also mainly imported due to better quality, more cost-effective prices, and shorter lead times.
- The components that can realistically be localised are already so, and there seems to be little opportunity for further localisation.
- Almost all companies have self-funded research and development, design, manufacture, trial, testing, and certification.
- Most companies have not leveraged any form of assistance from government or other institutions and have developed their technologies on their own.
- Due to the high number of CPS suppliers operating in the country, the local market share for individual companies is small and investment in further development of local manufacturing becomes prohibitive.

Critical success factors

Some of the key critical success factors mentioned by the companies include:

- Strong collaboration with a variety of stakeholders is crucial to developing new CPS technologies and eventually deploying these into the market.
- Collaborating with mining companies is important for determining and specifying user requirements, as well as allowing on-site testing and providing development assistance.
- Collaborating with the University of Pretoria for assistance with verification testing, certification and product development. Comprehensive testing (i.e., testing that is performed under well-controlled conditions; that uses appropriate test equipment; that uses experienced human resources to conduct the tests and considers well-defined test procedures to ensure repeatability) guarantees robustness under the harshest conditions.
- A passion for innovation and continuous improvement results in the development of groundbreaking, fit-for-purpose solutions.
- The development of tailored solutions and having a flexible approach to meeting client needs.
- Extensive and customised internal training of engineers and technicians is crucial for the development and deployment of appropriate CPS solutions.

Challenges experienced and pitfalls to avoid

Some of the challenges experienced by the companies are summarised below:

- Specialised electronic components such as chips, screens, batteries and cabling are imported and have long lead times.
- Access to markets can be challenging and obtaining client buy-in is difficult.
- Industry growth is likely to come from exports, but international marketing is costly. Attending international expos and trade shows is viewed as prohibitively expensive. Targeted government assistance in this regard would enable the industry to grow internationally by increasing exports.
- Overcoming barriers to compete with international companies requires persistence and proof of reliability.
- The need for rigorous testing and validation, requires continuous resources and financial investment.
- Ensuring a skilled workforce through ongoing and extensive training investment is sometimes exacerbated by the ‘brain drain’.
- There is an ongoing need to educate end users on technical and regulatory requirements for effective solutions.
- There is a need for ongoing alignment between CPS companies and testing institutions on the testing methodology and criteria.

- Lack of a clear understanding by some customers of the solutions needed to solve specific problems. This leads to the development of an unclear scope of work.
- Some customers are unable to understand and interpret the data received from the system.
- Some customers attempt to integrate new technology with the old on legacy equipment.
- Some OEMs do not see value in being part of partnerships that address CPS compliance.
- Access to funding, both for technology and product development as well as for establishing and developing the business, is a challenge and own funding is generally used.
- It can be very difficult to secure a contract with a mining company, especially if they already have installations from other suppliers.
- Whilst enclosures can be made locally, the cost of tooling is prohibitively expensive for small product volumes.

Lessons learnt

Below is a summary of some of the key lessons learnt:

- Significant investment is required for upskilling and training electricians and auto electricians, as these skills are key to operations and are in short supply.
- Ensuring safety is a fundamental driver of success.
- Investing in the development of local expertise drives and enhances innovation.
- Training must be accessible, inclusive, and practical. Tailoring training to diverse workforces improves understanding.
- Recruitment strategies must focus on talent that is fit-for-purpose. Selecting the right people improves implementation efficiency.
- Effective stakeholder engagement is fundamental. Transparency and collaboration minimise bottlenecks and enhance cooperation.
- Successful localisation requires a good understanding of local market needs. It is important to quantify the demand for the products and systems, and solutions must be tailored to customer requirements. It is also important to ensure that the necessary skills and knowledge are available.
- Off the shelf modules are useful for concept validation, but custom designs are required for the final product to meet all requirements such as power usage, reliability and environmental compliance, amongst others.
- Continued relevance in the industry is achieved by keeping abreast with industry developments, including legislation, and consistently meeting the customer's brief.

General advice on localisation

Some general advice on CPS localisation is listed below:

- Localisation is key to a prosperous South Africa. However, it does require high levels of perseverance, and a focus on self-reliance rather than importing when convenient. The pursuit of safety and Zero-Harm on the mines is a big unifying factor (and rallying call) that can help in this domain.
- It is important to leverage industry associations for policy support and market access.
- Localisation should be consistently and continuously promoted as a key driver of economic growth.
- Companies should partner with local suppliers to drive South Africa’s GDP growth and build a resilient economy, ensuring fair opportunities for South African companies by fostering a supportive market environment.
- Companies should engage with universities and research institutions to access research and development support, and to ensure that solutions are scientifically validated.
- Local manufacturing capabilities should be strengthened to reduce dependence on imports and enhance supply chain resilience.
- South African innovations should be showcased, and locally developed technologies should be promoted through dedicated platforms. Government needs to develop mechanisms to showcase South African products.

- Government should help to promote local South African CPS companies by driving minimum thresholds for local content.
- Due to the high costs of participating in promotional events, it will be important for the relevant government departments to provide support to companies to attend these events and take advantage of any opportunities to export their products and systems.
- To effectively support localisation, government departments such as the Department of Science, Technology and Innovation (DSTI) and the Department of Trade, Industry and Competition (the DTIC) should be more accessible and should proactively assist in the localisation drive. It would be useful to entrepreneurs if these departments invested in small scale electronics and other production facilities so that local start-ups do not need to seek assistance in China.
- Localisation embodies many aspects and can have many meanings. There is no common understanding, and localisation needs to be defined within the context of CPS.
- Localisation needs to be driven by the buyers of equipment, and the regulators need to provide an enabling environment that will support local developments and encourage local purchases.

7 CONCLUSIONS

A study was conducted to assess the feasibility of localising collision prevention system components for trackless mobile machinery. The key conclusions from this study are provided below:

- South Africa's TMM regulations have stimulated the related technology and product developments as well as the establishment and growth of several companies competing in the market.
- The CPS industry is in a volatile growth phase, and there are many companies active in the market. It is likely that not all companies will survive, and local consolidation will take place through mergers and acquisitions. This has already happened in recent years. The more successful companies will merge or partner with TMM OEMs or large international companies active in this market segment.
- Most of the CPS products and components are already being localised and this has warranted significant investment of own resources by the companies, with very little non-financial and financial support provided by government.
- There is a need to assist the CPS ecosystem to develop, manufacture, test, certify and deploy their products and systems. Such support could be provided by both local and international, public and private sector players.
- As with all technology-based products, development is not a once-off event, but rather an ongoing activity to stay ahead of the competition. There will be a continuous need to invest in research and development to develop the next-generation CPS.
- The CPS ecosystem has made significant investments to train employees in product development, and the integration and installation of CPS systems. There is a shortage of installation and maintenance skills in the form of auto electricians.
- Some form of local collaborative approach and centralised support would assist South Africa to maintain and even expand its current lead.
- The local automotive and electronics sectors have strong technological and manufacturing expertise that could be harnessed to assist CxD OTMs. Potential areas for collaboration include:
    - Core technologies such as LiDAR, radar, V2X communication, and sensor fusion are already prevalent in the auto sector and directly applicable to TMM CPS systems.
    - Both domains leverage vehicle interface controllers, HMIs, and intervention logic, enabling reuse of platforms and components.
    - The CPS development in mining presents an added market for the automotive and electronics sectors.
    - Automotive suppliers offer established, scalable manufacturing and integration capabilities for sensors, embedded systems, and HMIs.
- South Africa's lead in this field does provide international market opportunities as other countries adopt similar regulations. Exploiting this opportunity will entail significant marketing efforts and associated costs.
- TMM population data requires further validation and verification as some data is missing from the submission. The data analysis result, percentage, is however representative as it reflects similar numbers to 2017 DMRE data.
- South Africa has the capacity and capability to conduct testing according to MOSH requirements.
- Assessments were conducted on the 12 CPS opportunities identified for local manufacture and assembly. Eight of these opportunities are unlikely to be feasible for localisation due to factors such as too small market demand and too expensive to produce. The following opportunities warranted more detailed investigation for localisation: CPS-ready cap lamp test station, control system wiring, back-up battery assembly, and enclosures.
- Five new potential localisation opportunities were identified through consultations with CPS companies, namely pedestrian tags, batteries and cells, PCB material, enclosures and cabling. These opportunities were investigated.

8 RECOMMENDATIONS

Flowing from the work done during the project, and specifically the conclusions, the following recommendations are made:

- To support the local CPS ecosystem, and the SAMI to achieve TMM regulatory compliance, it is recommended that two Sector-Wide Technology Assistance Packages (SWTAPs) be established. These initiatives will need to be investigated and unpacked further, leading to the development of sound business cases.
    - *CPS Product Design and Manufacture SWTAP*. The aim of this SWTAP will be to provide CPS companies access to product design and manufacturing capabilities and facilities that are available at science councils, government-funded entities, universities, and local and international private sector companies.
    - *CPS Testing and Certification SWTAP*. The aim of this SWTAP will be to provide CPS companies with access to testing and certification capabilities and facilities that are available at the University of Pretoria and other local and international facilities. A secondary objective could be the capacitation of UP to offer the full range of testing and certification services at reasonable lead times.
- Whilst recognising that the CPS market is a competitive environment, the formation of a CPS industry body or forum (possibly under the Mandela Mining Precinct) should be considered with a view to strengthening the sector by addressing common problems and issues such as:
    - Standards
    - Testing
    - Installation and maintenance skills base
    - Commonisation of non-proprietary components
    - International marketing
- It is recommended that an initiative to provide international market development assistance to the CPS ecosystem be investigated and developed with the dtic. This could include:
    - International market development
    - Development of a brand South Africa product identity
    - Promotion of South Africa as a leader in the field
    - Support for international market development including trade missions and exhibitions
- It is recommended that CPS orientated auto electrician training be provided to ease the pressures regarding installation and maintenance.
- The opportunities to localise CPS-ready cap lamp test station, batteries and cells, PCB material, enclosures and cabling should be investigated further through joint engagements with the CPS ecosystem.
- The opportunity to use a digital tool such as digital twins to support the demonstration of CPS system performance in a representative environment should be investigated. The digital twin can be used to verify the robustness of CPS products and can be extended to testing beyond TRL 6 to mitigate against safety risks while operating in a representative environment.
- The potential to access an independent mock or test mine facility should be investigated. This will enable the testing of TMMs in a representative environment without impacting negatively on operations and safety.
- It is recommended that the TMM population data be further validated and verified, especially regarding the classification of “legacy, intelligent” and “legacy, unintelligent”, and a determination of which machines can be retrofitted with CPS systems.

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APPENDIX A - AUTOMOTIVE COMPANIES CPS COMPONENTS RELEVANCE

Companies	Tier	Categories	Products	Province	CPS Relevance Summary	Potential Application
A	Tier 3	Manufacturers of Parts & Accessories for Motor Vehicles	Accessories	Eastern Cape	Robotic Vision Systems, Spot Welding	Control Unit and Processors
			Engineering			Lidar Systems
						Radar Systems
B	Tier 2	Manufacturers of Parts & Accessories for Motor Vehicles	Abrasives	Gauteng	Manufactures and distributes brake systems	Braking and Control Actuators
			Brakes / Braking Systems / Components			
			Springs			
C	Tier 1	Manufacturers of Parts & Accessories for Motor Vehicles	Brakes / Braking Systems / Components	Gauteng	Produce Brake Drums and disks	Braking and Control Actuators
			Castings & Forgings			
			Chassis / Chassis Assemblies			
			Control Arms			
			Differentials - Assemblies / Components			
			Drivetrain Components			
			Flywheels / Housings / Assemblies			
			Front End / Module Assemblies			
			Knuckles			
			Spindles			
			Spline Shafts			
			Tie Rods / Tie Rod Ends			
D	Tier 1 & Tier 2	Manufacturers of Parts & Accessories for Motor Vehicles	Airbags	Gauteng	Manufacturers of seatbelts, steering wheels and airbags, pressed and injection moulded components	Driver Interface and Alert Systems
			Castings & Forgings			Proximity Detection Sensors
			Safety Belts / Seat Belts / Components			
			Steering			
E	Tier 1	Manufacturers & Importers of Motor Vehicles	Wiring Harnesses / Harness Protection / Cushioning		Specialisation in wiring harnesses	Control Unit and Processors
						Braking and Control Actuators
F		Manufacturers of Bodies for Motor Vehicles; Trailers & Semi Trailers	Vehicle Security Systems	Gauteng	Manufacturer of armoured vehicles, maintenance, upgrades, and military vehicle retrofits	Proximity Detection Sensors
			ELECTRONICS (Incorporating Body / Comfort / Control / Telemetry / Data Loggers / Drivetrain / Engine Management / Instrument Clusters / GSM)			Radar Systems
						Control Unit and Processors
G		Manufacturers of Bodies for Motor Vehicles; Trailers & Semi Trailers	Accessories For Trucks / SUVs / MPVs / LCVs	Gauteng	Produces tactical unmanned aerial and ground vehicles, known as drones	Control Unit and Processors
			Adaptor Plates			
			Automotive Fasteners / Fastening Systems			Proximity Detection Sensors
			Plastics			Radar Systems
			Raw Materials			

Companies	Tier	Categories	Products	Province	CPS Relevance Summary	Potential Application
H		Auto Salvage Sector	Accessories For Trucks / SUVs / MPVs / LCVs	Gauteng	IT and technology solutions	Proximity Detection Sensors
			Air Ducting			
			Airbags			
			Airconditioning / Climatic Control Systems / Lines			
			Alternators / Components			
			Aluminium Products			
			Aluminium Washing			
			Anchor Pins			
			Armrests / Armrest Assembly			
			Automotive Carpets / Mats / Overlay Mats / Vacuum Formed Mats			
			Automotive Fasteners / Fastening Systems			
			Automotive Glass			
			Automotive Sliding Windows			
			Automotive Wires & Cables (Electrical)			
			Axles - Assemblies / Components			System Software and Analytics
			Badges / Chevrons / Emblems / Graphics / 3-d Trim / Boards			
			Batteries / Trays / Accessories			
			Bearings			
			Bonding / Adhesive Systems / Transfer Adhesives			
			Brackets			
			Brakes / Braking Systems / Components			
			Brass Fittings / Components			
			Bumpers			
			Load bins / Load bin Mechanisms / Linings			
			Plastics			
			Raw Materials			
			Shackle Pins / Bushes			
			Tool & Die Makers			
I	Tier 1	Manufacturers of Parts & Accessories for Motor Vehicles	Wiring Harnesses / Harness Protection / Cushioning	Gauteng	Manufactures wiring harness for Automotive	Proximity Detection Sensors
						Radar Systems
	Tier 2	Designs, manufacture and supplies	Plastics			Lidar Systems
						V2V Communication Modules

Companies	Tier	Categories	Products	Province	CPS Relevance Summary	Potential Application
J	Tier 1	Manufacturers of Parts & Accessories for Motor Vehicles	Cables ELECTRONICS (Incorporating Body / Comfort / Control / Telemetry / Data Loggers / Drivetrain / Engine Management / Instrument Clusters / GSM) Instrumentation / Panels Wiring Harnesses / Harness Protection / Cushioning	KwaZulu-Natal	Manufactures automotive wiring harnesses	Control Unit and Processors Proximity Detection Sensors Radar Systems Lidar Systems
K	Tier 1 Tier 2	Manufacturers of Parts & Accessories for Motor Vehicles	Leather / Plastic / Cloth / Vinyl	Eastern Cape Gauteng	Manufacturing seating systems for commercial vehicles	Driver Interface and Alert Systems
L	Tier 2	Manufacturers of Parts & Accessories for Motor Vehicles	Aluminium Products Batteries / Trays / Accessories Catalytic Converters / Components ELECTRONICS (Incorporating Body / Comfort / Control / Telemetry / Data Loggers / Drivetrain / Engine Management / Instrument Clusters / GSM) Engineering Exhaust Systems / Silencers / Components Pressed Metal Parts Raw Materials Vacuum Formed Products / Assemblies Windscreen Washer Bottles Wiring Harnesses / Harness Protection / Cushioning	Gauteng	Global leader in sustainable technology solutions, including automotive emissions control	Proximity Detection Sensors
M	Tier 2	Service Delivery	Wire Products	North West	Wiring harnesses, cable systems, and related components for the automotive sector.	Proximity Detection Sensors Radar Systems Lidar Systems GPS Systems Control Unit and Processors
N	Tier 1	Manufacturers of Parts & Accessories for Motor Vehicles	ELECTRONICS (Incorporating Body / Comfort / Control / Telemetry / Data Loggers / Drivetrain / Engine Management / Instrument Clusters / GSM) Headrests - Conventional / Pour-in-place Leather / Plastic / Cloth / Vinyl Wiring Harnesses / Harness Protection / Cushioning	Eastern Cape	Manufacturing of electrical power distribution systems.	Control Unit and Processors Proximity Detection Sensors
O	Tier 1 Tier 2	Manufacturers of Parts & Accessories for Motor Vehicles	Lighting	Eastern Cape	Lumotech designs, manufactures and supplies automotive lighting systems, vehicle signaling and warning equipment	Proximity Detection Sensors

Companies	Tier	Categories	Products	Province	CPS Relevance Summary	Potential Application
P	Tier 1	Manufacturers & Importers of Motor Vehicles	Abrasives Glove Boxes Vacuum Formed Products / Assemblies	Gauteng	Wiring harnesses, molding, and electronic integration.	Control Unit and Processors
Q	Tier 1	Manufacturers of Parts & Accessories for Motor Vehicles	ELECTRONICS (Incorporating Body / Comfort / Control / Telemetry / Data Loggers / Drivetrain / Engine Management / Instrument Clusters / GSM)	KwaZulu-Natal	Develops security and telematics solutions, vehicle tracking, and electronic control systems.	Driver Interface and Alert Systems GPS Systems Proximity Detection Sensors Radar Systems System Software and Analytics V2V Communication Modules
R	Tier 1	Manufacturers of Parts & Accessories for Motor Vehicles		Eastern Cape	Safety technology designed in bumper systems prevent potential accidents. Intelligent and proactive. The integrated sensors, such as parking-assist systems, lane-change assistants or short-range radars, meet high technical standards. Remaining virtually invisible.	
S	Tier 1	Manufacturers of Parts & Accessories for Motor Vehicles	Air Brake Systems / Components Alternators / Components Brakes / Braking Systems / Components Drivetrain Components ELECTRONICS (Incorporating Body / Comfort / Control /Telemetry / Data Loggers/Drivetrain / Engine Management / Instrument Clusters / GSM) Engine Fuel Systems/Pumps / Carburettor Kits Fuel Systems / Pumps / Carburettor Kits Vehicle Security Systems	North West	Assistance systems Automated driving Displays Electronic components Driving safety Vehicle computer Transmission technology Infotainment Interior Camera Power electronics Steering Parking Sensors Software and services Connectors Control units Connectivity Solutions for off-highway and large-engines Solutions for commercial vehicles	Control Unit and Processors Driver Interface and Alert Systems Proximity Detection Sensors Radar Systems System Software and Analytics GPS Systems V2V Communication Modules

Companies	Tier	Categories	Products	Province	CPS Relevance Summary	Potential Application
T	Tier 2	Designs, manufacture and supplies	Automotive Wires & Cables (Electrical)	Eastern Cape	Solutions that power electric vehicles, aircraft, digital factories & smart homes.	Control Unit and Processors
			Shackle Pins / Bushes			Driver Interface and Alert Systems
			Switches			Proximity Detection Sensors
			Wire Products			System Software and Analytics
			Wiring Harnesses / Harness Protection / Cushioning			
U	Tier 1	Manufacturers of Parts & Accessories for Motor Vehicles	Automotive Wires & Cables (Electrical)	Gauteng	Specializes in braking, control actuators, and vehicle safety systems	Braking and Control Actuators
			Brakes / Braking Systems / Components			Control Unit and Processors
			Cables			Driver Interface and Alert Systems
		Service Delivery	ELECTRONICS (Incorporating Body / Comfort / Control / Telemetry / Data Loggers / Drivetrain / Engine Management / Instrument Clusters / GSM)			Proximity Detection Sensors
			Gearbox Components / Housings / Selector Shafts			Radar Systems
			Pipes / Pipe Bending / Pipe Assemblies / Hoses / Hose Clamps / Clamps			V2V Communication Modules
V	Importers and Distri-buters	Domestic Vehicle Sales; Maintenance & Repair of Motor Vehicles: Dealerships	Air Ducting	Gauteng	Plastic components, possible enclosures for CPS sensors	
			Automotive Carpets / Mats / Overlay Mats / Vacuum Formed Mats			
			Consoles			
			Glove Boxes			
			Grilles / Grille Guards			
			Intake Pipes / Ducts			
			Interior Trim Components / Assembly			
			Lighting			
			Moulded Insulation Components / Panels			
			Parcel Shelves / Trays			
			Plastics			
			Post Covers / Trim			
			UNDERSHIELDS / COVERS - Metal / Plastics / LFT / Other			
W	Tier 1	Manufacturers of Parts & Accessories for Motor Vehicles	Axles - Assemblies / Components	Gauteng	Automotive motion control, braking, and steering systems	Braking and Control Actuators
						Control Unit and Processors
						Driver Interface and Alert Systems
			Strut Assemblies			Lidar Systems
						Proximity Detection Sensors
						Radar Systems

APPENDIX B - ELECTRONICS COMPANIES CP COMPONENTS RELEVANCE

Company	Company Offering	Products	Province	Company Type	Quality Rating	Potential Application
A	Electronic Manufacturing Services	PCB Assembly & Prototyping	Gauteng	OEM Tier 2	ISO 9001:2015 SABS Approved	Control Unit and Processors System Software and Analytics
B	Electronic Manufacturing Services	PCB Assembly & Prototyping	KwaZulu-Natal	OEM Tier 2	ISO 9001:2015	Control Unit and Processors
C	Electronics Engineering, Design & Manufacturing	Custom Electronics Solutions	Gauteng	OEM	ISO 9001:2015 ISO 14001:2015	System Software and Analytics Control Unit and Processors
D	Electronic Manufacturing Services	Electronic Components & Devices PCB Assembly & Prototyping	Gauteng	OEM Tier 2	ISO 9001:2015	Control Unit and Processors
E	Electronics Engineering, Design & Manufacturing	Embedded & Digital Products Custom Electronics Solutions PCB Assembly & Prototyping	Gauteng	OEM	ISO 9001:2015	Control Unit and Processors Driver Interface and Alert Systems GPS Systems
F	Industrial Electronics & PCB Manufacturing	Embedded & Digital Products	Gauteng	OEM	ISO 9001:2015 IPC-J-STD-001-Class 2 and 3 (Workmanship)	GPS Systems Control Unit and Processors
		IoT & Smart Devices		Tier 2	IPC-A-610-Class 2 and 3	System Software and Analytics
G	Alarm & Monitoring Equipment	Alarm & Monitoring Systems	Gauteng	OEM Tier 1	ICASA SABS Approved	Control Unit and Processors System Software and Analytics
H	Electronics Engineering, Design & Manufacturing	PCB & Electronic Hardware	Gauteng	OEM	ISO 9001:2015	Control Unit and Processors
				Tier 1	ISO 14001:2015	
		PCB Assembly & Prototyping		Tier 2	IPC-612	System Software and Analytics
I	Electronics Companies & Custom Solutions	PCB & Electronic Hardware	Western Cape	OEM Tier 1	IATA – International Air Transport Association ISO 9001:2015	Control Unit and Processors
J	Electronic Manufacturing Services	Sensors & Industrial Electronics	Gauteng	OEM Tier 1	ISO 9001:2015 ISO 45001: 2018	V2V Communication Modules System Software and Analytics
K	Prototyping & Product Development	PCB Assembly & Prototyping Embedded & Digital Products	Free State	OEM Tier 2	ISO 9001:2015	Control Unit and Processors
L	Electronic Manufacturing Services	PCB Assembly & Prototyping	Gauteng	Tier 2	IPC J-STD-001 IPC-A-600	Control Unit and Processors
M	Electronic Manufacturing Services	PCB & Electronic Hardware	Gauteng	OEM	ISO 9001:2015	Control Unit and Processors

Company	Company Offering	Products	Province	Company Type	Quality Rating	Potential Application
N	Electronics Engineering, Design & Manufacturing	Embedded & Digital Products	Gauteng	OEM	ISO 9001:2015 IPC-A-610	Control Unit and Processors
		PCB & Electronic Hardware		Tier 1	IPC J-STD-001 IPC-7711/7721	System Software and Analytics
		Electronic Components & Devices		Tier 2	WHMA-A-620	
O	Cloud-Based & IoT Systems	IoT & Smart Devices	Gauteng	OEM Tier 1 Tier 2	ISO 9001:2015	Control Unit and Processors Proximity Detection Sensors System Software and Analytics
P	Electronic Manufacturing Services	PCB Assembly & Prototyping	Gauteng	OEM	ISO 9001:2015 ISO 14001:2015 IPC-A-600K	Control Unit and Processors
		Electronic Components & Devices		Tier 2	IPC-612 IPC-6013D	
Q	Industrial Electronics & PCB Manufacturing	Automation & Industrial Control Custom Electronics Solutions	Gauteng	OEM Tier 2	ISO 9001:2015	GPS Systems Braking and Control Actuators
R	Cloud-Based & IoT Systems	RFID & Barcode Solutions	Gauteng	OEM Tier 1 Tier 2	ICASA	Proximity Detection Sensors System Software and Analytics
S	Electronics Engineering, Design & Manufacturing	Embedded & Digital Products Custom Electronics Solutions	Gauteng	OEM Tier 2	ISO 9001:2015 ISO 45001: 2018	Control Unit and Processors System Software and Analytics