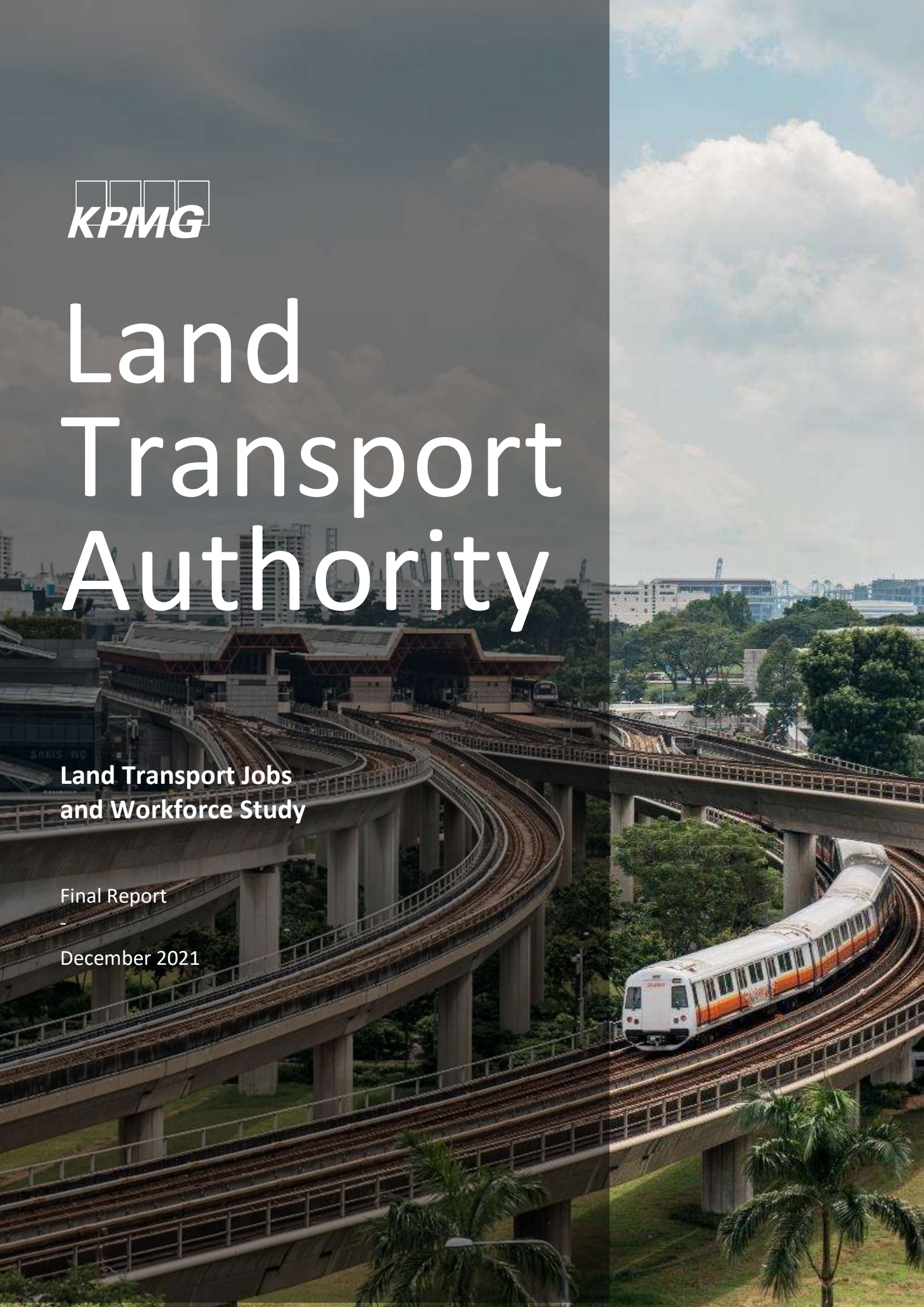

KPMG

Land Transport Authority

Land Transport Jobs and Workforce Study

Final Report

-

December 2021

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IMPACT OF TECHNOLOGY TRENDS ON LAND TRANSPORT INDUSTRY

INDUSTRY 4.0 (I4.0)

Industry 4.0 (I4.0) is the current trend of smart automation and data exchange and it includes different technological pillars such as Big Data and Analytics, Cloud Computing, Advanced Robotics, Internet of Things (IoT), Cybersecurity and more.

The proliferation of I4.0 in land transport has permeated many facets within the industry today, changing day-to-day tasks, eliminating the need of manual works and modifying current processes to be more efficient.

ELECTRIC VEHICLES (EVs)

Given Singapore government's mandate to replace all ICE vehicles with greener vehicles by 2040 and commitment to install 60,000 charging points by 2030, EVs and its technology will arrive quickly.

AUTONOMOUS VEHICLES (AVs)

Given AV is still in its nascent stage with ongoing trials in the local scene, there could be increased opportunities for progress to attain level 4/5 commercialization in the next 20 years or beyond which may bring in new AV technologies. Should this happen, increased investment would be expected in building corresponding capabilities.

New I4.0 Rail job roles

- Data Analyst

New EV job roles

- EV Technician
- Charging Infrastructure Electrician

New AV job roles

- AV Onboard Safety Operator
- AV Maintenance Technician
- AV Fleet Manager

Impact of I4.0 on existing Rail job roles

- HIGH on 4 job roles → Displacement
- MEDIUM on 8 job roles → Redesign
- LOW on 6 job roles → Incremental change

Impact of EV on existing job roles

- MEDIUM on 5 job roles → Redesign
- LOW on 2 job roles → Incremental change

Impact of AV on existing job roles

- HIGH on 2 job roles → Displacement
- MEDIUM on 2 job roles → Redesign

Impact of I4.0 on Rail job tasks

I4.0 WILL AUTOMATE

- Manual, labour intensive tasks in operations and maintenance (e.g. track inspection, monitoring)
- Administrative, scheduling (e.g. maintenance scheduling, report writing, duty rostering)
- Inventory tracking and supply chain management (e.g. inventory management)

EXPERTISE AREAS:

- Data usage and analytics
- Robotics and Automation
- Predictive maintenance
- Cybersecurity

Impact of EV on job tasks

EV WILL AUGMENT

- Fundamental technology in repair and maintenance of EVs (e.g. High voltage, batten modules, electric drivetrain)
- Component replacing compared to repairing, less frequent maintenance schedules

EV WILL SUPPLEMENT

- Driving with adaptation to regenerative braking and acceleration

EXPERTISE AREAS:

- Diagnostic testing
- Electrical-based maintenance
- High-voltage work safety environment

Impact of AV on job tasks

AV WILL AUTOMATE

- Driving with driverless technology

AV WILL AUGMENT

- Fundamental technology in repair and maintenance of AVs (e.g. Automatic vehicle control, network and vehicular communications, perception sensor)

EXPERTISE AREAS:

- Diagnostic testing
- Sensors and perception system
- Automatic control system
- Network vehicular communication systems

New I4.0 Rail job skills

- Data and Statistical Analytics
- Data Usage and Implementation
- Innovation Management
- IoT Application
- Robotics and Automation Application
- Sensor Monitoring Management
- Technology Application

New EV job skills

- EV Dashboard Diagnostic
- Battery System Maintenance
- Electric Drivetrain System Maintenance
- High Voltage System Maintenance
- EV Fleet System Planning

New AV job skills

- AV Operations
- AV Equipment and System Operation
- AV Dashboard Diagnostic
- Automatic Vehicle Control System
- General Control System
- Network and Vehicular Communications
- Perception System Sensor Diagnostic and Replacement
- Remote Diagnostic Recovery Management
- AV Planning and Route Management
- AV Remote Control and Management

1. Executive Summary

The Land Transport Authority ("LTA") of Singapore has commissioned KPMG Services Pte Ltd ("KPMG Singapore") to conduct a Land Transport Jobs and Workforce Study ("Study"). The aim of the Study is to understand key technology and social trends' impact on key land transport job families and corresponding skills and workforce requirements in the near, medium and long term.

This report provides an assessment of the current demographics of the land transport workforce, the demand and supply factors affecting the industry, and the impact on relevant jobs and skills in the immediate (5 years from now), medium (10 years from now) and long term (20 years from now). There will also be high level recommendations for possible interventions such as job transitions, skills upgrading and pipeline resourcing to address any skill gaps or manpower changes identified.

Land Transport Industry Overview

The Land Transport Industry is critical to the provision of land transport in helping to service, operate, maintain the main modes of transportation in rail, bus, point-to-point (P2P) and motor workshop segments.

The total number of companies in the Land Transport Industry is approximately 3,000, and the workforce size is estimated at 100,000. Self-employed persons (i.e. taxi and Private Hire Car drivers) from the P2P segments, makes up of 65% of the workforce with 10% and 25% of the workforce coming from the rail and bus segments respectively.

Jobs impact analysis

Industry 4.0 and Impact on Rail Jobs Segment

Industry 4.0 (I4.0) entails the digitalisation of industrial production and it is implemented in land transport through the Intelligent Transport System (ITS) and various Internet-of-Things (IoT) applications in Singapore. These technologies can improve productivity and reliability in operations and maintenance of transport systems and reduce manual tasks for related job roles.

In the short term of 5 years, I4.0 will likely reduce manual, labour-intensive tasks in the rail landscape through automation, particularly in the operations and maintenance (O&M) phase such as track inspection, inventory tracking, scheduling and documentation. Specifically, the use of robotics and automation will complement O&M verticals of transportation and improve overall maintenance productivity and reliability such as automation of maintenance works at depots, drones for structure integrity inspections, machine learning for preventive maintenance of rolling stock and Robotics Process Automation (RPA) for documentation works in corporate functions such as HR and Finance. More value-adding tasks such as strategic planning, business solutioning and innovation management will remain necessary and enhanced by technology.

As trains become automated and driverless, 4 job roles, namely Train Captains, Crew Managers, Customer Service Officers/ Rover and Communication Controllers are projected to have a high possibility of job displacement or redundancy. The actual transition will be dependent on easing

concerns for service delay and associated perception on reliability and availability. 8 job roles such as rail technicians, service controllers, station managers and others are projected to face job redesign as their core tasks would be largely complemented and augmented by data driven technologies. 6 job roles held by rail engineers are projected to see lower degree of change hence only undergo incremental changes.

Electric Vehicles and Impact on Bus, P2P and Motor Workshops Jobs Segment

By 2040, all vehicles across the bus, and P2P segments are mandated to be run on cleaner energy. As a result, EVs will be seen adopted in more bus and P2P operations raking up demand for EV and associated charging infrastructure support. In the next 10 years, the current tasks performed by bus technicians, bus engineers, car mechanics for maintenance would be largely augmented by Electric Vehicles (EV) technologies and will be vastly different from Internal Combustion Engine (ICE) vehicles due to different components required. The repair and maintenance regimes for EVs will also be focused on components replacements and become less frequent. Operating of EVs by bus drivers and taxi/ Private Hire Car (PHC) drivers are projected to remain largely unchanged as only slight differences in braking and acceleration is observed. EV charging infrastructure supporting EV adoption will also require installation and maintenance. EV bus operations will have to include fleet management of EV buses together with the ICE buses.

Consequently, 5 job roles such as bus technicians, bus engineers, interchange officers, controllers and car mechanics are projected to have a possibility of job redesign while 2 job roles such as bus captains, taxi/ PHC drivers are projected to undergo low degree of impact hence only facing incremental job changes.

Autonomous Vehicles and Impact on Bus, P2P and Motor Workshops Jobs Segment

In Singapore, Autonomous Vehicle (AV) are expected to remain in the pilot stage between 2020 and 2030 as trials are currently conducted at level 4 in public transport. While self-driving and automated vehicles are not projected to hit mainstream in Singapore until after 2040, when it does, vehicle operations (driving) of vehicles may eventually be displaced. Driving task may shift to customer service, high level supervision and emergency and accident management. Job roles with high degree of interactions with technical systems (e.g. drive train, network vehicular communication and sensors and perception systems) would require augmenting of maintenance regimes and installation support.

Consequently, 2 job roles such as bus captain and taxi/ PHC drivers may be at risk due to driverless technology. While 2 job roles such as bus technician and car mechanics may face job redesign to build capabilities for AV technologies.

Skills Impact Analysis

Due to I4.0's automation and technology, some skills would have to be improved and upgraded to fulfil I4.0 job tasks while some skills associated with more manual, repetitive and labour-intensive tasks such as data entry, documentation, report generation, supply chain management or ticketing are projected to face a decline. Please see figure 1 for illustration.

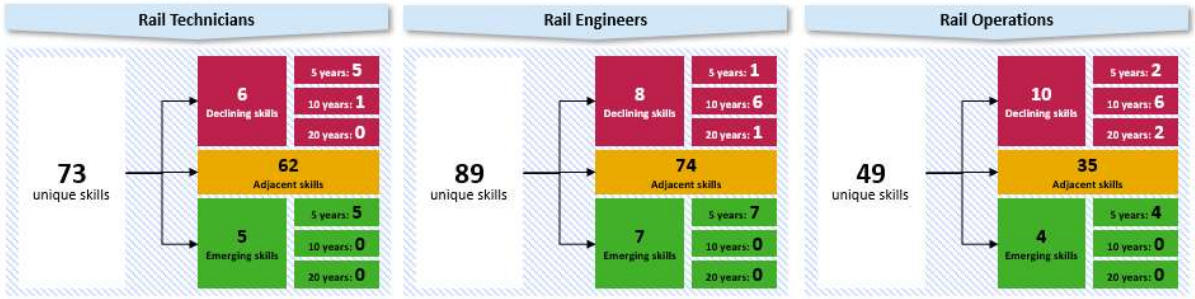


Figure 1: Skills changes for Rail job families

Due to emergence of EVs, maintenance and repair skills would have to be upgraded to better support EVs while driving related skills may only experience minimal changes specifically to braking and accelerating. However, with adoption of AV technologies, skills related to maintenance of AV specific systems and equipment will be emerging such as sensors and perception, network vehicular communication and automatic control systems. Please see figure 2 to 4 for illustration.

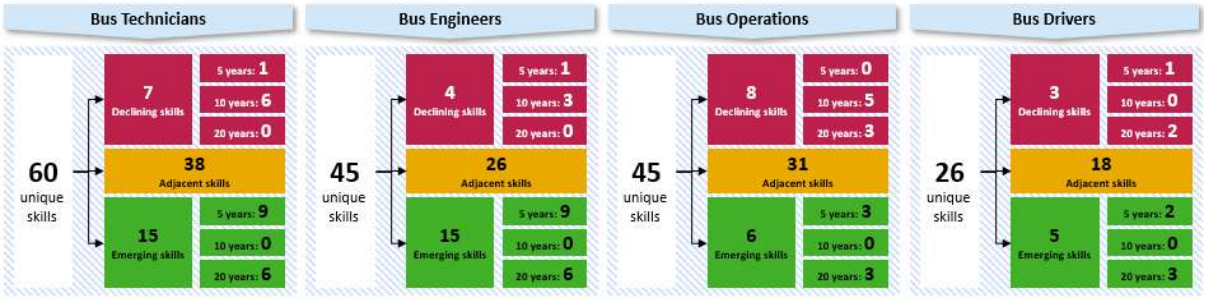


Figure 2: Skills changes for Bus job families

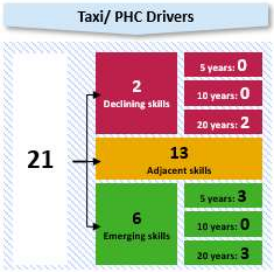


Figure 3: Skills changes for Taxi/ PHC drivers job family

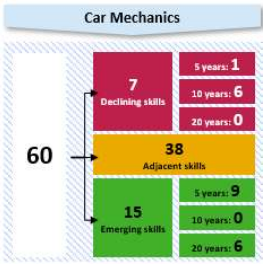


Figure 4: Skills changes for Car Mechanics job family

Aging Workforce and Foreign Dependency

With an ageing workforce whereby a majority of Bus Captains, Taxi Drivers and Car mechanics are aged 55 and above, and with younger locals being less inclined to join due to negative perceptions of the industry, employers face increasing challenges with recruitment. Despite the higher statutory retirement age at 67, ageing employees and lower replacements are continuously putting pressure on labour supply. In light of this situation, re-skilling would be required to train older workers in adapting to new technologies and maintaining their productivity in the workforce. Initiatives to provide a more inclusive and age-friendly work environment will have to be looked into as well.

High dependency on foreign employment is prevalent in Singapore in certain job families such as bus captains and car mechanics as these roles are not sufficiently filled by Singaporeans. With a drive to increase local workforce to enhance resiliency, significant local manpower supply will need to be recruited to fill this gap. Locals will also have to be upskilled in areas relating to new technologies with the advent of EVs and AVs to prepare them for higher level work in place of foreign workers. As such, the Singapore government and Institutions of Higher Learning (IHL) play a vital role in creating industry awareness. This could come in the form of industry workshops, outreach events, land transport career fairs as well as incentive schemes to attract the locals.

Mobility shifts and new travel preferences will change commuting patterns. The COVID-19 pandemic has severely disrupted public transport ridership due to mobility restrictions arising from the circuit breaker and shifts to remote working arrangements. This has had cascading effects on the Land Transport Industry and the employees in relevant job roles. In the future, given Singapore's ambition to become a car-lite society, mass transit will form the backbone of commuting in Singapore. However, plans for decentralised workforce, enabled flexible working arrangements with collaborative platforms and convenience of home-based services will reduce overall mobility needs. As commuter travel patterns and market dynamics change, transport operators will need to rethink their business models and leverage on adjacencies.

2 Introduction

2. Introduction

The Land Transport Authority ("LTA") of Singapore has commissioned KPMG Services Pte Ltd ("KPMG Singapore") to conduct a Land Transport Jobs and Workforce Study ("Study"). The aim of the Study is to understand key technology and social trends' impact on key land transport job families and corresponding skills and workforce requirement in the near, medium, and long term.

The information contained in this report is a synthesis of data and observations gathered from the quantitative survey, stakeholder interviews, focus group discussions and desktop research. Unless otherwise stated, the terms "Public Transport" refers to public bus, mass rapid transit and light rail transit services that are available to the public, that run on fixed routes and are charged at predetermined distance-based fare rates, "Point-to-Point (P2P) Transport" refers to taxi, private hire cars (PHC), rideshare and third-party taxi booking services that provide point-to-point passenger transport services for a fare while "Motor Workshops" refer to private workshops that hire car mechanics who repair and maintain motor vehicles.

2.1 Objective and Scope

The objective of the Study is to analyse the impact of key technological and social trends on 9 key job families identified in the immediate, medium, long term and whether these jobs will change incrementally, be redesigned or displaced. Adjacent roles may be an option for easy transition for these jobs. An assessment of the emerging skills required to perform identified new job roles and tasks, adjacent skills for relevant job roles and tasks and declining skills for at-risk jobs will be conducted as well. Thereafter, high level recommended interventions to address skill gaps will be provided.

The scope of the Study involves the gathering and analysis of information about the Industry. This includes its current state, skills and training needs, career progression pathways, and the high-level recommendations to support the overall manpower development plans and training for the Land Transport Industry.

Specifically, this Study covers 9 key land transport job families that fall under the rail, bus, P2P and motor workshops segments, namely rail technicians, rail engineers, rail operations, bus drivers, bus technicians, bus engineers, bus operations, taxi/ PHC drivers and car mechanics. A new job family including future jobs identified from emerging key technologies will also be covered in Section 4.7 Detailed analysis - New Job Roles.

2.2 Study Methodology

The Study utilised a multi-pronged approach, involving a quantitative survey, in-depth stakeholder qualitative interviews, focus group discussions and desktop research, to collect data along the following key dimensions:

a. Factors in macro-environment shaping the Industry;
b. Trends and issues in manpower supply and demand;
c. Demographics of the land transport workforce; and
d. Investment in technology.

2.3 Stakeholder Groups

To ensure that a holistic and comprehensive view is taken into consideration, the following 8 stakeholder groups were engaged for the Study:

a. Rail, bus and P2P service providers, motor workshops;
b. Government agencies/ regulators;
c. Institutes of Higher Learning (IHLs)/ research institutes;
d. Students;
e. Manufacturers and suppliers;
f. Unions and associations;
g. Transport infrastructure companies; and
h. Workers.

In addition, face to face interviews were conducted with key management staff from 8 service providers, 5 regulators and government agencies, 8 unions, 9 suppliers, 4 transport infrastructure companies. 10 Institutes of Higher Learning (IHLs) and Research Institutes were also interviewed along with 3 employee focus group discussions (FGDs) and 4 student focus groups.

3 Industry Overview

3. Land Transport Industry Overview

This section provides an overview of the key characteristics of the Land Transport Industry and articulates the trends, challenges, and opportunities of the Industry. The information and analysis presented here are based on the quantitative survey, qualitative interviews and focus group discussions with stakeholders, feedback from LTA, as well as KPMG's desktop research.

The Land Transport Industry undertakes the service and operation of the land transport system in Singapore including public and P2P transport systems. This includes four main jobs segments directly supporting the operations and maintenance of public service delivery, namely rail, bus, P2P. The study also covered motor workshops as this is an important supporting segment that needs to be transformed to support the vehicle electrification roadmap.

There are approximately 3,000 companies in the Land Transport Industry. Figure 5 shows the breakdown of the operations and maintenance workforce in the different land transport and related segments.

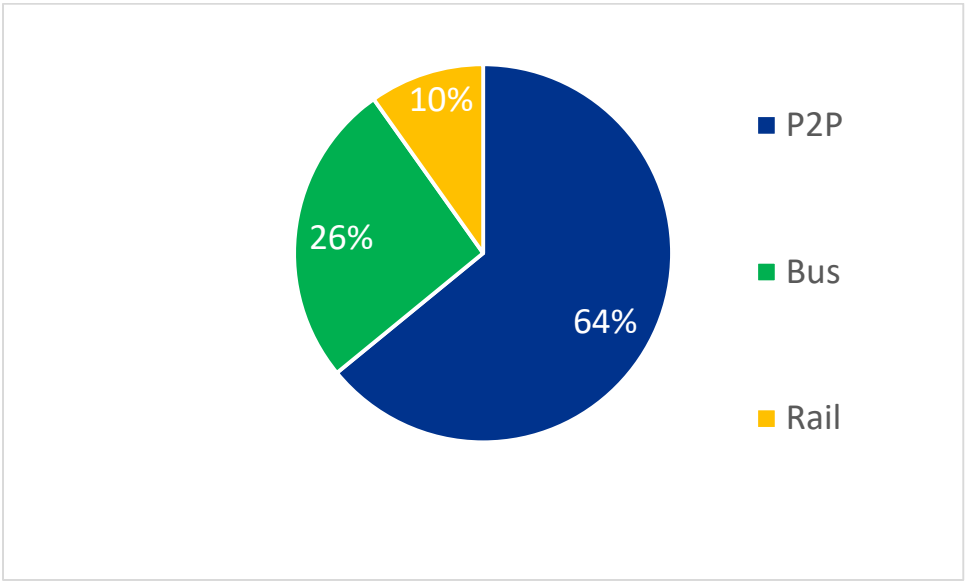


Figure 5: Breakdown of workers in different Land Transport and related segments excluding administrative, contracts, HR, IT, finance, marketing

The subsequent sections will provide the current job descriptions, core job tasks and job skills of each job role within each job family. Overall, insights on workforce demographics, key trends and challenges will be included for each segment. Majority of the insights were derived from aggregated responses from the land transport manpower survey and interviews administered by KPMG, as aforementioned.

3.1 Jobs, skills and workforce landscape – Rail

3.1.1 Workforce demographics for Rail

Workforce size and Age

Within the rail segment, there are more than 9,000 workers are in rail operations and maintenance, with a majority in technical maintenance roles such as engineers and technicians while non-technical roles like rail operations make up less than half of the workforce.

The rail workforce is relatively younger, with a median age of 40.

Education level

Out of those with specific academic qualifications such as polytechnic diploma and bachelor's degree, the relevant disciplines are in areas such as electrical, mechanical, and power engineering. Although not mandatory, there are professional certifications and accreditations for engineers such as Chartered Engineers, Licensed Electrical Workers that are recognised given that these certificates level up the workforce with the necessary skillsets.

3.1.2 Rail Engineers

Rolling stock/ Engineering Train

Description:

The Assistant Engineer/ Senior Engineer/ Engineer (Rolling Stock/ Engineering Train) supervises the team in performing preventive and corrective maintenance work on passenger/ engineering trains and plans the maintenance work activities. He provides technical advice, proposes recommendations to workflow improvements and supervises complex issues pertaining to fault analyses and testing. He manages the team's performance and external contractors and ensures their safety and work quality. Senior level engineers for this function leads cross-functional teams in maintenance work involving trains. He establishes competency and engineering standards for staff.

Core job tasks:

1. Apply rolling stock/ engineering train technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on passenger/ engineering trains
3. Provide technical guidance and on-the-job coaching to the team
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors

Core job skills:

- Rolling Stock Auxiliary Systems, Power Systems, Propulsion Systems Maintenance
- Condition-Based Assets Monitoring Management
- Multi-function Vehicle, Track Tamping Vehicle, Locomotive Maintenance

- Workplace Facilities Safety Management
- Systems Engineering Thinking

Permanent Way and Civil Structure

Description:

The Assistant Engineer/ Senior Engineer/ Engineer (Permanent Way and Civil Structure) supervises the team in performing preventive and corrective maintenance work on train tracks, railway reserves and buildings and plans the maintenance work activities. The engineer provides technical advice, supervises complex issues and is adept in using various test equipment for the maintenance of permanent ways and civil structures. He also manages the team's performance and external contractors and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in the maintenance work involving train tracks, railway reserves and buildings. The lead establishes competency and engineering standards for staff.

Core job tasks:

1. Apply permanent way and civil structure technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses and testing.
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on permanent way and civil structures.
3. Provide technical guidance and on-the-job coaching to the team.
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors.

Core job skills:

- Rail Track Inspection and Maintenance
- Civil Structure and Third Rail Maintenance
- Condition-Based Assets Monitoring Management
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

Power

Description:

The Assistant Engineer/ Senior Engineer/ Engineer (Power) supervises the team in performing preventive and corrective maintenance work on rail power systems. The engineer provides technical analysis, supervises complex rail power systems issues. The engineer also proposes workflow improvements to improve the maintenance regime of the rail power systems, manages the team's performance and external contractors, and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in collaborative work to support rail power

systems maintenance and enhancement. He establishes competency and engineering standards for staff.

Core job tasks:

1. Apply power engineering technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing.
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on rail power systems.
3. Provide technical guidance and on-the-job coaching to the team.
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors.

Core job skills:

- High/ Low Voltage Power Systems Maintenance
- Condition-Based Assets Monitoring Management
- Work at Heights
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

Mechanical and Electrical

Description:

The Assistant Engineer/ Senior Engineer/ Engineer (Mechanical and Electrical) supervises the team in performing preventive and corrective maintenance work on mechanical and electrical systems. The engineer proposes workflow improvements to improve the reliability of the mechanical and electrical systems. He also manages his team's performance and external contractors and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in maintenance work involving mechanical and electrical systems. He establishes competency and engineering standards for staff.

Core job tasks:

1. Apply mechanical and electrical technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing.
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on mechanical and electrical systems.
3. Provide technical guidance and on-the-job coaching to the team.
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors.

Core job skills:

- Escalator, Travellator, Air Conditioning, Ventilation Systems Maintenance

- Fire Protection Systems Maintenance
- Condition-Based Assets Monitoring Management
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

Signal and Communications

Description:

The Assistant Engineer/ Senior Engineer/ Engineer (Signal and Communications) supervises his/her team in performing preventive and corrective maintenance work on signal, communication and control systems. The engineer provides technical advice to team members, supervises complex maintenance issues pertaining to fault analyses and testing of signal, communication and control systems. The engineer contributes to workflow improvements to enhance the reliability of the signal, communication and control systems, manages his team's performance and external contractors, and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in maintenance work involving signal, communication and control systems. He establishes competency and engineering standards for staff.

Core job tasks:

1. Apply signal and communication technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing.
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on signal, communication and control systems.
3. Provide technical guidance and on-the-job coaching to the team.
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors.

Core job skills:

- Communication Auxiliary Systems, Communication Backbone System, Communication Power System Maintenance
- Emergency and Security Communication System Maintenance
- Condition-Based Assets Monitoring Management
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

Automatic Fare Collection

Description:

The Assistant Engineer/ Senior Engineer/ Engineer (Automatic Fare Collection) supervises the team in performing preventive and corrective maintenance work on Automatic Fare Collection (AFC) systems.

The engineer proposes workflow improvements to improve the reliability of the AFC systems, manages the team's performance and external contractors, and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in maintenance work involving AFC systems. He establishes competency and engineering standards for staff.

Core job tasks:

1. Apply automatic fare collection technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing.
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on AFC systems.
3. Provide technical guidance and on-the-job coaching to the team.
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors.

Core job skills:

- Automatic Fare Collection Auxiliary Systems, Automatic Fare Collection Gate Maintenance
- Automatic Fare Collection Sales Device Maintenance
- Condition-Based Assets Monitoring Management
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

3.1.3 Rail Technicians

Rolling stock/ Engineering Train

Description:

The Technician/ Senior Technician (Rolling Stock/ Engineering Train) performs preventive and corrective maintenance on passenger/ engineer trains through deployment of engineering trains in the main line and assisting in the conduct of fault analysis, repair and modifications of electronics, electrical and mechanical equipment and train systems. The technician also assists in the preparation of tools, equipment and checklist required for maintenance activities, supervises the work of contractors and external stakeholders in ensuring compliance to safety requirements and operating standards.

Core job tasks:

1. Perform preventive maintenance on passenger and engineering trains through deploying engineering trains in the main line and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures.
2. Perform corrective maintenance through conducting repair and modifications of electronics, electrical and mechanical equipment and passenger and engineering train systems.
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.

4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.

Core job skills (non-exhaustive list):

- Rolling Stock Auxiliary Systems, Power Systems, Propulsion Systems Maintenance
- Condition-Based Assets Monitoring Management
- Engineering Train and Rolling Stock Operation
- Multi-function Vehicle, Track Tamping Vehicle, Locomotive Maintenance
- Workplace Facilities Safety Management

Permanent Way and Civil Structure

Description:

The Technician/ Senior Technician (Permanent Way and Civil Structure) performs preventive and corrective maintenance of civil structures, train tracks and/or third rail. The technician operates engineering trains to support rail track maintenance, conducts trouble shooting, fault analysis and repair of electrical and mechanical track equipment and systems, performs track-walk inspections and assists in the inspection and general maintenance of train stations and depot buildings. The technician operates various types of engineering work trains and train mounted equipment to aid in the maintenance of train tracks, train tunnels and various rail structures. The technician also supervises contractors and external stakeholders in ensuring adherence to work and safety standards.

Core job tasks:

1. Perform preventive maintenance on civil structures, train tracks and third rail through deploying engineering trains and train-mounted equipment on rail tracks and performing track-walk inspections, and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures.
2. Perform corrective maintenance on train tracks and/or third rail through conducting repair of electrical and mechanical track equipment and systems.
3. Perform general maintenance on civil infrastructure, including train stations and depot buildings.
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.

Core job skills (non-exhaustive list):

- Rail Track Inspection and Maintenance
- Civil Structure and Third Rail Maintenance
- Condition-Based Assets Monitoring Management
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

Power

Description:

The Technician/ Senior Technician (Power) performs preventive and corrective maintenance of rail power systems through assisting in pre-maintenance activities including preparation of tools and equipment and carries out workplace safety measures as required. The technician identifies and rectifies rail power systems faults, tests power equipment, and performs general housekeeping tasks. The technician also provides technical guidance and on-the-job coaching to the team. The technician also supervises the work of contractors and external stakeholders in ensuring adherence to safety requirements and operating standards.

Core job tasks:

1. Perform preventive maintenance of rail power systems and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures.
2. Perform corrective maintenance through identifying and rectify rail power system faults to operational conditions.
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.

Core job skills (non-exhaustive list):

- High/ Low Voltage Power Systems Maintenance
- Condition-Based Assets Monitoring Management
- Rail Regulatory Compliance
- Work at Heights
- Workplace Facilities Safety Management

Mechanical and Electrical

Description:

The Technician/ Senior Technician (Mechanical and Electrical) performs preventive and corrective maintenance of mechanical and electrical systems at various rail premises. The technician assists in the preparation of maintenance work, performs routine maintenance, conducts fault analysis and testing to improve the reliability of mechanical and electrical systems. The technician also provides technical guidance and on-the-job coaching to the team. The technician also supervises the work of contractors and external stakeholders in ensuring compliance to safety requirements and operating standards.

Core job tasks:

1. Perform preventive maintenance of mechanical and electrical systems and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures.
2. Perform corrective maintenance through conducting repair and modifications of electronics, electrical and mechanical equipment and mechanical and electrical systems.
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.

Core job skills (non-exhaustive list):

- Escalator, Travellator, Air Conditioning, Ventilation Systems Maintenance
- Fire Protection Systems Maintenance
- Condition-Based Assets Monitoring Management
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

Signal and Communications

Description:

The Technician/ Senior Technician (Signal and Communications) performs preventive and corrective maintenance of signal, communication, and control systems to improve the reliability of signal, communication, and control systems. The technician assists in maintenance activities, is adept in handling electronics and computer-based systems and equipment for maintenance and provides technical guidance and on-the-job coaching to the team. The technician also supervises the work of contractors and external stakeholders in ensuring adherence to operating requirements and safety standards.

Core job tasks:

1. Perform preventive maintenance of signal, communication and control systems and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures.
2. Perform corrective maintenance through conducting repair and modifications of electronics and computer-based systems and equipment needed for signal, communication, and control systems.
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.

Core job skills (non-exhaustive list):

- Communication Auxiliary Systems, Communication Backbone System, Communication Power System Maintenance

- Emergency and Security Communication System Maintenance
- Condition-Based Assets Monitoring Management
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

Automatic Fare Collection

Description:

The Technician/ Senior Technician (Automatic Fare Collection) performs preventive and corrective maintenance of Automatic Fare Collection (AFC) Line Replacement Units (LRUs). The technician is responsible for the preparation of materials, tools, equipment, and checklists required, conduct of fault analysis and testing to improve the reliability of the AFC systems. The technician also provides technical guidance and on-the-job coaching to his team and supervises the work of contractors and external stakeholders in ensuring compliance to safety requirements and operating standards.

Core job tasks:

1. Perform preventive maintenance on AFC LRUs and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures.
2. Perform corrective maintenance through conducting fault analysis and repair of AFC systems.
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.

Core job skills (non-exhaustive list):

- Automatic Fare Collection Auxiliary Systems, Automatic Fare Collection Gate Maintenance
- Automatic Fare Collection Sales Device Maintenance
- Condition-Based Assets Monitoring Management
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

3.1.4 Rail Operations

Train Service/ Traffic/ Train Controller

Description:

The Train Service Controller/ Depot Train Controller/ Depot Traffic Controller/ Chief Controller/ Controller/ Operations Control Centre (OCC) Manager/ Head monitors, controls, regulates, and manages train services in real-time in the OCC to provide regular and efficient train services, and directs the movement of trains within the depot. He coordinates with operations and maintenance centres across the rail network to manage activities for daily train services and implements service

recovery measures during rail incidents and/or accidents. He manages track access to ensure the protection and safety of maintenance personnel and coordinates with relevant internal and external stakeholders to execute first-line recovery of trains during train service disruptions.

Core job tasks:

1. Monitor and control train services in real-time and related daily activities.
2. Implement and execute service recovery measures during rail emergencies and incidents.
3. Provide technical guidance and on-the-job coaching.
4. Establish and ensure workplace safety standards and competencies.

Core job skills (non-exhaustive list):

- Civil Emergency, Rail Emergency Response, Rail Incident Management
- Rail Operations Control/ Train Depot Control Management
- Service Orientation and Excellence
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

<u>Station/ Service/ Station Operations/ Train Operations Manager</u>

Description:

The Assistant Station Manager/ Senior Station Manager/ Station Manager/ Deputy Station Manager/ Rail Service Manager/ Service Operations Manager/ Duty Operations Manager/ Station Operations Manager/ Train Operations Manager supports the day-to-day operations of the train station, which includes preparing the station for rail service, conducting security patrols at station premises and on train platforms, providing customer service, and performing duties in the Passenger Service Centre. Senior positions are responsible for the achievement of rail service and station operations performance standards, recommends and implements continuous improvement initiatives to enhance overall rail services, coordinates improvement initiatives for station facilities and implements security measures.

Core job tasks:

1. Monitor train station operations.
2. Implement and execute service recovery measures during rail emergencies and incidents.
3. Provide technical guidance and on-the-job coaching.
4. Establish and ensure workplace safety standards and competencies.

Core job skills (non-exhaustive list):

- Civil Emergency, Rail Emergency Response and Rail Incident Management
- Security and Crowd, Train Fare and Ticket Management
- Passenger Train Operations, Train Station Operations Management

- Service Excellence and Orientation
- Workplace Facilities Safety Management

Communication Controller

Description:

The Communication Controllers keeps track of daily rail operation activities and supports the Operations Control Centre (OCC) in executing its tasks and requirements by monitoring passenger activities and train operations via close-circuit television (CCTV) and communication and alert systems, to provide train service information and updates to commuters and the public.

Core job tasks:

1. Monitor passenger activities and train operations.
2. Provide real-time train service information and updates.
3. Perform documentation and reporting.
4. Implement and execute service recovery measures during rail emergencies and incidents.

Core job skills (non-exhaustive list):

- Rail Operations Control Management
- Rail Emergency Response, Rail Incident Management
- Security Management
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

Customer Service Officer/ Rover

Description:

The Customer Service Officer/ Rover supports the daily train services and operations, which includes conducting patrols on passenger trains and at station premises to ensure the operability of equipment, performing first-line recovery of train and station equipment malfunctions, and serving as an emergency train operator.

Core job tasks:

1. Conduct patrol, crowd and security management on passenger trains and station premises.
2. Conduct recovery of train and station equipment in malfunction.
3. Manage and address service challenges of passengers.
4. Implement and execute service recovery measures during rail emergencies and incidents.

Core job skills (non-exhaustive list):

- Civil Emergency, Rail Emergency Response, Rail Incident Management
- Crowd and Security Management
- Passenger Train Operations, Train Station Operations Management
- Service Excellence and Orientation
- Workplace Facilities Safety Management

Train Captain

Description:

The Train Captain operates passenger trains to provide a safe, reliable, and efficient commute for passengers and to achieve the overall train service standards. The captain is well-versed in train operations and the functions of train-borne systems and equipment, monitors and analyses the train operations from the cabs of the trains in order to make quick and sound operational decisions to maintain and improve train service standards and reliability.

Core job tasks:

1. Operate passenger trains and meet overall train service standards.
2. Maintain communication with the Operations Control Centre (OCC).
3. Maintain passenger safety onboard of trains.
4. Implement and execute service recovery measures during rail emergencies and incidents

Core job skills (non-exhaustive list):

- Civil Emergency, Rail Emergency Response, Rail Incident Management
- Crowd and Security Management
- Passenger Train Operations
- Service Excellence and Orientation
- Workplace Facilities Safety Management

Crew Manager

Description:

The Crew Manager manages the daily operations and duties of Train Captains through preparation of duty rosters, deploying resources, ensuring discipline, well-being, and performance standards of Train Captains. The manager is well-versed with train service operations and service standards and is required to execute crew reformation and deployment plans to maintain train service standards and reliability, as well as safety standards of train operations.

Core job tasks:

1. Prepare duty rosters and ensure deployment of Train Captains.

2. Oversee the performance and well-being of Train Captains.
3. Execute crew reformation and deployment plans to comply with train service and safety standards.
4. Conduct corrective actions on performance of Train Captains.

Core job skills (non-exhaustive list):

- Civil Emergency, Rail Emergency Response, Rail Incident Management
- Innovation and Inventory Management
- Service Excellence and Orientation
- Rail Regulatory Compliance
- Workplace Facilities Safety Management

3.1.5 Key trends and challenges impacting Rail

Industry 4.0 (I4.0)

I4.0 refers to the digitalisation of industrial production, which will revolutionise the transport industry. With an aim towards developing Rail 4.0, the government has shown commitment towards embracing I4.0 and Internet-of-Things (IoT) to transform the Land Transport Industry. IoT-related technologies will be developed and implemented by transport providers in Singapore.

Given that the rail length and rolling stock are forecasted to almost double by 2040 according to LTA's Land Transport Master Plan, I4.0 advancements will improve productivity and reliability in operations and maintenance of systems. Particularly, predictive maintenance leverages on big data analytics, allowing the prediction of future failures in asset performance and prescribing the most effective preventive measure. Through advanced data analytic techniques, technical condition, usage, environment, maintenance history and equipment resourcing can be provided. This will bring about a reduction of manhours for related job roles. It will also bring new employment opportunities and require reskilling to effectively leverage upon data-driven systems and sensor technology.

Key transport providers in Singapore such as SMRT Trains, SBS Transit and ComfortDelGro[1] are currently innovating and adopting various initiatives to support Rail 4.0:

Condition monitoring

a. Rolling Stock Maintenance Analytics Platform and Platform Screen Doors (PSD) monitoring system – These are used to identify and assess reliability issues with SMRT trains.

1 Sources: SMRT Trains Ltd. Operations Review 2020, SBS Transit Annual Report 2020, ComfortDelGro Annual Report 2020

b. The Integrated Supervisory Control System (ISCS) – This system effectively controls stations, trains, tunnels and depot on the North-East Line and ensures optimal performance and effective train operations.

Artificial Intelligence (AI) and Data Analytics

a. Cloud-based Common Data Environment (CDE).
b. Building up Smart Mobility, Situation Awareness and Predictive Maintenance AI capabilities – e.g. Proof of Value in crowd sensing and automated machine learning Proof of Concept on feedback classification).
c. Centre of Excellence – Set up by SBS Transit in partnership with ComfortDelGro's Digital Office to drive projects to strengthen train operations and enhance reliability of train services (e.g. pre-empting system failures)
d. Data analytics – Used to monitor daily operation of sump pumps in Downtown Line's rail tunnels to prevent occurrence of flooring

Track Access Management System (TAMS)

Single integrated digital platform – To optimise track access allocation planning, prevent human error, and provide real-time updates to enhance maintainability and reliability through a more efficient and optimised track access management of SMRT rail lines. Phase 1 covering North-South and East-West Lines is near completion as of 2020; Phase 2 will cover Circle Line, train depots and Bukit Panjang LRT.

Digital Twin

Virtual replicas of physical systems – Real-world data is taken as input to enable real-time monitoring for proactive intervention and predictive capability across 3 areas: Rail Operations, Stations, and Interchanges, as well as Depot Operations.

Feedback Management

a. Defect reporting systems – Mobile-based iLink and web-based Rail Corrective Mechanism integrated to ensure defects are monitored and addressed more centrally and efficiently
b. Commuter feedback platforms

Ageing Population

Singapore is currently facing an ageing population. In 2020, based on Singstat data, 15.2% of residents were aged 65 years and above, and the resident old-age support ratio (OASR) was at 4.3, indicating a low number of working-age adults replacing ageing workforce. By 2030, 1 in 4 Singaporeans will be aged 65 and older. The median age is estimated to increase by 5 years for every 10 years period, and similarly the median age of the resident population is expected to increase from 42 years old in 2020 to 49 years old in 2040.

Though the rail workforce is relatively younger at a median age of 40, it is projected that ~20% of the rail workers will retire in the next 10 years. Assistive technology could help complement the population in conducting their day-to-day work especially for job tasks that require high levels of manual work.

Job task today	How age will affect job task	Technology	Interventions	Transition pathways
Preventive maintenance	— Declining physical health conditions due to age such as decreased vision, impaired hearing and slower motor reflexes causes difficulties in utilizing tools, navigate confined spaces and conduct delicate repairs for rolling stocks — Cognitive capabilities may also be negatively impacted leading to a decline in quick decision-making during accidents — May face difficulties in climbing and bending to inspect high or low checkpoints and lifting of heavy objects, all activities crucial for rolling stock inspections and repairs	— Redesign workplaces to factor in more safety precautions such as non-slip floors, handles and grips — Assistive technology such as RPA can ensure that train systems data is collected and analysed via centralized systems which will reduce the need for human intervention — Integrated fleet of autonomous robots to allow inspections through HD images and real-time processing	— Conduct more health checks at frequent intervals to identify concerns regarding eyesight, hearing and reflexes prematurely — Collaborate with institutions such as SP and SIT to develop workplace learning programmes comprising bite-sized modules, assessments and chalk up credits and training hours to obtain a rail technology diploma, such that they are supported in working with data and new technology — Identify staff requiring assistance to transition to less hazardous work environments	— Pivot to job roles which are less physical-demanding — Examples of transition jobs: — Driving Instructors — Security guard — Housekeeping and Janitorial Managers — Administrative staff
Corrective maintenance		Integrated fleet of autonomous robots to allow inspections through HD images and real-time processing		
Maintenance scheduling and general workshop housekeeping		Maintenance scheduling and logging systems with more elderly-friendly user interfaces, such as larger fonts and streamlined steps for data input Magnifying glasses to identify and clean equipment and tools more effectively		
Supervision and adherence to safety operating standards		Digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation, streamlining the process of vendor and stakeholder management which reduces human errors		

Table 1: Ageing population in rail technicians/ engineers job families

3.2 Jobs, skills and workforce landscape – Bus

3.2.1 Workforce demographics for Bus

Workforce size and Age

Within the bus segment, there are more than 25,000 workers with about 50% of the workforce in public bus segment.

The public bus segment registered a relatively older workforce with median age of 41-50.

Education level

For bus driver roles, the appropriate class 4 or 4A driving licenses and bus driver's vocational vehicle licenses to operate buses and heavy vehicles are pre-requisite.

The survey also found that for more technical roles such as bus technicians and engineers, most have ITE or Diploma qualifications. The common disciplines include electrical, mechanical, software and materials engineering.

Nationality

There are significantly fewer younger Singaporeans joining the bus segment for roles such as bus captains and bus technicians. They have cited reasons such as the poor perception of land transport jobs and availability of more desirable jobs in terms of flexible workhours (e.g. less restrictive working schedules) and more competitive remuneration packages. As such, foreigners are hired to supplement local supply, resulting in a multi-national workforce. However, the need to build up resiliency to ensure continued delivery of public bus services in the face of border closures experienced during COVID19 has made the need to attract and retain a local bus workforce more pressing.

3.2.2 Bus Engineers

Description:

The Engineer monitors the performance of the bus fleet to ensure operational safety and reliability, identify bus system degradation, diagnose root causes and implement mitigation actions to reduce service downtime. He provides technical advice to bus maintenance team for fleet-wide engineering and maintenance based on in-depth knowledge of bus systems and engineering principles. He conducts engineering studies and sources for technology application to improve bus operations. The Engineering Manager reviews fleet performance audit data to establish fleet engineering and maintenance standards and commissions engineering studies and technology application projects.

Core job tasks:

1. Diagnose root cause of bus system degradation through ICE diagnostic tools and ICE based engineering knowledge; implement improved maintenance or future mitigation actions to slow down system degradation.
2. Provide technical advice to ICE bus maintenance team for complex issues and oversee the maintenance works in complicated cases.
3. Conduct engineering studies for overall ICE equipment and vehicles; source for new technology application applicable to ICE maintenance work for increased efficiency and effectiveness.

4. Review fleet performance audit data to establish standards that are relevant and applicable in today's context.

Core job skills (non-exhaustive list):

- Bus Engine System, Bus Drivetrain Systems, Bus Brake Systems, Bus Steering and Suspension Systems Maintenance
- Bus Air Conditioning Systems, Body Work Maintenance
- Engineering Maintenance and Project Management
- Bus Regulatory Compliance
- Workplace Facilities Safety Management

3.2.3 Bus Technicians

Description:

The Technician/ Technical Specialist performs routine general and/or specific bus sub system servicing and preventive corrective maintenance activities. He prepares work activities, performs assigned servicing and maintenance tasks, performs general housekeeping of workshop tools and equipment, and adheres to Workplace Safety and Health (WSH) procedures. He also supports on-the-road bus breakdown assistance and recovery. The seniors/ masters coordinate the routine scheduled bus maintenance operations of the team/ section, plan and assign daily work tasks, provide technical guidance and on-the-job coaching, and propose workflow improvements. The managers support coordination of cross functional teams, supports budget forecasting, and conducts engineering studies for improvement initiatives.

Core job tasks:

1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance such as oil, filter changing, tire rotations or specific bus sub system servicing such as air condition maintenance, engine system maintenance, mechanical drivetrain system and body work maintenance.
2. Coordinate routine scheduled bus maintenance operations based on last maintenance session and condition of bus vehicles; ensure bus vehicles completes routine maintenance sessions.
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment via a log system and maintenance scheduling system.
4. Support on-the-road bus breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works.

Core job skills (non-exhaustive list):

- Bus Engine System, Bus Drivetrain Systems, Bus Brake Systems, Bus Steering and Suspension Systems Maintenance
- Bus Air Conditioning Systems, Body Work Maintenance
- Bus Recovery and Towing

- Bus Regulatory Compliance
- Workplace Facilities Safety Management

3.2.4 Bus Operations

Interchange/ Depot Officer/Manager/Operations Manager

Description:

The Interchange Officer/ Interchange Assistant performs daily operations at the bus interchange/ bus depot to support the smooth running of bus services to serve passengers through monitoring of bus arrival and departure timings, regulating bus departure timings, redeploying bus captains to operate bus service routes and conducting bus checks to ensure service readiness. He also helps passengers in need of assistance and ensures safety of passengers by performing traffic and crowd control and daily security checks. He provides support to respond to incidents and accidents. He supports compliance management to fulfil organisational and legislative requirements and provides feedback on gaps in operational efficiency to contribute towards continuous improvements. The supervisors/ managers liaise with vendors to carry out contract works, manage the team performance and development, upkeep interchange facilities, prepare contingency plans, implement improvement initiatives, and oversee budget and manpower allocation.

Core job tasks:

1. Perform daily operations at bus interchange/ bus depot such as monitoring and regulating bus arrival and departure timings; driving buses within the interchange/ depot if required.
2. Provide customer service in the interchange such as answering enquiries or providing assistance for commuters, conduct security checks, facilitate traffic, and crowd control.
3. Provide support to emergencies, incidents, accidents in the interchange/ depot for vehicle-related and commuter-related.
4. Support compliance to organisational and legislative requirements and improve ICE bus service performance standards.

Core job skills (non-exhaustive list):

- Bus Interchange, Bus Depot Operations
- Crisis, Change, Crowd Management
- Service Excellence and Orientation
- Bus Regulatory Compliance
- Workplace Traffic Safety Management

Bus Operations Control Centre Controller/ Manager/ Chief

Description:

The Chief Bus Controller/ Bus Operations Control Centre Controller performs daily operations at the Bus Operations Control Centre (BOCC) to ensure bus service reliability on the road. He works closely

with Bus Captains and other stakeholders to regulate bus services in real-time environment to maintain bus service performance standards and minimise service delays. He also provides on-the-job coaching to Bus Captains and is required to respond to emergencies and restore bus service disruptions, assist in investigation and documentation of incidents and/or accidents. He takes on administrative duties in data compilation and contributes towards continuous improvement by providing feedback on gaps observed in operational activities. The manager oversees and supervises the team within BOCC, work with relevant authorities and other stakeholders to uphold and improve bus service performance standards and manages team performance, manpower allocation, training, and budgeting.

Core job tasks:

1. Perform daily operations in BOCC to ensure bus service reliability by regulating bus services in real-time environment, bus monitoring and supervising to ensure bus follows schedules.
2. Provide on-the-job coaching to Bus Captains according to bus service standards by providing constructive advice for service improvements.
3. Provide support to emergencies, incidents, accidents, and bus service disruptions when buses are inside/ outside of interchanges/ depots by providing situation analysis and best approach solution to resolve the crisis.
4. Improve bus service performance standards through consistent reviews and improvements to current practices.

Core job skills (non-exhaustive list):

- Bus Operations Control Management
- Continuous Improvement, Crisis, Change, Resource Management
- Stakeholder and Staff Performance Management
- Bus Regulatory Compliance
- Workplace Safety and Health for Incident and Accident Investigation

3.2.5 Bus Captains

Description:

The Bus Captain operates various bus types on scheduled routes and timetables and performs pre-trip and post-trip bus checks to ensure bus readiness for daily service commencement and routine procedures upon service termination respectively. He works closely with the Bus Operations Control Centre (BOCC) to ensure adherence to scheduled journey timings and to seek support during incidents and/or accidents. He also provides customer service to passengers and contributes towards continuous improvement by providing feedback on gaps in service standards. The Senior Bus Captain assists in assessments for new bus service routes and provides coaching and briefings to guide junior bus captains. The Chief Bus Captain/ Master Bus Captain drives service culture and supports team performance

Core job tasks:

1. Driving and operating of ICE buses on schedule routes and timetables to board and alight passengers at bus stops.
2. Conduct high level checks on bus controls and on-board equipment such as testing bus doors, fare readers and engine to ensure vehicle readiness for service commencement and termination.
3. Provide high quality customer service such as answering enquires, facilitating cash payment or card payment via bus reader devices and assisting disabled or elderly passengers to board and alight from the bus.
4. Work with BOCC to execute crisis management procedures in emergencies or accidents such as ushering passengers to safe points or follow up of journey continuation methods to resume operations.

Core job skills (non-exhaustive list):

- Bus Vehicle Operations
- Bus Equipment and Systems Operation
- Bus Fare Management
- Bus Service Route Operations Training and Development
- Workplace Traffic Safety Management

3.2.6 Key trends and challenges impacting Bus

Electric Vehicle (EV)

By 2040, all vehicles across the public bus segment will run on cleaner energy and the Singapore government has launched schemes and incentives to encourage adoption. As a result, demand for EV and their associated charging points is expected to increase. New jobs may emerge throughout the EV value chain to support the ecosystem. New jobs may be created in EV assembly and charging infrastructure related charging infrastructure related installation, operation, maintenance, and replacement.

In 2020, the proportion of EVs for the bus stood at below 2% of their fleet sizes. These proportions are expected to grow over the next 10 to 20 years in line with the Government's push towards 100% cleaner vehicles by 2040. Leading up to this, registration of new diesel vehicles and taxis in Singapore will cease from 2025 as announced by Minister for Transport in March 2021.

According to qualitative interviews from associations and regulators, public bus services would likely adopt EVs earlier than private bus services as the government pushes towards decarbonization for long term sustainability and assets are owned by the government under the Bus Contracting Model. However, the actual pace of electrification may be subject to the readiness of supporting infrastructure (e.g. charging stations) and the current asset lifecycle.

The main challenges when it comes to charging infrastructure for the bus segment would be lack of space and costs. Buses may have to be stationed at designated parking lots and to charge overnight. However, due to the lack of space, the necessary charging infrastructure is limited.

In addition, chargers are expensive to install and maintain and fast chargers can cost several times more than regular ones. Due to higher voltage needed to charge larger vehicles, switch rooms may have to be upgraded to cater to higher electricity capacity requirements. Cables running in remote locations where private bus parking lots are usually situated incur high costs as well.

For more information on EV trends, refer to Appendix E: EV related Government policies and trends.

Autonomous Vehicle (AV)

Currently, level 4 AV trials are being conducted in the public transport scene. However, level 5 automation is still in the nascent stage and will likely gain traction only from 2040 onwards. Figure 6 illustrates the scale of the level of autonomy for AVs for more details.

When AV becomes mainstream, new job roles are expected to be created to support the new AV ecosystem. Corresponding reskilling would be anticipated for jobs in AV and infrastructure related system maintenance and replacement.

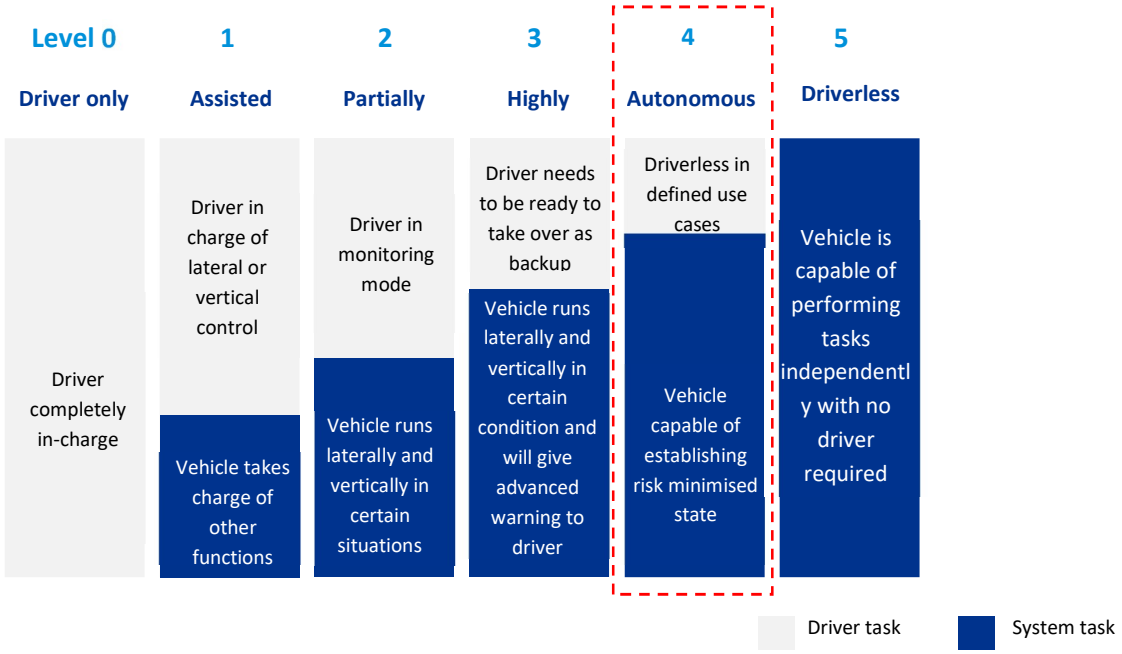


Figure 6: Scale of the level of autonomy for AVs

Since 2020, AV trials have been conducted by A*STAR, MIT, ST Engineering, NTU, NUS and ST Kinetics in Sentosa, Marina Bay Jurong Island, NTU and NUS Campus and more, testing 21 passenger cars, shuttle buses and trucks. However, advancements in technology of components such as lidar sensors, navigation technologies and communication technologies needed to bring AV closer to level 5 is not expected within the next 10 years.

Ageing Population and Foreign Dependency

With an ageing land transport workforce and younger locals less inclined to join the industry, workforce supply for certain job roles will be declining and facing issues with recruitment.

The median age is estimated to increase by 5 years for every 10 years, and similarly the median age of the resident population is expected to increase from 42 years old in 2020 to 49 years old in 2040 (Figure 7).

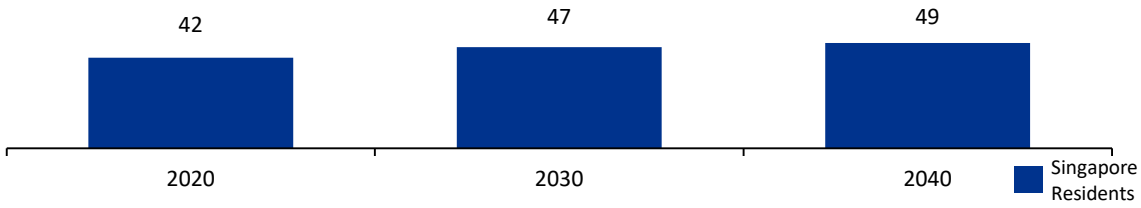


Figure 7: Forecasted median age of Singapore's resident population

The Bus Driver segment feels the impact of an aging workforce more acutely as the workforce here tends to be older, mature workers. Building an age-friendly environment becomes important to retain these workers. Technology could be a solution for the aging workforce in conducting their day-to-day work especially for job tasks that require high levels of manual work. Please see the impact of the impact of bus driver job family in Table 2 below.

Job task today	How age will affect job task	Technology	Interventions	Transition pathways
Driving	Declining physical health conditions due to age such as decreased vision, impaired hearing, slower motor reflexes making it difficult to manoeuvre and steer buses Cognitive capabilities may also be negatively impacted, such as quick decision-making in urgent road situations Visual degradation may impair sight during night driving	Modify bus vehicles to include automatic transmission, power steering and power brakes Assistive technology such as Advanced Driver Assist Systems (ADAS) that uses cameras, radars, other sensors to detect road conditions, lane keeping assistance, advanced braked systems Track identifiable red flags or warning signals of unsafe driving using telematics such as sudden lane changes, drifting, sudden braking or acceleration, sharp bends	Conduct more health checks at frequent intervals to identify concerns regarding eyesight, hearing and reflexes prematurely Assist in career transitions by conducting courses for the elderly Engage mid-aged bus captains (30-45 years) to transit to backend roles within bus segment to enhance career pathways (e.g. operation control center, route supervisor/ manager) Identify and groom high-potential bus captains to become route managers	Pivot to job roles which are less physical-demanding Examples of transition jobs: Driving Instructors Security guard Customer Service Managers Housekeeping and Janitorial Managers
Inspection checks	May face difficulties in climbing or bending to inspect high or low checkpoints essential for bus vehicle health May face difficulties in actively managing commuters on the ground and assisting in	Integrated fleet of autonomous robots to allow inspections through HD images and real-time processing for buses in interchanges		
Customer service		Interactive customer service robo-advisors will automate addressing basic/ common commuter		

Job task today	How age will affect job task	Technology	Interventions	Transition pathways
	inspections/ simple repairs	queries outside of commuting or via mobile app		
Emergency or accident management		Integrated fleet of autonomous robots to allow inspections through HD images and real-time processing Automatic recorded messages will be activated on speakers during an emergency or accident to instruct commuters on SOP		

Table 2: Ageing population in bus driver job family

Due to Singapore's ageing population, workforce demographics and local perceptions of the land transport industry, reliance on foreign employment is necessary as essential land transport roles are not filled up by Singaporeans.

In the long term, companies are encouraged to reduce reliance on foreign investments and adopt technology to automate manual processes. Reskilling of locals in new technologies like EVs and AVs will prepare them for higher level work, taking over the foreign workers that are less experienced in the future.

3.3. Jobs, skills and workforce landscape – P2P

3.3.1 Workforce demographics for P2P

Workforce size and Age

There are more than 60,000 Taxi and PHC drivers. The P2P segment registered a relatively older workforce with median age of 55.

Education level

The appropriate Class 3 driving licenses and taxi / PHC driver's vocational vehicle licenses (TDVL/ PDVL) to operate taxis and passenger vehicles and basic English communication skills must be obtained.

Nationality

For taxi/ PHC drivers, there are locals that remain keen to join the industry due to flexibility of work schedules. Furthermore, taxi/PHC drivers are mandated to be Singaporeans above 30 years old. PHC drivers have also been a bolster transition job during the COVID-19 pandemic when many locals had difficulty retaining their original jobs. Hence, taxi/ PHC drivers are observed to be majority locals.

3.3.2 Taxi/ PHC Drivers

Description:

The Taxi/ PHC Driver provides point-to-point services on taxis or passenger cars and performs pre-trip and post-trip vehicle checks to ensure vehicle readiness for daily service commencement and service termination respectively. He operates the devices and systems that receive rides and ensures adherence to pick up and drop off locations. He works with the Associations and street-hail/ride-hail operators to handle incidents and/or accidents if occurred during operations. He provides customer service to passengers in need of assistance and contribute towards continuous improvement by providing feedback on gaps in service standards.

Core job tasks:

1. Driving and operating of ICE vehicles on planned routes according to GPS and within estimated time allocated.
2. Conduct high level checks on vehicle controls and on-board equipment such as testing of mobile applications/ devices, meters, and engine to ensure vehicle readiness for service commencement and termination.
3. Provide high quality customer service such as answering enquires, facilitating cash payment or card payment, assisting disabled or elderly passengers to board, alight or load baggage to the vehicle storage area.
4. Work with Associations and street-hail/ride-hail operators to handle accidents or emergencies such as ushering passengers to safe points or follow up of journey continuation methods to resume operations.

Core job skills (non-exhaustive list):

- Car Vehicle Operations
- Car Equipment and Systems Operation

- Service Excellence and Orientation
- Car Regulatory Compliance
- Workplace Traffic Safety Management

3.3.3 Key trends and challenges impacting P2P

Electric Vehicle (EV)

By 2040, all vehicles across P2P segments will run on cleaner energy and the Singapore government has launched schemes and incentives to encourage adoption. Taxi and PHC operators have also committed to adopting EVs for 50% of their fleet by 2030. The impact on driver jobs, however, is expected to be minimal.

Ageing Population

Despite the higher statutory retirement age at 67, ageing workers and lower replacements continue to put a strain on labour supply. With more than two-thirds of taxi drivers aged 55 and above, the statutory age to hold the vocational vehicle license for taxi drivers has been extended to age 75, subject to annual health checks for drivers above 65. However, there are safety concerns to further extension of retirement age. PHV drivers tend to be younger and tends to be more mobile in terms of ability to transit, as most treat drive PHV as a pit stop in between career switches, or a lifestyle choice.

3.4 Jobs, skills and workforce landscape – Motor Workshops

3.4.1 Workforce demographics for Motor Workshops

Workforce size, Age and Nationality

For the purposes of this study, car mechanics make up the entire workforce in this segment. There are more than 7,000 mechanics involved in the servicing, maintenance, and repairs of cars, and approximately 50% of mechanics are locals.

The motor workshop segment registered a relatively older workforce with 55% of locals aged 50 years old and above.

Education level

Most car mechanics possesses ITE and Diploma qualifications, with disciplines include electrical, mechanical, software and materials engineering.

3.4.2 Car Mechanics

Description:

The Technician/ Technical Specialist performs routine general and/or specific vehicle sub system servicing and preventive corrective maintenance activities. He prepares work activities, performs assigned servicing and maintenance tasks, performs general housekeeping of workshop tools and equipment, and adheres to Workplace Safety and Health (WSH) procedures. He also supports on-the-road vehicle breakdown assistance and recovery. The seniors/ masters coordinate the routine scheduled vehicle maintenance operations of the team/ section, plan and assign daily work tasks, provide technical guidance and on-the-job coaching, and propose workflow improvements. The managers support coordination of cross functional teams, supports budget forecasting, and conducts engineering studies for improvement initiatives

Core job tasks:

1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance such as oil, filter changing, tire rotations or specific vehicle sub system servicing such as air condition maintenance, engine system maintenance, mechanical drivetrain system and body work maintenance.
2. Coordinate routine scheduled vehicle maintenance operations based on last maintenance session and condition of vehicles; ensure vehicles complete routine maintenance sessions.
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment via a log system and maintenance scheduling system.
4. Support on-the-road vehicle breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works.

Core job skills (non-exhaustive list):

- Car Engine System, Car Drivetrain Systems, Car Brake Systems, Car Steering and Suspension Systems Maintenance

- Car Air Conditioning Systems, Body Work Maintenance
- Car Recovery and Towing
- Car Regulatory Compliance
- Workplace Facilities Safety Management

3.4.3 Key trends and challenges impacting Motor Workshops

Electric Vehicles (EV)

To meet the new demands in servicing EVs, the automotive mechanic workforce will need to be re-skilled in the relevant electrical, diagnostics and high-voltage competencies. To many of the existing mechanics who are mechanical-trained, these are totally new concepts and skillsets that they would need to pick up.

In addition, due to safety considerations, specific EV servicing job functions are restricted to mechanics certified at the right level, for example, mechanics will need to have basic level 1 high-voltage certification to perform a basic power discharge for an EV, while only level 3 experts are allowed to repair EV components. Given the brand-specific vehicle IP/manuals and safety, OEM manufacturers also require the mechanics to be trained and certified in-house before the latter can perform servicing jobs. This segment is likely to see a consolidation of existing workshops as well as new business models emerging.

As EVs become mainstream and the repair and maintenance competencies required become more electrical, electronics, and software based. Automotive workshops will have to compete for these talents with other industries given the high demand due to the growing trend of digitalisation and Industry 4.0.

Autonomous Vehicle (AV)

AVs are EVs with more advanced navigation systems and telematics. Automotive workshop will have to augment the training of the workforce to repair and maintenance complex systems and technological as lidar sensors, navigation technologies, communication technologies (Vehicle-to-infrastructure (V2I) or vehicle-to-everything (V2X)).

Ageing Population

The impact of an aging population on the motor workshop workforce is mitigated by the large pool of non-resident workforce and the transition to EV, which would require different skillsets and attract a different talent pool. In addition, where viable, especially for larger workshops and as part of the transition to support EV maintenance and repairs, workshops should consider implementing age friendly workplace features like assistive technology to help the aging workforce in conducting their day-to-day work especially for job tasks which are physically demanding.

Job task today	How age will affect job task	Technology	Interventions	Transition pathways
Preventive maintenance of ICE vehicles	— Possible declining physical health conditions due to age such as decreased vision, impaired hearing, slower motor reflexes for maintenance and repair work — May experience difficulties in climbing or bending to inspect and repair components eithers too high or low (e.g. under a vehicle) — Cognitive capabilities may also be negatively impacted, such as decision-making in times of crisis (e.g. vehicle recovery)	— Integrated fleet of autonomous robots to allow inspections through HD images and real-time processing — Maintenance of specific EV/ AV parts will be less frequent and diagnostic testing in nature — Power chairs for postural and pressure management	— Conduct more health checks at frequent intervals to identify concerns regarding eyesight, hearing and reflexes prematurely — Reduce duration of work shifts to allow more time for rest and recovery (in line with AV components requiring lesser maintenance) — ICT courses for elderly who may not be as familiar with technology (e.g. BizSafe, using maintenance scheduling and logging systems etc) — Assist in career transitions by conducting courses for the elderly	— Pivot to job roles which are less physically demanding — Examples of transition jobs: — Software testes — Housekeeping and Janitorial Managers — Security guard — Maintenance manager
Maintenance scheduling		— Maintenance scheduling and logging systems with more elderly-friendly user interfaces, such as larger fonts and streamlined steps for data input		
General workshop housekeeping		— Reduced complexity in maintenance of cars due to modular design of vehicle components such as those found on EVs		
On-the-road vehicle breakdown assistance and recovery		— Integrated fleet of autonomous robots to allow inspections through HD images and real-time processing — Dashboard diagnostics will trigger alerts on SOP using AI / machine learning, reducing need for decision-making		

Table 3: Ageing population in car mechanic job family

4 Jobs Impact Analysis

4. Job Impact Analysis

Technology trends have been identified as the key drivers impacting land transport job roles in Singapore.

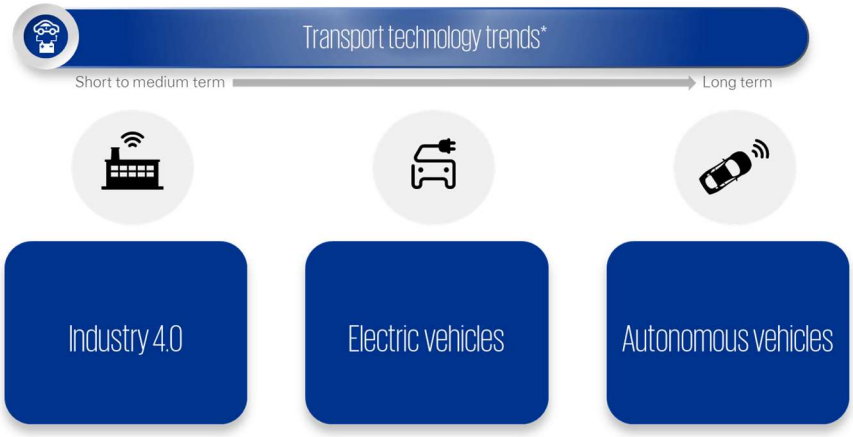


Figure 8: Key technology trends impacting the Land Transport industry

Overall, in the short term of around 5 years, Industry 4.0 will impact the jobs landscape in the rail segment by creating new opportunities and evolving current job roles. In the medium term of around 10 years, Electric Vehicles will impact the jobs landscape in the bus, P2P and motor workshop segments by creating new opportunities and evolving current job roles. Lastly, beyond 2040, Autonomous Vehicles will impact the jobs landscape in the bus, P2P and motor workshop segments.

These evident time frames are specifically highlighted to capture the insight of which trends would provide the most significant impacts on the various segments correspondingly. Nonetheless, it must be kept in mind that the different segments will all still be impacted to different degrees over the 20-year time span, as can be seen in Appendix B: Summary of overall impact on job roles.

For example, while the trend of I4.0 starts to significantly impact the rail segment in the next 5 years, there will be residual effects across the 10- and 20-year time frames. Conversely, while the bus, P2P and motor workshop segments will not face strong impact from I4.0, Artificial Intelligence (A.I.), Big Data and Data Analytics and Cybersecurity, certain job tasks and skills may still be minimally impacted, however that will not be covered in this Study.

Furthermore, the technology for EVs and AVs are not expected to fully mature and impact the bus, P2P and motor workshop segment until the 10- and 20-year or beyond time frames respectively.

4.1 Methodology

To assess the impact of these trends, existing process flows are broadly analysed to understand whether new trends will complement or replace them.

Thereafter, a deep dive into the evaluation of current and future state of job tasks, skills and roles is conducted according to the question matrix below (Figure 9). The degree of change of job tasks, the impact on job skills and job roles is defined and determined (Table 4).

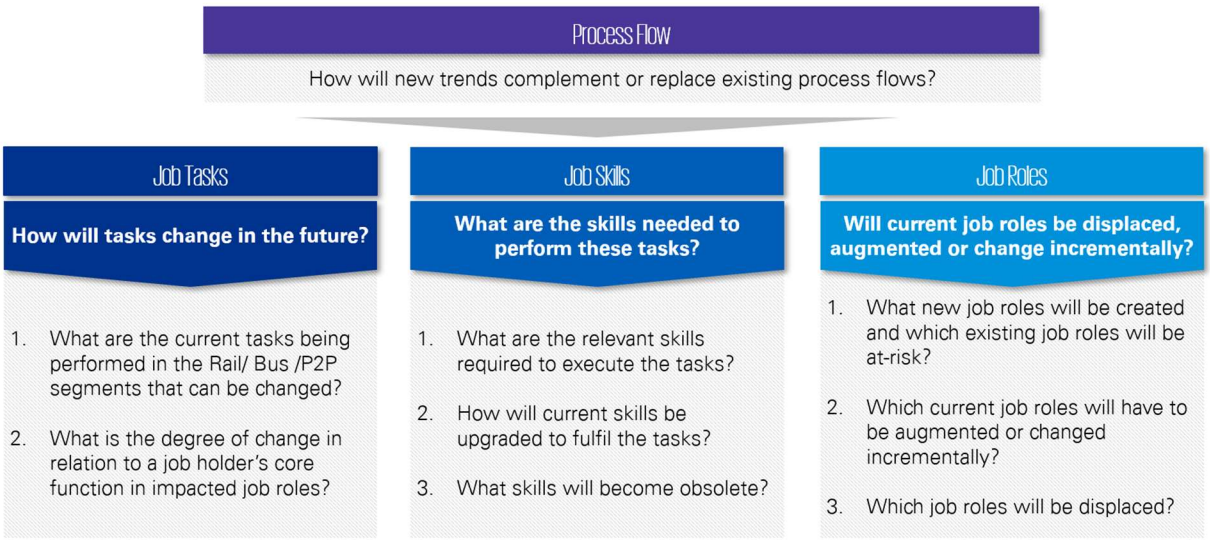


Figure 9: Approach for jobs and skills analysis

1. Degree of Change in Job Tasks		
 **High** A significant proportion of the job tasks will be impacted by the key technology, thus eliminating or replacing current job tasks.	 **Medium** A medium proportion of the job tasks will be impacted by the key technology, thus augmenting or reducing current job tasks.	 **Low** A small proportion of the job tasks will be impacted by the key technology, thus evolving current job tasks incrementally.
2. Impact on Expected Skills		
New skills required Need to reskill job holders with new skills to maintain their employability.	**Substantial upskilling required** Require job holders to upgrade existing skills and/or acquire new skills to remain competitive.	**Limited upskilling required** Current skills or limited skills will be sufficient for job holders to remain up to date.
3. Impact on Job Roles		
Job will undergo displacement The job role will become obsolete (e.g. converge with another job role and/or be replaced by new job roles).	**Job role will require redesign** The job role will transform to take on additional duties over and beyond what is currently required.	**Job role will change incrementally** The job role will continue to deliver current duties with slight changes.

Table 4: 3-step methodology for analysing impact on job tasks, skills, and roles

To quantify the impact on job tasks, each task is assigned values and the total summation of scores across 4 job tasks will determine whether the job role will go through displacement, redesign, or incremental change (Table 5).

1. Impact at task-level		
 **High Impact (4 points)** Technology will fully replace human requirements to perform the job task.	 **Medium impact (2 points)** Technology will partially replace human requirements to perform the job task, and/or reduce manhours required to perform the job task.	 **Low impact (0 points)** Technology will have limited impact or no impact to existing job tasks. partially replace human requirements to perform the job task, and/or reduce manhours required to perform the job task.
2. Total summation of scores		
If the sum of the tasks impacts' score points belongs to this interval  **>10.7 to 16**	If the sum of the tasks impacts' score points belongs to this interval.  **>5.3 to 10.7**	If the sum of the tasks impacts' score points belongs to this interval  **0 to 5.3**
3. Impact on Job Roles		
Job will potentially undergo **displacement**	Job role will potentially require **redesign**	Job role will potentially **change incrementally**

Table 5: Quantifying impact on job tasks, skills, and roles

Faethm AI engine is used to assess the impact on job skills. Faethm AI engine analyses the time spent to complete job tasks and estimates the time saved in future to complete the task given the likelihood of automation and augmentation. This is mapped against the repository of skills for land transport job roles. Based on the percentage of time saved, a skill is subsequently classified to be declining, adjacent or emerging accordingly, based on the following criteria (Table 6).

Land Transport Job skill	Job Skill Classification
Declining 	— % of time saved: More than or equal to 30%
Adjacent 	— % of time saved: between 0% to 29% — Alternatively, job skill is a generic or business/foundational skill which is consistently required in the long term
Emerging 	— Job skill is a new skill which requires training in future

Table 6: Job Skill Classification

Key points to note:

— Job role transition is subjected to the organisation's resources and capabilities to drive reskilling and upskilling initiatives as well as the willingness of job holders to transition to these roles.

— These are suitable roles within the land transport industry to transition into; other external roles can also be considered.

4.2 Overview of job impact analysis for key trends

4.2.1 Industry 4.0

As mentioned in Section 3.1.5 Key trends and challenges impacting Rail, I4.0 is the current trend of smart automation and data exchange and it includes different technological pillars such as Big Data and Analytics, Cloud Computing, Advanced Robotics, Internet of Things (IoT), Cybersecurity and more.

The proliferation of I4.0 in land transport has permeated many facets within the industry today, changing day-to-day tasks, eliminating the need for manual work, and modifying current processes to be more efficient. The extent of change is dependent on the adoption rate of I4.0 and the type of I4.0 solutions implemented in the job task.

The job tasks across rail segment can be impacted differently:

a. Job tasks that will be automated by I4.0 technologies – These tasks will experience a high degree of change and hence job roles associated will undergo displacement.
b. Job tasks that will be augmented by I4.0 technologies – These tasks will experience a medium degree of change and hence job roles associated will require redesign.
c. Job tasks that will be supplemented by I4.0 technologies – These tasks will experience a low degree of change and hence job roles associated will change incrementally.

Based on our findings, I4.0 may eliminate manual, labour-intensive tasks in the rail landscape particularly in the operations and maintenance (O&M) phase such as track inspection, inventory tracking, scheduling and documentation. Specifically, the use of robotics and automation is expected to complement O&M verticals of transportation and improve overall maintenance productivity and reliability such as automation of maintenance works at depots, drones for structure integrity inspections, machine learning for preventive maintenance of rolling stock and RPA for documentation work in corporate functions such as HR and Finance. More value-adding tasks such as strategic planning, business solutioning and innovation management will remain necessary and enhanced by technology.

The table below shows the different technology enablers and how they will be deployed to reduce manual tasks.

Technology enabler	Segment	Use cases	Description of application
Robotics	Rolling stock	Depot automation of maintenance work	Optimization of the entire maintenance process, on-site preventive maintenance, reporting and evaluations, acquisition of operating data and visualization.
	Rail	Field automation of actual maintenance work	Robots allow maintenance to be done remotely in inaccessible or high danger areas such as underframe of rolling stock.
Autonomous Mobile Robots	Station systems	Inspection, cleaning	Based on standard cleaning machines equipped with necessary robot functions

Technology enabler	Segment	Use cases	Description of application
			to drive around large cleaning areas in stations and depots.
	Rolling stock	Cleaning	Services such as sweeping, vacuuming, scrubbing, high pressure cleaning, and window and train car body cleaning.
Drones	Substructure	Inspection	Inspection of infrastructure substructure in areas which are difficult to access or out of reach.
IoT/Sensors Data	Station systems	Passenger flow monitoring	Crowd management systems in stations and trains.
	Communications and signalling	Communication based control technology	Train transmits its exact position and direction to the control centre and receives movement authority, permissible speed, and route data.
	Manpower and safety	Real time location sensing	Biometrics for personnel identification for access control to confined spaces and restricted locations.
Vision Based Sensor	Station	Security	Video analytics for object identification and hazard detection.
Machine vision algorithm detection and classification	Rail	Automated defect detection	Apply image processing techniques and deep learning to detect defects and cracks on tunnels and rail tracks.
Machine Learning	Sleepers and ballast	Preventive maintenance	Apply image processing techniques and deep learning to detect missing fasteners, cracks etc.

Table 7: Technology enablers and use cases

Some global examples of how industry 4.0 technologies have impacted the job tasks in the rail segment can also be found:

a. Hong Kong – The Mass Transit Railway (MTR) in Hong Kong has implemented Maintenance Cloud System and Condition Monitoring Hardware to manage manpower and monitor real-time train performance.
b. France – The French national railway operator (SNCF) has utilized Digital Twins to construct virtual replicas of the entire rail network, taking real-world data as input to enable testing and planning. SNCF has also deployed drones to perform remote train roof maintenance, cutting maintenance time from 1 day to 1 hour.

Interviews and focus group discussions with key land transport players have indicated that traditional operating models will be replaced with more agile and flexible ones that can accommodate the use of technology in day-to-day operations focusing on automation.

As a result of I4.0, job roles with high degree of manual work are projected to undergo drastic changes due to automation while roles which currently involves some level of I4.0 related skills, such as data analytics, may see a need for redesign. At this stage, 4 rail job roles may be at risk and 8 rail job roles may require redesign over the next 5 to 10 years as found in Table 8.

4.2.2 Electric Vehicles

Given Singapore government's mandate to replace all ICE vehicles with greener vehicles by 2040 and commitment to install 60,000 charging points by 2030, EVs and its technology will arrive quickly in the medium term.

The current tasks performed for maintenance will be largely augmented by EV technologies and will be vastly different from ICE vehicles due to different components required. The repair and maintenance regimes for EVs will also be focused on component replacement and become less frequent. Operating of EVs will remain largely unchanged as only slight differences in braking and acceleration is observed. Overall, the extent of change is dependent on the adoption rate of EV and the permeability of its technology in the particular job task.

The job tasks across bus, P2P and motor workshop segment will be impacted differently:

a. Job tasks that will be augmented by EV technology – These tasks will experience a medium degree of change and hence job roles associated will require redesign.
a. Job tasks that will be supplemented by EV technology – These tasks will experience a low degree of change and hence job roles associated will change incrementally.

Some global examples of how EVs have impacted the job tasks in the bus, P2P and motor workshop can also be found:

a. Tesla – Tesla cars can self-diagnose problems with high accuracy for various systems such as the Power Conversion System; 90% of issues in Tesla cars can be diagnosed remotely and 80% of repairs can be done outside of service centres.
b. NIO and Tesla – These companies introduced mobile services to provide on-site repair and maintenance services. For example, the NIO app allows users to report a flat tire and a NIO service specialist will be dispatched to fix the issue on-site.

Traditional job roles associated with maintenance of ICE vehicles in the bus, P2P and motor workshop segment will require major redesign to accommodate new technologies in EV. Primary interviews and focus group discussions with key land transport players have indicated that EV specific work and their related maintenance will be vastly different from ICE vehicles. According to SMWA, it is estimated that only 5% of workshops in Singapore employ technicians that are capable of repairing and maintaining hybrids and/ or EVs.

The emergence of EVs will cause job roles with high degree of interactions with technical systems (e.g. drive train) to undergo major redesign due to different technologies between ICE vehicles and EVs. Roles which currently involve driving of ICE vehicles may only see an incremental change in job roles. At this stage, 5 job roles are estimated to require redesign over the next 5 to 10 years as found in Table 8.

4.2.3 Autonomous Vehicles

Since 2020, AV trials have been conducted by A*STAR, MIT, ST Engineering, NTU, NUS and ST Kinetics in Sentosa, Marina Bay Jurong Island, NTU and NUS Campus and more, testing 21 passenger cars, shuttle buses and trucks. However, advancements in technology of components such as lidar sensors, navigation technologies and communication technologies needed to bring AV closer to mainstream operational readiness is not expected within the next 10 years.

Overall, the extent of change is dependent on the adoption rate of AV and the permeability of its technology in the job task.

The job tasks across bus and P2P segment will be impacted differently:

a. Job tasks that will be automated by AV technology – These tasks will experience a high degree of change and hence job roles associated will undergo displacement.
b. Job tasks that will be augmented by AV technology – These tasks will experience a medium degree of change and hence job roles associated will require redesign.
c. Job tasks that will be supplemented by technology – These tasks will experience a low degree of change and hence job roles associated will change incrementally

Based on our findings, vehicle operations of AVs will no longer be required due to the driverless technology. Driving task is expected to shift to customer service, high level supervision and emergency and accident management.

The proliferation of AVs may result in job roles highly involved in vehicle operations to undergo drastic changes due to driverless technology involved for AVs. Job roles with high degree of interactions with technical systems (e.g. drive train) would undergo some redesign due to different technologies between EVs vehicles and AVs. At this stage, 2 job roles are expected to be displaced and 2 job roles would require redesign over the next 20 years as found in Table 8: Impact on Job Tasks.

High impact on job tasks

Roles may be at risk

Medium impact on job tasks

Roles projected to require redesign

Low impact on job tasks

Roles projected to change incrementally

RAIL OPERATIONS (in 10 years)

1. *Communication Controller*
2. *Customer Service Officer/ Rover*
3. *Train Captain/ Senior Train Captain*
4. *Crew Manager*

RAIL TECHNCIANS (in 5 years)

1. *Technician/ Senior Technician (Rolling Stock/ Engineering Train)*
2. *Technician/ Senior Technician (Permanent Way and Civil Structure)*
3. *Technician/ Senior Technician (Power)*
4. *Technician/ Senior Technician (Mechanical and Electrical)*
5. *Technician/ Senior Technician (Signal and Communications)*
6. *Technician/ Senior Technician (Automatic Fare Collection)*

BUS OPERATIONS (in 10 years)

1. *Senior Interchange Officer/ Senior Interchange Assistant/ Interchange Officer/ Interchange Assistant/ Senior Interchange Supervisor/ Interchange Supervisor/ Interchange Manager/ Senior Depot Officer/ Senior Depot Assistant/ Depot Officer/ Depot Assistant/ Senior Depot Supervisor/ Depot Supervisor/ Depot Operations Manager/ Depot Manager*
2. *Chief Bus Controller/ Bus Operations Control Centre Controller/ Deputy Bus Operations Control Centre Manager/ Bus Operations Control Centre Manager*

RAIL ENGINEERS (in 5 years)

1. *Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Rolling Stock/ Engineering Train)*
2. *Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Permanent Way and Civil Structure)*
3. *Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Power)*
4. *Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Mechanical and Electrical)*
5. *Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Signal and Communications)*
6. *Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Automatic Fare Collection)*

RAIL OPERATIONS (in 10 years)

1. *Train Service Controller/ Depot Traffic Controller/ Depot Train Controller/ Chief Controller/ Controller/ Operations Control Centre Manager/ Head, Operations Control Centre*
2. *Senior Assistant Station Manager/ Assistant Station Manager/ Senior Station Manager/ Station Manager/ Deputy Station Manager/ Rail Service Manager/ Service Operations Manager/ Duty Operations Manager/ Station Operations Manager/ Train Operations Manager/ Head, Train Operations/ Head, Station Operation/ Head, Passenger Services*

BUS ENGINEERS (in 5 years)

1. *Engineer/ Engineering Manager*

BUS TECHNICIANS (in 5 years)

1. *Technician/ Senior Technician/ Section Supervisor/ Foreman/ Workshop Supervisor/ Senior Foreman/ Technical Specialist/ Senior Technical Specialist/ Master Technical Specialist/ Deputy Workshop Manager/ Workshop Manage*

BUS / TAXI / PHC DRIVERS (in 20 years)

1. *Bus Captain/ Senior Bus Captain/Chief Bus Captain/ Master Bus Captain*
2. *Taxi Driver/ PHC Driver*

CAR MECHANICS (in 5 years)

1. *Technician/ Senior Technician/ Section Supervisor/ Foreman/ Workshop Supervisor/ Senior Foreman/ Technical Specialist/ Senior Technical Specialist/ Master Technical Specialist/ Deputy Workshop Manager/ Workshop Manager/ Head of Workshop*

BUS TECHNICIANS / CAR MECHANICS (in 20 years)

1. *Technician/ Senior Technician*
2. *Technical Specialist/ Senior Technical Specialist*

BUS DRIVERS (in 10 years)

1. *Bus Captain/ Senior Bus Captain/ Chief Bus Captain/ Master Bus Captain*

TAXI/ PHC DRIVERS (in 10 years)

1. *Taxi/ PHC Driver*

Table 8: Impact on Job Tasks

4.3 Detailed analysis – Rail

Figure 10 below provides a summary on the impact projected for rail job roles arising from i4.0, with 4 job roles (Crew Manager, Senior Train Captain/ Train Captain, Communication Controller, and Customer Service Officer/ Rover) may be at risk in the next 10 to 20 years, 18 job roles projected to be resigned and 34 job roles projected to remain unchanged.

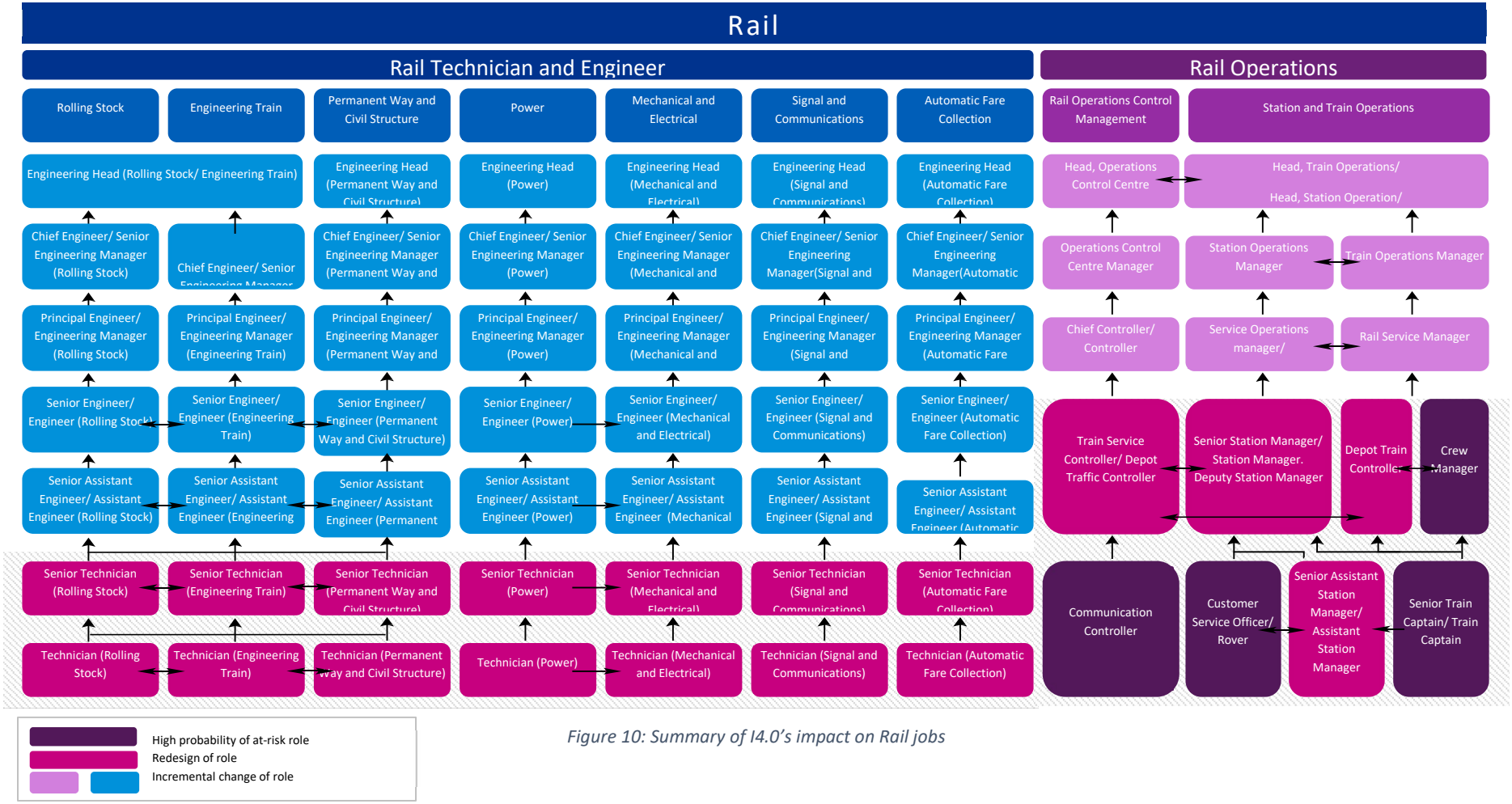


Figure 10: Summary of I4.0's impact on Rail jobs

4.3.1 Rail Engineers

Rail engineers job tasks such as:

1. Applying technical expertise to propose recommendations for workflow improvements and supervising complex issues around fault analyses and testing;
1. Planning and scheduling maintenance work activities and supervising teams performing preventive and corrective maintenance work;
2. Providing technical guidance and on-the-job coaching to the team; and
3. Establishing and ensuring engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors

will experience a low degree of change due to human judgement remaining highly relevant in the above job tasks and are unlikely to be greatly affected by technology brought about by I4.0.

Please refer to Section 5.1.1 of this report for the evolution of job tasks for rail engineers over 5, 10 and 20-year windows.

Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer / Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Rolling Stock/ Engineering Train)

Job description: The Senior Assistant Engineer/Assistant Engineer/ Senior Engineer/ Engineer (Rolling Stock/ Engineering Train) supervises the team in performing preventive and corrective maintenance work on passenger/ engineering trains and plans the maintenance work activities. He provides technical advice, proposes recommendations to workflow improvements and supervises complex issues pertaining to fault analyses and testing. He manages the team's performance and external contractors, and ensures their safety and work quality. Senior level engineers for this function leads cross-functional teams in maintenance work involving trains. He establishes competency and engineering standards for staff.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Apply rolling stock/ engineering train technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing	• Technical expertise from engineers would be required to analyse train health data acquired from various sensors such as temperature and voltage sensors to develop workflow improvements.	
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on passenger/ engineering trains	• Continue to supervise maintenance work, with predictive technology such as condition monitoring and sensors streamlining the troubleshooting process	
3. Provide technical guidance and on-the-job coaching to the team	• Human interaction required to conduct on-the-job coaching • Leverage on performance management systems to guide training and development programmes for junior engineers/technicians	
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors	• Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions • Human judgment is a crucial aspect of formulating, identifying and developing safety standards and competencies across rail function	

A MINIMAL proportion of the job tasks will be impacted by the key trend, thus slightly evolving the current job tasks

LOW degree of change

Within the next **5 - 20 years**, the job role(s) could potentially undergo

INCREMENTAL CHANGE

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Rolling Stock Auxiliary Systems Maintenance
- Condition-Based Assets Monitoring Management
- Manpower Planning and Deployment
- People Development
- Strategy Planning
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Contract Engineer (Train component)
- Sales Engineer (Train component)
- Budget and Planning Manager (Train component)

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Permanent Way and Civil Structure)

Job description: The Senior Assistant Engineer/Assistant Engineer/ Senior Engineer/ Engineer (Permanent Way and Civil Structure) supervises the team in performing preventive and corrective maintenance work on train tracks, railway reserves and buildings and plans the maintenance work activities. The engineer provides technical advice, supervises complex issues and is adept in using various test equipment for the maintenance of permanent ways and civil structures. He also manages the team's performance and external contractors, and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in the maintenance work involving train tracks, railway reserves and buildings. The lead establishes competency and engineering standards for staff.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Apply permanent way and civil structure technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing	• Technical expertise from engineers would be required to analyse permanent way and civil structure health data acquired from civil structure sensors and rail track monitoring equipment to develop workflow improvements.	
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on permanent way and civil structures	• Continue to supervise maintenance work, with predictive technology such as condition monitoring and sensors streamlining the troubleshooting process	
3. Provide technical guidance and on-the-job coaching to the team	• Human interaction required to conduct on-the-job coaching • Leverage on performance management systems to guide training and development programmes for junior engineers/technicians	
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors	• Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions • Human judgment is a crucial aspect of formulating, identifying and developing safety standards and competencies across rail functions	

A MINIMAL proportion of the job tasks will be impacted by the key trend, thus slightly evolving the current job tasks

LOW degree of change

Within the next **5 - 20 years**, the job role(s) could potentially undergo

INCREMENTAL CHANGE

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Rail Track Maintenance
- Condition-Based Assets Monitoring Management
- Manpower Planning and Deployment
- People Development
- Strategy Planning
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Contract Engineer (Structural)
- Sales Engineer (Structural)
- Budget and Planning Manager (Structural)

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Power)

Job description: The Senior Assistant Engineer/Assistant Engineer/ Senior Engineer/ Engineer (Power) supervises the team in performing preventive and corrective maintenance work on rail power systems. The engineer provides technical analysis, supervises complex rail power systems issues. The engineer also proposes workflow improvements to improve the maintenance regime of the rail power systems, manages the team's performance and external contractors, and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in collaborative work to support rail power systems maintenance and enhancement. He establishes competency and engineering standards for staff.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Apply power engineering technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing	• Technical expertise from engineers would be required to analyse data acquired from high and low voltage systems to develop workflow improvements.	
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on rail power systems	• Continue to supervise maintenance work, with predictive technology such as condition monitoring and sensors streamlining the troubleshooting process	
3. Provide technical guidance and on-the-job coaching to the team	• Human interaction required to conduct on-the-job coaching • Leverage on performance management systems to guide training and development programmes for junior engineers/technicians	
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors	• Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions • Human judgment is a crucial aspect of formulating, identifying and developing safety standards and competencies across rail functions	

A MINIMAL proportion of the job tasks will be impacted by the key trend, thus slightly evolving the current job tasks

LOW degree of change

Within the next **5 - 20 years**, the job role(s) could potentially undergo

INCREMENTAL CHANGE

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- High/ Low Voltage Power Systems Maintenance
- Condition-Based Assets Monitoring Management
- Manpower Planning and Deployment
- People Development
- Strategy Planning
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Contract Engineer (Voltage System)
- Sales Engineer (Voltage System)
- Budget and Planning Manager (Voltage System)

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

RAIL ENGINEERS

Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Mechanical and Electrical)

Job description: The Senior Assistant Engineer/Assistant Engineer/ Senior Engineer/ Engineer (Mechanical and Electrical) supervises the team in performing preventive and corrective maintenance work on mechanical and electrical systems. The engineer proposes workflow improvements to improve the reliability of the mechanical and electrical systems. He also manages his team's performance and external contractors, and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in maintenance work involving mechanical and electrical systems. He establishes competency and engineering standards for staff.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Apply mechanical and electrical technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing	• Technical expertise from engineers would be required to analyse data acquired from fire protection systems, lift systems, air-conditioning systems to develop workflow improvements.	
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on mechanical and electrical systems	• Continue to supervise maintenance work, with predictive technology such as condition monitoring and sensors streamlining the troubleshooting process	
3. Provide technical guidance and on-the-job coaching to the team	• Human interaction required to conduct on-the-job coaching • Leverage on performance management systems to guide training and development programmes for junior engineers/technicians	
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors	• Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions • Human judgment is a crucial aspect of formulating, identifying and developing safety standards and competencies across rail functions	

A MINIMAL proportion of the job tasks will be impacted by the key trend, thus slightly evolving the current job tasks

LOW degree of change

Within the next **5 - 20 years**, the job role(s) could potentially undergo

INCREMENTAL CHANGE

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Escalator and Travellator Maintenance
- Condition-Based Assets Monitoring Management
- Manpower Planning and Deployment
- People Development
- Strategy Planning
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Contract Engineer (Mechanical)
- Sales Engineer (Mechanical)
- Budget and Planning Manager (Mechanical)

Legend for job tasks & skills

High impact | Declining skills
Medium impact | Adjacent skills
Low impact | Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

RAIL ENGINEERS

Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Signal and Communications)

Job description: The Senior Assistant Engineer/Assistant Engineer/ Senior Engineer/ Engineer (Signal and Communications) supervises his/her team in performing preventive and corrective maintenance work on signal, communication and control systems. The engineer provides technical advice to team members, supervises complex maintenance issues pertaining to fault analyses and testing of signal, communication and control systems. The engineer contributes to workflow improvements to enhance the reliability of the signal, communication and control systems, manages his team's performance and external contractors, and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in maintenance work involving signal, communication and control systems. He establishes competency and engineering standards for staff.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Apply signal and communication technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing	• Technical expertise from engineers would be required to analyse data acquired from network systems, radio systems, signal and information systems to develop workflow improvements.	
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on signal, communication and control systems	• Continue to supervise maintenance work, with predictive technology such as condition monitoring and sensors streamlining the troubleshooting process	
3. Provide technical guidance and on-the-job coaching to the team	• Human interaction required to conduct on-the-job coaching • Leverage on performance management systems to guide training and development programmes for junior engineers/technicians	
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors	• Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions • Human judgment is a crucial aspect of formulating, identifying and developing safety standards and competencies across rail functions	

A MINIMAL proportion of the job tasks will be impacted by the key trend, thus slightly evolving the current job tasks

LOW degree of change

Within the next **5 - 20 years**, the job role(s) could potentially undergo

INCREMENTAL CHANGE

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Communication Auxiliary Systems Maintenance
- Condition-Based Assets Monitoring Management
- Manpower Planning and Deployment
- People Development
- Strategy Planning
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Contract Engineer (Comms Systems)
- Sales Engineer (Comms Systems)
- Budget and Planning Manager (Comms Systems)

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Senior Assistant Engineer/ Assistant Engineer/ Senior Engineer/ Engineer/ Principal Engineer/ Engineering Manager/ Chief Engineer/ Senior Engineering Manager/ Engineering Head (Automatic Fare Collection)

Job description: The Senior Assistant Engineer/Assistant Engineer/ Senior Engineer/ Engineer (Automatic Fare Collection) supervises the team in performing preventive and corrective maintenance work on Automatic Fare Collection (AFC) systems. The engineer proposes workflow improvements to improve the reliability of the AFC systems, manages the team's performance and external contractors, and ensures their safety and work quality. Senior level engineers for this function lead cross-functional teams in maintenance work involving AFC systems. He establishes competency and engineering standards for staff.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Apply automatic fare collection technical expertise by proposing recommendations for workflow improvements and supervising complex issues around fault analyses & testing	• Technical expertise from engineers would be required to analyse data acquired from AFC systems to develop workflow improvements.	
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on AFC systems	• Continue to supervise maintenance work, with predictive technology such as condition monitoring and sensors streamlining the troubleshooting process	
3. Provide technical guidance and on-the-job coaching to the team	• Human interaction required to conduct on-the-job coaching • Leverage on performance management systems to guide training and development programmes for junior engineers/technicians	
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors	• Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions • Human judgment is a crucial aspect of formulating, identifying and developing safety standards and competencies across rail functions	

A MINIMAL proportion of the job tasks will be impacted by the key trend, thus slightly evolving the current job tasks

LOW degree of change

Within the next **5 - 20 years**, the job role(s) could potentially undergo

INCREMENTAL CHANGE

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Automatic Fare Collection Auxiliary Systems Maintenance
- Condition-Based Assets Monitoring Management
- Manpower Planning and Deployment
- People Development
- Strategy Planning
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Contract Engineer
- Sales Engineer
- Budget and Planning Manager

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

4.3.2 Rail Technicians

Rail maintenance job tasks such as:

1. Performing preventive, corrective and general maintenance work on the tracks and systems; and
2. Supervising work of contractors and external stakeholders to ensure adherence to safety requirements and operating standards.

may also observe a medium degree of change as automation, predictive technology and data analytics can enhance the maintenance and data collection process. Job tasks that require human intervention such as interpretation of data, operations and compliance management would remain relevant.

As such, rail technicians will face a high possibility of job redesign as their core tasks are projected to be largely complemented and augmented by data driven technologies. In place of manual inspection works, these roles are expected to instead perform data gathering, interpretation and analysis. Such technologies have already been implemented in MTR Hong Kong in where Underframe Inspection Robots are used for underframe inspection of 8-car trains. The system utilizes image recognition and A.I. to identify abnormalities and wear and tear of parts. Hence, the role of the technician would shift to acquiring knowledge surrounding the interpretation of the data generated from the various sensors.

Please refer to Section 5.1.2 of this report for the evolution of job tasks for rail technicians over 5, 10 and 20-year windows.

RAIL TECHNICIANS

Technician/ Senior Technician (Rolling Stock/ Engineering Train)

Job description: The Technician/ Senior Technician (Rolling Stock/ Engineering Train) performs preventive and corrective maintenance on passenger/ engineer trains through deployment of engineering trains in the main line and assisting in the conduct of fault analysis, repair and modifications of electronics, electrical and mechanical equipment and train systems. The technician also assists in the preparation of tools, equipment and checklist required for maintenance activities, supervises the work of contractors and external stakeholders in ensuring compliance to safety requirements and operating standards.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Perform preventive maintenance on passenger and engineering trains through deploying engineering trains in the main line and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures	• Continue to interpret train health data collected from various sensors such as temperature and voltage sensors to identify potential failure modes. • RPA can ensure that train systems data is collected and analysed via centralized systems which will reduce the need for human intervention.	
2. Perform corrective maintenance through conducting repair and modifications of electronics, electrical and mechanical equipment and passenger and engineering train systems	• Continue to perform repair work. • Predictive technology such as condition monitoring and sensors can streamline the troubleshooting process and reduce manual effort.	
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.	• Continue to conduct visual checks on tools, vehicles and equipment to maintain working condition. • Data analytics would support the preparation of standardized reports, conduct digital data logging and documentation.	
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.	• Human intervention and judgment remain critical in overseeing operations and ensuring compliance. • Digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation as part of vendor and stakeholder management.	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **5 - 20 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Rolling Stock Auxiliary Systems Maintenance
- Condition-Based Assets Monitoring Management
- Report Writing
- Rail Regulatory Compliance
- Vendor Management
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Technician / Senior Technician (Permanent Way and Civil Structure) - 89.1

Legend for job tasks & skills

High impact · Medium impact · Low impact

Declining skills · Adjacent skills · Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Technician/ Senior Technician (Permanent Way and Civil Structure)

Job description: The Technician/ Senior Technician (Permanent Way and Civil Structure) performs preventive and corrective maintenance of civil structures, train tracks and/or third rail. The technician operates engineering trains to support rail track maintenance, conducts trouble shooting, fault analysis and repair of electrical and mechanical track equipment and systems, performs track-walk inspections and assists in the inspection and general maintenance of train stations and depot buildings. The technician operates various types of engineering work trains and train mounted equipment to aid in the maintenance of train tracks, train tunnels and various rail structures. The technician also supervises contractors and external stakeholders in ensuring adherence to work and safety standards.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Perform preventive maintenance on civil structures, train tracks and third rail through deploying engineering trains and train mounted equipment on rail tracks and performing track-walk inspections, and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures	• Continue to interpret permanent way and civil structure health data collected from civil structure sensors and rail track monitoring equipment to identify potential failure modes. • RPA can ensure that permanent way and civil structure systems data is collected and analysed via centralized systems which will reduce the need for human intervention such as track-walk inspections.	
2. Perform corrective maintenance on train tracks and/or third rail through conducting repair of electrical and mechanical track equipment and systems	• Continue to perform repair work. • Predictive technology such as condition monitoring and sensors can streamline the troubleshooting process and reduce manual effort.	
3. Perform general maintenance on civil infrastructure, including train stations and depot buildings	• Continue to perform general maintenance works on civil infrastructure.	
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.	• Human intervention and judgment remain critical in overseeing operations and ensuring compliance. • Digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation as part of vendor and stakeholder management.	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **5 - 20 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Rail Track Maintenance
- Condition-Based Assets Monitoring Management
- Report Writing
- Rail Regulatory Compliance
- Vendor Management
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Technician / Senior Technician (Rolling Stock/ Engineering Trains) – 86.5

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Technician/ Senior Technician (Power)

Job description: The Technician/ Senior Technician (Power) performs preventive and corrective maintenance of rail power systems through assisting in pre-maintenance activities including preparation of tools and equipment, and carries out workplace safety measures as required. The technician identifies and rectifies rail power systems faults to operational conditions, test power equipment and general housekeeping tasks. The technician also provides technical guidance and on-the-job coaching to the team. The technician also supervises the work of contractors and external stakeholders in ensuring adherence to safety requirements and operating standards.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Perform preventive maintenance of rail power systems and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures	• Continue to interpret rail power systems health data collected from low and high voltage power systems to identify potential failure modes. • RPA can ensure that rail power systems data is collected and analysed via centralized systems which will reduce the need for human intervention.	
2. Perform corrective maintenance through identifying and rectify rail power system faults to operational conditions	• Continue to perform repair work. • Predictive technology such as condition monitoring and sensors can streamline the troubleshooting process and reduce manual effort.	
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.	• Continue to conduct visual checks on tools, vehicles and equipment to maintain working condition. • Data analytics would support the preparation of standardized reports, conduct digital data logging and documentation.	
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.	• Human intervention and judgment remain critical in overseeing operations and ensuring compliance. • Digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation as part of vendor and stakeholder management.	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **5 – 20 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- High/ Low Voltage Power Systems Maintenance
- Condition-Based Assets Monitoring Management
- Report Writing
- Rail Regulatory Compliance
- Vendor Management
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Rail operations control management – 59.6[1]

Legend for job tasks & skills

High impact · Medium impact · Low impact · Declining skills · Adjacent skills · Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Note(s): 1. This is a suitable role within the land transport industry to transition into; other external roles can also be considered.

RAIL TECHNICIANS

Technician/ Senior Technician (Mechanical and Electrical)

Job description: The Technician/ Senior Technician (Mechanical and Electrical) performs preventive and corrective maintenance of mechanical and electrical systems at various rail premises. The technician assists in the preparation of maintenance work, performs routine maintenance, conducts fault analysis and testing to improve the reliability of mechanical and electrical systems. The technician also provides technical guidance and on-the-job coaching to the team. The technician also supervises the work of contractors and external stakeholders in ensuring compliance to safety requirements and operating standards.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Perform preventive maintenance of mechanical and electrical systems and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures	• Continue to interpret mechanical and electrical systems health data collected from fire protection systems, lift systems, air-conditioning systems to identify potential failure modes. • RPA can ensure that mechanical and electrical systems data is collected and analysed via centralized systems which will reduce the need for human intervention.	
2. Perform corrective maintenance through conducting repair and modifications of electronics, electrical and mechanical equipment and mechanical and electrical systems	• Continue to perform repair work. • Predictive technology such as condition monitoring and sensors can streamline the troubleshooting process and reduce manual effort.	
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.	• Continue to conduct visual checks on tools, vehicles and equipment to maintain working condition. • Data analytics would support the preparation of standardized reports, conduct digital data logging and documentation.	
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.	• Human intervention and judgment remain critical in overseeing operations and ensuring compliance. • Digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation as part of vendor and stakeholder management.	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **5 – 20 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Escalator and Travellator Maintenance =
- Condition-Based Assets Monitoring Management =
- Report Writing =
- Rail Regulatory Compliance =
- Vendor Management =
- WSH Confined Spaces =
- WSH Electrical Safety =
- Problem Solving =
- Data Usage and Implementation ▲
- Internet of Things Application ▲
- Robotics and Automation Application ▲
- Sensor Monitoring Management ▲

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Technician / Senior Technician (Power) – 86.0

Legend for job tasks & skills

High impact · Medium impact · Low impact

Declining skills · Adjacent skills · Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Technician/ Senior Technician (Signal and Communications)

Job description: The Technician/ Senior Technician (Signal and Communications) performs preventive and corrective maintenance of signal, communication and control systems to improve the reliability of signal, communication and control systems. The technician assists in maintenance activities, is adept in handling electronics and computer-based systems and equipment for maintenance and provides technical guidance and on-the-job coaching to the team The technician also supervises the work of contractors and external stakeholders in ensuring adherence to operating requirements and safety standards.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Perform preventive maintenance of signal, communication and control systems and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures	• Continue to interpret signal, communication and control systems health data is collected from network systems, radio systems, signal and information systems to identify potential failure modes. • RPA can ensure that signal, communication and control systems data is collected and analysed via centralized systems which will reduce the need for human intervention.	
2. Perform corrective maintenance through conducting repair and modifications of electronics and computer-based systems and equipment needed for signal, communication and control systems	• Continue to perform repair work. • Predictive technology such as condition monitoring and sensors can streamline the troubleshooting process and reduce manual effort.	
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.	• Continue to conduct visual checks on tools, vehicles and equipment to maintain working condition. • Data analytics would support the preparation of standardized reports, conduct digital data logging and documentation.	
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.	• Human intervention and judgment remain critical in overseeing operations and ensuring compliance. • Digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation as part of vendor and stakeholder management.	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **5 – 20 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Communication Auxiliary Systems Maintenance
- Condition-Based Assets Monitoring Management
- Report Writing
- Rail Regulatory Compliance
- Vendor Management
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Technician / Senior Technician (Power) – 86.8

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Technician/ Senior Technician (Automatic Fare Collection)

Job description: The Technician/ Senior Technician (Automatic Fare Collection) performs preventive and corrective maintenance of Automatic Fare Collection (AFC) Line Replacement Units (LRUs). The technician is responsible for the preparation of materials, tools, equipment and checklists required, conduct of fault analysis and testing to improve the reliability of the AFC systems. The technician also provides technical guidance and on-the-job coaching to his team and supervises the work of contractors and external stakeholders in ensuring compliance to safety requirements and operating standards.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Perform preventive maintenance on AFC LRUs and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures	• Continue to interpret AFC systems health data collected to identify potential failure modes. • RPA can ensure that AFC LRU data is collected and analysed via centralized systems which will reduce the need for human intervention.	
2. Perform corrective maintenance through conducting fault analysis and repair of AFC systems	• Continue to perform repair work. • Predictive technology such as condition monitoring and sensors can streamline the troubleshooting process and reduce manual effort.	
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities.	• Continue to conduct visual checks on tools, vehicles and equipment to maintain working condition. • Data analytics would support the preparation of standardized reports, conduct digital data logging and documentation.	
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards such as ISOs, Workplace Safety and Health Act, etc.	• Human intervention and judgment remain critical in overseeing operations and ensuring compliance. • Digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation as part of vendor and stakeholder management.	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **5 – 20 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Automatic Fare Collection Auxiliary Systems Maintenance
- Condition-Based Assets Monitoring Management
- Report Writing
- Rail Regulatory Compliance
- Vendor Management
- WSH Confined Spaces
- WSH Electrical Safety
- Problem Solving
- Data Usage and Implementation
- Internet of Things Application
- Robotics and Automation Application
- Sensor Monitoring Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Technician / Senior Technician (Mechanical and Electrical) - 79.3
- Technician / Senior Technician (Power) – 77.9

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

4.3.3 Rail Operations

Selected rail operations job tasks such as:

1. Monitoring and controlling train services and operations in real-time and related daily activities;
3. Perform documentation and reporting; and
4. Preparing duty rosters and ensuring deployment of Train Captains;

may observe a high degree of change. This is because these train operations which are manual and administrative are projected to be largely automated using IoT, RPA, machine learning and robotics technologies brought about by I4.0.

New job tasks are expected to be created which will revolve around more value-adding activities and activities requiring higher cognitive functions.

On the other hand, there are other rail operations job tasks such as:

1. Implementing and executing service recovery measures during rail emergencies and incidents.
2. Managing and addressing service challenges of passengers.

which may observe a medium degree of change. This is because while the technologies can help to augment service recovery activities and reduce the manpower needed, human intervention and judgement is still critical to determine best approach solutions and communicating with the passengers.

Given the impact of I4.0 on job tasks, based on preliminary qualitative analysis, our current hypothesis indicates that the below job roles have high degree of automatability in their core job tasks, which increases the possibility of job displacement and redundancy:

1. Senior Train Captain/ Train Captain
2. Crew Manager
3. Customer Service Officer/ Rover
4. Communication Controller

Please refer to Section 5.1.3 of this report for the evolution of job tasks for rail operations over 5, 10 and 20-year windows.

Communication Controller

Job description: The Communication Controllers keeps track of daily rail operation activities and supports the Operations Control Centre (OCC) in executing its tasks and requirements by monitoring passenger activities and train operations via close-circuit television (CCTV) and communication and alert systems, to provide train service information and updates to commuters and the public.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Monitor passenger activities and train operations	• The focus of the Communication Controller within station will shift to crisis management and he/she will handle multiple stations instead of one station via centralized control centres. • Station monitoring will be automated via vision based sensors installed within station premises.	
2. Provide real-time train service information and updates	• The role of a Communication Controller will be consolidated to multi-station environments instead of one station. • Train service information and updates can be conveyed via centralized systems with minimal need for human intervention.	
3. Perform documentation and Reporting	• The role of a Communication Controller will need to shift from basic documentation and logging of daily activities to value-added tasks such as data interpretation and service quality improvements. • RPA can be used to generate standardized reports, conduct digital data logging and documentation reducing manual work	
4. Implement and execute service recovery measures during rail emergencies and incidents	• The Communication Controller will continue to act under pressure in instances of crisis and select the best approach to address rail emergencies and incidents. • Digital communication tools and virtual signages would supplement service recovery activities and may reduce manpower required during unforeseen circumstances	

A SIGNIFICANT proportion of job tasks will be automated by key technologies, tasks performed will have a

HIGH degree of change

Within the next **10 – 20 years**, the job role(s) could potentially change

DISPLACEMENT

Reskilling is required

To take on adjacent job role(s) the skills below will become critical:

- Rail Operations Control Management
- Report Writing
- Rail Regulatory Compliance
- Rail Incident Management
- Rail Emergency Response Management
- Workplace Facilities Safety Management
- WSH Incident and Accident Investigation
- WSH Culture Development
- Health and Fatigue Risk Management
- Data Usage and Implementation
- Sensor Monitoring Management
- Innovation Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Station manager

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Customer Service Officer/ Rover

Job description: The Customer Service Officer/ Rover supports the daily train services and operations, which include conducting patrols on passenger trains and at station premises to ensure the operability of equipment, performing first-line recovery of train and station equipment malfunctions, and serving as an emergency train operator.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Conduct patrol, crowd and security management on passenger trains and station premises	• Manual patrolling work will no longer be needed with the use of Intelligent Security Surveillance System which provide real-time passenger information whether in trains or stations. • The job holder will be focus on remote monitoring of passengers, analysis of passenger flow data and on-site deployment for crowd management.	
2. Conduct recovery of train and station equipment in malfunction	• IoT devices and sensors will perform remote diagnostics of train and station system malfunctions and report incidences. • The Rover will focus mainly on monitoring of sensor data and interpreting signals before site mobilization for first-line recovery and close-up inspections.	
3. Manage and address service challenges of passengers	• Management of passenger crowd and customer service will become a core task of the Customer Service Officer / Rover, complemented by the use of real-time crowd management solutions such as Distributed Intelligent Video Analytics.	
4. Implement and execute service recovery measures during rail emergencies and incidents	• The Customer Service Officer/ Rover will continue to act under pressure in instances of crisis and select the best approach to address rail emergencies and incidents. • Digital communication tools and virtual signages would supplement service recovery activities and may reduce manpower required during unforeseen circumstances	

A SIGNIFICANT proportion of job tasks will be automated by key technologies, tasks performed will have a

HIGH degree of change

Within the next **10 – 20 years**, the job role(s) could potentially change

DISPLACEMENT

Reskilling is required

To take on adjacent job role(s) the skills below will become critical:

- Train Fare and Ticket Management
- Train Station Operations Management
- Rail Regulatory Compliance
- Rail Incident Management
- Rail Emergency Response Management
- Workplace Facilities Safety Management
- WSH Incident and Accident Investigation
- WSH Culture Development
- Health and Fatigue Risk Management
- Data Usage and Implementation
- Sensor Monitoring Management
- Innovation Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Bus Operations Control Centre Controller
- Company Secretaries
- Customer Service Manager

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Train Captain/ Senior Train Captain

Job description: The Senior Train Captain/ Train Captain operates passenger trains to provide a safe, reliable and efficient commute for passengers and to achieve the overall train service standards. The captain is well-versed with train operations and the functions of train-borne systems and equipment, monitors and analyses the train operations from the cabs of the trains in order to make quick and sound operational decisions to maintain and improve train service standards and reliability.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Operate passenger trains and meet overall train service standards	• Modern trains are highly automated, operate in confined environment and equipped robust signalling systems which automates tasks such as setting train in motion, stopping train, door closure and operation in event of disruption. • The Train Captain's focus will shift towards monitoring technology solutions and interpreting data to manage exceptions through train dashboards.	
2. Maintain communication with the Operations Control Centre (OCC)	• Train related information are collected via train-borne sensors and train-to-ground communications are established automatically with trackside communication systems. • The role of the Train Captain will be limited to monitoring and handling of exceptions.	
3. Maintain passenger safety onboard of trains	• Train-borne Video Surveillance Systems can be accessed via OCC and safety surveillance can be conducted remotely • The role of the Train Captain will be restricted to reporting of safety non-compliance incidences onboard trains and apply judgment on corrective measures	
4. Implement and execute service recovery measures during rail emergencies and incidents	• The Train Captain will continue to act under pressure in instances of crisis and select the best approach to address rail emergencies and incidents. • Digital communication tools and virtual signages would supplement service recovery activities and may reduce manpower required during unforeseen circumstances	

A SIGNIFICANT proportion of job tasks will be automated by key technologies, tasks performed will have a

HIGH degree of change

Within the next **10 – 20 years**, the job role(s) could potentially change

DISPLACEMENT

Reskilling is required

To take on adjacent job role(s) the skills below will become critical:

- Passenger Train Operations
- Rail Regulatory Compliance
- Rail Incident Management
- Rail Emergency Response Management
- Workplace Facilities Safety Management
- WSH Incident and Accident Investigation
- WSH Culture Development
- Health and Fatigue Risk Management
- Data Usage and Implementation
- Sensor Monitoring Management
- Innovation Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Bus operations control centre controller
- Rail operations control management

Legend for job tasks & skills

High impact	Declining skills
Medium impact	Adjacent skills
Low impact	Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Note(s): 1. This is a suitable role within the land transport industry to transition into; other external roles can also be considered.

Crew Manager

Job description: The Crew Manager manages the daily operations and duties of Train Captains through preparation of duty rosters, deploying resources, ensuring discipline, well-being and performance standards of Train Captains. The manager is well-versed with train service operations and service standards, an is required to execute crew reformation and deployment plans to maintain train service standards and reliability, as well as safety standards of train operations.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Prepare duty rosters and ensure deployment of Train Captains	• Roster scheduling solutions will automate the allocation of Train Captains using optimization algorithms to save deployment time. • The role of the Crew Manager will shift from rostering works to utilizing data to enhance performance of Train Captains and further reduce costs.	
2. Oversee the performance and well-being of Train Captains	• The tasks performed of Train Captains will be largely automated and may lead to Crew Managers managing a smaller pool of Train Captains in areas of performance assessment and service feedback. • IoT sensors onboard trains will gather data and feedback on performance of Train Captains and stored in a central database for processing and analysis by the Crew Manager.	
3. Execute crew reformation and deployment plans to comply with train service and safety standards	• Duties and rosters of Train Captains will be pushed automatically to mobile devices maintained by each Train Captain without the need for intervention by Crew Managers. • Crew Managers will focus on onboarding activities of Train Captains, staff motivation and analysis of data collected to ensure no scheduling exceptions are found.	
4. Conduct corrective actions on performance of Train Captains	• The focus of the Crew Manager will be on understanding the situation and conduct corrective actions with the Train Captains • Data collected on performance of Train Captains by sensors onboards trains are summarized and analysed by the Crew Manager.	

A SIGNIFICANT proportion of job tasks will be automated by key technologies, tasks performed will have a

HIGH degree of change

Within the next **10 – 20 years**, the job role(s) could potentially change

DISPLACEMENT

Reskilling is required

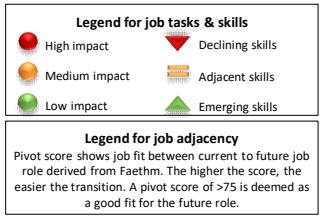
To take on adjacent job role(s) the skills below will become critical:

- Inventory Management
- Report Writing
- Rail Regulatory Compliance
- Rail Incident Management
- Rail Emergency Response Management
- Workplace Facilities Safety Management
- WSH Incident and Accident Investigation
- WSH Culture Development
- Health and Fatigue Risk Management
- Data Usage and Implementation
- Sensor Monitoring Management
- Innovation Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Bus Operations Control Centre Controller
- Company Secretaries
- Customer Service Manager



Train Service Controller/ Depot Traffic Controller/ Depot Train Controller/ Chief Controller/ Controller/ Operations Control Centre Manager/ Head, Operations Control Centre

Job description: The Train Service Controller/ Depot Train Controller/ Depot Traffic Controller/ Chief Controller/ Controller/ Operations Control Centre (OCC) Manager/ Head monitors, controls, regulates, and manages train services in real-time in the OCC to provide regular and efficient train services, and directs the movement of trains within the depot. He coordinates with operations and maintenance centres across the rail network to manage activities for daily train services and implement service recovery measures during rail incidents and/or accidents. He manages track access to ensure the protection and safety of maintenance personnel and coordinates with relevant internal and external stakeholders to execute first-line recovery of trains during train service disruptions.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Monitor and control train services in real-time and related daily activities	• The focus of the controller within the station will shift to crisis management and he/she will handle multiple stations / depots instead of one station / depot via centralized control centres. • Train services monitoring will be automated via vision based sensors installed within station premises and on trains.	
2. Implement and execute service recovery measures during rail emergencies and incidents	• The controller will continue to act under pressure in instances of crisis and select the best approach to address rail emergencies and incidents. • Digital communication tools and virtual signages would supplement service recovery activities and may reduce manpower required during unforeseen circumstances	
3. Provide technical guidance and on-the-job coaching	• Human interaction would continue to be required to conduct on-the-job coaching • Performance management systems can be utilised to guide training and development programmes for junior engineers/ technicians	
4. Establish and ensure workplace safety standards and competencies	• Human judgment is a crucial aspect of formulating, identifying and developing safety standards and competencies across rail functions. • The controller is expected to promulgate safety standards and develop initiatives to ensure compliance across rail functions	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **10 – 20 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skill

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Security Management
- Track Access Management
- Train Depot Control Management
- Decision making
- Rail Regulatory Compliance
- Rail Incident Management
- Rail Emergency Response Management
- Workplace Facilities Safety Management
- WSH Incident and Accident Investigation
- People Development
- Data Usage and Implementation
- Sensor Monitoring Management
- Innovation Management
- Data and Statistical Analytics

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Station manager

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Senior Assistant Station Manager/ Assistant Station Manager/ Senior Station Manager/ Station Manager/ Deputy Station Manager/ Rail Service Manager/ Service Operations Manager/ Duty Operations Manager/ Station Operations Manager/ Train Operations Manager/ Head, Train Operations/ Head, Station Operation/ Head, Passenger Services

Job description: The Senior Assistant Station Manager/ Assistant Station Manager/ Senior Station Manager/ Station Manager/ Deputy Station Manager/ Rail Service Manager/ Service Operations Manager/ Duty Operations Manager/ Station Operations Manager supports the day-to-day operations of the train station, which includes preparing the station for rail service, conducting security patrols at station premises and on train platforms, providing customer service, and performing duties in the Passenger Service Centre. Senior positions are responsible for the achievement of rail service and station operations performance standards, recommends and implements continuous improvement initiatives to enhance overall rail services, coordinates improvement initiatives for station facilities and implements security measures.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Monitor train station operations	• The focus of the Station Manager within station will shift to crisis management and he/she will handle multiple stations instead of one station via centralized control centres. • Station monitoring will be automated via vision based sensors installed within station premises.	
2. Implement and execute service recovery measures during rail emergencies and incidents	• The Station Manager will continue to act under pressure in instances of crisis and select the best approach to address rail emergencies and incidents. • Digital communication tools and virtual signages would supplement service recovery activities and may reduce manpower required during unforeseen circumstances	
3. Provide technical guidance and on-the-job coaching	• Human interaction would continue to be required to conduct on-the-job coaching • Performance management systems can be utilised to guide training and development programmes	
4. Establish and ensure workplace safety standards and competencies	• Human judgment is a crucial aspect of formulating, identifying and developing safety standards and competencies across rail functions. • The Station Manager is expected to promulgate safety standards and develop initiatives to ensure compliance across rail functions .	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **10 – 20 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skill

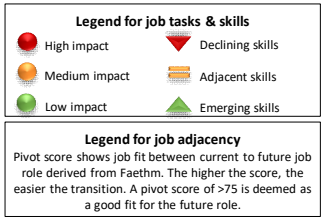
To take on adjacent/ new job role(s) the skills below will observe these changes:

- Security Management
- Track Access Management
- Decision making
- Rail Regulatory Compliance
- Rail Incident Management
- Rail Emergency Response Management
- Workplace Facilities Safety Management
- WSH Incident and Accident Investigation
- Health and Fatigue Risk Management
- People Development
- Data Usage and Implementation
- Sensor Monitoring Management
- Innovation Management
- Data and Statistical Analytics

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Operations Manager
- Administrative Services manager
- Venue Manager
- Facilities Manager



4.4 Detailed analysis – Bus

4.4.1 Bus Engineers

Bus maintenance job tasks of bus engineers such as:

1. Coordinating routine scheduled vehicle maintenance operations based on last maintenance session and condition of bus vehicles; ensure bus vehicles completes routine maintenance sessions;
2. Supporting on-the-road vehicle breakdown assistance and recovery using diagnostic tools to identify faults, completing simple repairs on-site or transport vehicles to workshops for more complicated works; and
3. Providing technical advice to vehicle maintenances teams for complex issues and overseeing the maintenance works in complicated cases;

may observe a medium degree of change. This is because the maintenance of EVs is vastly different from ICE vehicles in aspects of electric drivetrain, battery, charging components, cooling systems and sensors installed in the vehicle. There will be fewer components to be repaired and maintained as well given the fewer moving parts in electric vehicles. Charging infrastructure is also necessary to support the charging of EV fleets which creates new job tasks such as charging infrastructure installation and maintenance.

In the longer term when AV arrives, bus maintenance job tasks of bus engineers such as:

1. Coordinating routine scheduled vehicle maintenance operations based on last maintenance session and condition of vehicles; ensure vehicles complete routine maintenance sessions;
2. Performing general housekeeping of workshop tools and diagnostic equipment via a log system and maintenance scheduling system; and
3. Supporting on-the-road vehicle breakdown assistance and recovery using diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works;

may observe a medium degree of change. This is because these tasks are projected to have to be altered to support AVs instead of ICE vehicles, given that the maintenance of AVs would require deep expertise in AV related components and technology such as sensors, perception system, automatic general control system and network vehicular communication systems.

Please refer to Section 5.2.1 of this report for the evolution of job tasks for bus engineers over 5, 10 and 20-year windows.

BUS ENGINEERS

Engineer/ Engineering Manager

Job description: The Engineer monitors the performance of the bus fleet to ensure operational safety and reliability, identify bus system degradation, diagnose root causes and implement mitigation actions to reduce service downtime. He provides technical advice to bus maintenance team for fleet-wide engineering and maintenance based on in-depth knowledge of bus systems and engineering principles. He conducts engineering studies and sources for technology application to improve bus operations. The Engineering Manager reviews fleet performance audit data to establish fleet engineering and maintenance standards and commissions engineering studies and technology application projects.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Diagnose root cause of bus system degradation through ICE diagnostic tools and ICE based engineering knowledge; implement improved maintenance or future mitigation actions to slow down system degradation	• EV technical knowledge and expertise will be required to diagnose EV-specific root problems • Interpret bus health data collected from EV diagnostic tools and various sensors such as temperature and voltage sensors; implement improved maintenance or future mitigation actions to slow down system degradation	
2. Provide technical advice to ICE bus maintenance team for complex issues and oversee the maintenance works in complicated cases	• Fundamental differences in the system due to electrical based components such as batteries and electric drivetrain parts instead of mechanical components • EV technical knowledge and expertise will be required as well as knowhows of operating high-level EV diagnostics tools	
3. Conduct engineering studies for overall ICE equipment and vehicles; source for new technology application applicable to ICE maintenance work for increased efficiency and effectiveness	• The fundamental system of an EV is different from conventional ICE based vehicles hence conducting of engineering studies and sourcing for technology application for each technology will be different to improve bus maintenance operations	
4. Review fleet performance audit data to establish standards that are relevant and applicable in today's context	• Consistent review of fleet performance audit will remain similar to ensure improvements of bus operations and maintenance standards matching with the advancement of technology	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **5 – 20 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Bus Engine System Maintenance
- Bus Drivetrain System Maintenance
- Engineering Maintenance Management
- Bus Regulatory Compliance
- Workplace Facilities Safety Management
- Data and Statistical Analytics
- Internet of Things Application
- Robotics and Automation Application
- EV Dashboard Diagnostic
- Bus Battery System Maintenance
- Bus Electric Drivetrain System Maintenance
- Bus High Voltage System Maintenance

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- EV Bus Engineer

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

4.4.2 Bus Technicians

Similarly, bus maintenance job tasks of bus technicians such as:

1. Coordinating routine scheduled vehicle maintenance operations based on last maintenance session and condition of bus vehicles; ensure bus vehicles completes routine maintenance sessions;
2. Supporting on-the-road vehicle breakdown assistance and recovery using diagnostic tools to identify faults, completing simple repairs on-site or transport vehicles to workshops for more complicated works; and
3. Providing technical advice to vehicle maintenances teams for complex issues and overseeing the maintenance works in complicated cases;

may observe a medium degree of change. This is because the maintenance of EVs is vastly different from ICE vehicles in aspects of electric drivetrain, battery, charging components, cooling systems and sensors installed in the vehicle. Core tasks are projected to be largely augmented by EV technologies, in which dashboard diagnostics and testing of electrical, high voltage systems, battery components and module and parts replacement are done rather than repairing works. Although there are repair works that are common in both ICE vehicle and EVs such as body works and tyre replacement, EVs generally have fewer components to maintain and will not require as frequent maintenance as ICE vehicles. Charging infrastructure is also necessary to support the charging of EV fleets which creates new job tasks such as charging infrastructure installation and maintenance.

In the longer term when AV arrives, bus maintenance job tasks of bus technicians such as:

1. Coordinating routine scheduled vehicle maintenance operations based on last maintenance session and condition of vehicles; ensure vehicles complete routine maintenance sessions;
2. Performing general housekeeping of workshop tools and diagnostic equipment via a log system and maintenance scheduling system; and
3. Supporting on-the-road vehicle breakdown assistance and recovery using diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works;

may observe a medium degree of change. This is because these tasks will have to be altered to support AVs instead of ICE vehicles, given that the maintenance of AVs would require deep expertise in AV related components and technology such as sensors, perception system, automatic general control system and network vehicular communication systems.

Given the impact of EVs on job tasks in the bus segments, based on preliminary qualitative analysis, the bus technician job role would have medium degree of change in their core job tasks, which increases the possibility of job redesign while in the long term, the bus technician are projected to have a medium degree of change in their core job tasks to AV technology which increases the possibility of job redesign between 10 to 20 years or beyond.

Please refer to Section 5.2.2 of this report for the evolution of job tasks for bus technicians over 5, 10 and 20-year windows.

BUS TECHNICIANS

Technician/ Senior Technician/ Section Supervisor/ Foreman/ Workshop Supervisor/ Senior Foreman/ Technical Specialist/ Senior Technical Specialist/ Master Technical Specialist/ Deputy Workshop Manager/ Workshop Manager

Job description: The Technician/ Technical Specialist performs routine general and/or specific bus sub system servicing and preventive corrective maintenance activities. He prepares work activities, performs assigned servicing and maintenance tasks, performs general housekeeping of workshop tools and equipment and adheres to Workplace Safety and Health (WSH) procedures. He also supports on-the-road bus breakdown assistance and recovery. The seniors/ masters coordinate the routine scheduled bus maintenance operations of the team/ section, plan and assign daily work tasks, provide technical guidance and on-the-job coaching and propose workflow improvements. The managers support coordination of cross functional teams, supports budget forecasting and conducts engineering studies for improvement initiatives

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance such as oil, filter changing, tire rotations or specific bus sub system servicing such as air condition maintenance, engine system maintenance, mechanical drivetrain system and body work maintenance	• Utilize EV specific tools and diagnostics equipment to conduct inspection and maintenance for buses, interpret bus health data collected from various sensors such as temperature and voltage sensors • Replace electrical based components instead of mechanical components such as batteries and electrical drivetrain parts	
2. Coordinate routine scheduled bus maintenance operations based on last maintenance session and condition of bus vehicles; ensure bus vehicles completes routine maintenance sessions	• Frequency of maintenance will drop as EVs have lesser repairs required • Maintenance of specific EV parts which differ from ICE based vehicles will be allocated to specialists on the shop floor	
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment via a log system and maintenance scheduling system	• While the tools utilized for maintaining EVs are different from conventional ICE based vehicles, housekeeping remains a general task that must be performed by each technician in their work regime	
4. Support on-the-road bus breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	• EV diagnostic tools instead of ICE diagnostic tools will be used to ascertain if a fault is recoverable on–site • Less specialized repairs can be done on-site while more complicated repairs such as drive train faults will need to be conducted in the workshops with proper gears and equipment	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **5 – 10 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Bus Engine System Maintenance
- Bus Drivetrain System Maintenance
- Bus Regulatory Compliance
- Bus Body Work Maintenance
- Workplace Facilities Safety Management
- Data and Statistical Analytics
- Internet of Things Application
- Robotics and Automation Application
- EV Dashboard Diagnostic
- Bus Battery System Maintenance
- Bus Electric Drivetrain System Maintenance
- Bus High Voltage System Maintenance

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Car Mechanic
- EV Bus Technician
- EV Technician

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

BUS TECHNICIANS

Technician/ Senior Technician/ Section Supervisor/ Foreman/ Workshop Supervisor/ Senior Foreman/ Technical Specialist/ Senior Technical Specialist/ Master Technical Specialist/ Deputy Workshop Manager/ Workshop Manager

Job description: The Technician/ Technical Specialist performs routine general and/or specific bus sub system servicing and preventive corrective maintenance activities. He prepares work activities, performs assigned servicing and maintenance tasks, performs general housekeeping of workshop tools and equipment and adheres to Workplace Safety and Health (WSH) procedures. He also supports on-the-road bus breakdown assistance and recovery. The seniors/ masters coordinate the routine scheduled bus maintenance operations of the team/ section, plan and assign daily work tasks, provide technical guidance and on-the-job coaching and propose workflow improvements. The managers support coordination of cross functional teams, supports budget forecasting and conducts engineering studies for improvement initiatives

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance such as oil, filter changing, tire rotations or specific bus sub system servicing such as air condition maintenance, engine system maintenance, mechanical drivetrain system and body work maintenance	• Utilize AV specific tools and diagnostics equipment to conduct inspection and maintenance for vehicles • Replacement and repair of sensor perception systems, network and vehicular communications, vehicle control system and more	
2. Coordinate routine scheduled bus maintenance operations based on last maintenance session and condition of bus vehicles; ensure bus vehicles completes routine maintenance sessions	• Frequency of maintenance will drop as AVs are mostly electric and have less components which require repair work • Maintenance of specific AV parts which differ from ICE based vehicles will be allocated to specialists on the shop floor	
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment via a log system and maintenance scheduling system	• Housekeeping remains a general task that must be performed by each technician in their work regime for AV equipment and tools	
4. Support on-the-road bus breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	• AV diagnostic tools instead of ICE diagnostic tools will be used to ascertain if a fault is recoverable on–site • Less specialized repairs can be done on-site while more complicated repairs such as drive train faults will need to be conducted in the workshops with proper gears and equipment	

A MEDIUM proportion of job tasks will be automated by key technologies, tasks performed will have a

MEDIUM degree of change

Within the next **20 years or beyond**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Bus Engine System Maintenance
- Bus Drivetrain System Maintenance
- Maintenance Scheduling
- Equipment Maintenance and Housekeeping
- Workplace Facilities Safety Management
- Bus Electric Drivetrain System Maintenance
- Bus High Voltage System Maintenance
- AV Dashboard Diagnostic
- Perception System Sensor Diagnostic and Replacement
- Remote Diagnostic Recovery Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- AV Maintenance Technician

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

4.4.3 Bus Operations

Bus operations job tasks such as:

1. Providing support to emergencies, incidents, vehicle and consumer-related accidents and bus service disruptions when buses are inside/ outside of interchanges/ depots by providing situation analysis and best approach solution to resolve the crisis

may observe a medium degree of change. This is because human intervention and judgment remain critical in executing crisis management procedures and support for emergencies. However, knowledge in EV bus systems and EV vehicle operations on top of ICE bus systems and vehicle operations to provide proper analysis of service disruptions and provide best approach to resolve the crisis or emergency is crucial.

As such, the bus operations job role may have medium degree of change in their core job tasks, which increases the possibility of job redesign.

Please refer to Section 5.2.3 of this report for the evolution of job tasks for bus operations over 5, 10 and 20-year windows.

BUS OPERATIONS

Senior Interchange Officer/ Senior Interchange Assistant/ Interchange Officer/ Interchange Assistant/ Senior Interchange Supervisor/ Interchange Supervisor/ Interchange Manager/ Senior Depot Officer/ Senior Depot Assistant/ Depot Officer/ Depot Assistant/ Senior Depot Supervisor/ Depot Supervisor/ Depot Operations Manager/ Depot Manager

Job description: The Interchange Officer/ Interchange Assistant performs daily operations at the bus interchange/ bus depot to support the smooth running of bus services to serve passengers through monitoring of bus arrival and departure timings, regulating bus departure timings, redeploying bus captains to operate bus service routes and conducting bus checks to ensure service readiness. He also help passengers in need of assistance and ensure safety of passengers by performing traffic and crowd control and daily security checks. He provides support to respond to incidents and accidents. He supports compliance management to fulfil organisational and legislative requirements and provides feedback on gaps in operational efficiency to contribute towards continuous improvements. The supervisors/ managers liaise with vendors to carry out contract works, manage the team performance and development, upkeep interchange facilities, prepare contingency plans, implement improvement initiatives and oversee budget and manpower allocation.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Perform daily operations at bus interchange/ bus depot such as monitoring and regulating bus arrival and departure timings; driving buses within the interchange/ depot if required	• Monitor and regulate EV and ICE bus arrival and departure timings through intelligent transport systems such as computer aided dispatch, schedule adherence support, service compliance which are highly automated • Driving capabilities of staff within the bus interchange/ depot will need both ICE and EV bus vehicle operations expertise	
2. Provide customer service in the interchange such as answering enquiries or providing assistance for commuters, conduct security checks, facilitate traffic and crowd control	• Customer service will continue to be required to provide high quality service to answer enquires and assistance in the interchange • Security checks and traffic and crowd control in interchange will continue to be required	
3. Provide support to emergencies, incidents, accidents in the interchange/ depot for vehicle-related and commuter-related	• Human intervention and judgment remain critical in executing crisis management procedures and support for emergencies • Vehicle-related service disruptions for EVs will need EV bus operations and EV diagnostic skills	
4. Support compliance to organisational and legislative requirements and improve ICE bus service performance standards	• Compliance to organisational and legislative requirements will continue to be required • Bus service performance standards will be consistently reviewed and improved similarly to current practices	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **10 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Bus Interchange Operations ▼
- Bus Depot Operations ▼
- Bus Regulatory Compliance
- Workplace Traffic Safety Management
- Workplace Safety and Health for Incident and Accident Investigation
- Crisis Management
- Service Excellence
- Manpower Planning and Development
- EV Dashboard Diagnostic ▲
- EV Fleet System Planning ▲

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Bus Operations Control Centre Controller
- EV Fleet Manager

BUS OPERATIONS

Chief Bus Controller/ Bus Operations Control Centre Controller/ Deputy Bus Operations Control Centre Manager/ Bus Operations Control Centre Manager

Job description: The Chief Bus Controller/ bus Operations Control Centre Controller performs daily operations at the Bus Operations Control Centre (BOCC) to ensure bus service reliability on the road. He works closely with Bus Captains and other stakeholders to regulate bus services in real-time environment to maintain bus service performance standards and minimise service delays. He also provides on-the-job coaching to Bus Captains and is required to respond to emergencies and restore bus service disruptions, assist in investigation and documentation of incidents and/or accidents. He takes on administrative duties in data compilation and contributes towards continuous improvement by providing feedback on gaps observed in operational activities. The manager oversees and supervises the team within BOCC, work with relevant authorities and other stakeholders to uphold and improve bus service performance standards and manages team performance, manpower allocation, training and budgeting.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Perform daily operations in BOCC to ensure bus service reliability by regulating bus services in real-time environment, bus monitoring and supervising to ensure bus follows schedules	• Require additional basic knowledge on how EV buses work on top of ICE buses • Work closely with both ICE and EV bus captains to regulate bus services through intelligent transport systems such as computer aided dispatch, schedule adherence support, service compliance which are highly automated	
2. Provide on-the-job coaching to Bus Captains according to bus service standards by providing constructive advice for service improvements	• Continue to have overview of bus service standards and corresponding bus captain assigned to the bus route, provide constructive advice to bus captains for service improvements	
3. Provide support to emergencies, incidents, accidents and bus service disruptions when buses are inside/ outside of interchanges/ depots by providing situation analysis and best approach solution to resolve the crisis	• Human intervention and judgment remain critical in executing crisis management procedures and support for emergencies • Require to have knowledge in EV bus systems and EV vehicle operations on top of ICE bus systems and vehicle operations to provide proper analysis of service disruptions and provide best approach to resolve the crisis/ emergency	
4. Improve bus service performance standards through consistent reviews and improvements to current practices	• Bus service performance standards will be consistently reviewed and improved similarly to current practices	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **10 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Bus Operations Control Management
- Bus Regulatory Compliance
- Workplace Safety and Health for Incident and Accident Investigation
- Continuous Improvement Management
- Crisis Management
- Health and Fatigue Risk Management
- Manpower Planning and Development
- Organisational Planning and Target Setting
- Data and Statistical Analytics
- EV Dashboard Diagnostic
- EV Fleet System Planning

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Transportation manager
- EV Fleet Manager

4.4.4 Bus Captains

Core job tasks of bus captains such as:

1. Driving and operating of vehicles on planned routes according to GPS and within estimated time allocated;
2. Providing high quality customer service such as answering enquires, facilitating cash payment or card payment, assisting disabled or elderly passengers to board, alight or load baggage to the vehicle storage area; and
3. Working with the respective Associations and street-hail/ride-hail operators to handle accidents or emergencies such as ushering passengers to safe points or follow up of journey continuation methods to resume operations;

may observe a low degree of change. This is because driving, providing customer service, and crisis management would still be highly relevant core tasks and remain largely similar regardless of whether the vehicles are ICE vehicles or EVs. The incremental change would arise from small changes in driving operations such as braking or accelerating and high-level diagnostics of vehicle fault.

In the longer term when AV arrives, job tasks of bus captains such as:

1. Driving and operating of vehicles on designated routes and timings to transport passengers to destinations; and
2. Conduct high level checks on vehicle controls and on-board equipment to ensure that vehicle is ready for daily service commencement and termination.

These tasks may observe a high degree of change gradually shifting towards a focus on customer service, high level supervision and emergency & accident management.

With the impact of AV on job tasks, bus captain job role may have a high degree of obsolescence due to driverless technology in their core job tasks, which increases the possibility of job displacement and redundancy.

With the transition to driverless technology, the Bus captain job role will see a gradual decline in demand and a possibility of job redesigning to other roles such as Safety Operator.

Please refer to Section 5.2.4 of this report for the evolution of job tasks for bus captains over 5, 10 and 20-year windows.

BUS DRIVERS

Bus Captain/ Senior Bus Captain/ Chief Bus Captain/ Master Bus Captain

Job description: The Bus Captain operates various bus types on scheduled routes and timetables and performs pre-trip and post-trip bus checks to ensure bus readiness for daily service commencement and routine procedures upon service termination respectively. He works closely with the Bus Operations Control Centre (BOCC) to ensure adherence to scheduled journey timings and to seek support during incidents and/or accidents. He also provides customer service to passengers and contributes towards continuous improvement by providing feedback on gaps in service standards. The Senior Bus Captain assists in assessments for new bus service routes and provides coaching and briefings to guide junior bus captains. The Chief Bus Captain/ Master Bus Captain drives service culture and supports team performance

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Driving and operating of ICE buses on schedule routes and timetables to board and alight passengers at bus stops	• Driving and operating of buses will observe slight changes in acceleration and braking due to regenerative braking process in EVs	
2. Conduct high level checks on bus controls and on-board equipment such as testing bus doors, fare readers and engine to ensure vehicle readiness for service commencement and termination	• Conduct high level checks on EV bus controls and on-board equipment such as testing bus doors, fare readers and EV diagnostic dashboard to ensure that bus is ready for service commencement and termination	
3. Provide high quality customer service such as answering enquires, facilitating cash payment or card payment via bus reader devices and assisting disabled or elderly passengers to board and alight from the bus	• With new devices and technologies on board, Bus Captain will continue to provide high quality customer service to answer enquires and assistance in usage of the equipment • In light of the disabled or elderly, Bus Captain will remain the bridge to assist these passengers to board and alight from the bus	
4. Work with BOCC to execute crisis management procedures in emergencies or accidents such as ushering passengers to safe points or follow up of journey continuation methods to resume operations	• Human intervention and judgment will remain critical in executing crisis management procedures and support for emergencies • Work with BOCC to execute procedures under pressure and select the best approach to resolve the crisis or emergency	

A MINIMAL proportion of the job tasks will be impacted by the key trend, tasks performed will have a

LOW degree of change

Within the next **10 years**, the job role(s) could potentially undergo

INCREMENTAL CHANGE

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Bus Vehicle Operations
- Bus Equipment and Systems Operation
- Bus Regulatory Compliance
- Bus Service Route Operations Training and Development
- Service Excellence
- Workplace Traffic Safety Management
- Crisis Management
- Health and Fatigue Risk Management
- EV Dashboard Diagnostic
- Bus EV Equipment and System Operation

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Taxi/ PHC Driver
- Driving Instructor
- Bus Captain (EV based)

BUS/ TAXI/ PHC DRIVERS

Bus Captain/ Senior Bus Captain/ Chief Bus Captain/ Master Bus Captain/ Taxi Driver/ PHC Driver

Job description: The Bus Captain operates various bus types on scheduled routes and timetables and performs pre-trip and post-trip bus checks to ensure bus readiness for daily service commencement and routine procedures upon service termination respectively. He works closely with the Bus Operations Control Centre (BOCC) to ensure adherence to scheduled journey timings and to seek support during incidents and/or accidents. He also provides customer service to passengers and contributes towards continuous improvement by providing feedback on gaps in service standards. The Senior Bus Captain assists in assessments for new bus service routes and provides coaching and briefings to guide junior bus captains. The Chief Bus Captain/ Master Bus Captain drives service culture and supports team performance.
The Taxi/PHC Driver provides point-to-point services on taxis or passenger cars and performs pre-trip and post-trip vehicle checks. He operates the devices and systems that receive rides and ensures adherence to pick up and drop off locations. He works with the unions and taxi/ ride hire companies to handle incidents and/or accidents if occurred during operations. He provides customer service to passengers in need of assistance, and contribute towards continuous improvement by providing feedback on gaps in service standards

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Driving and operating of ICE vehicle on designated routes and timings to transport passengers to destinations	• No driving of the vehicle required hence bus/ car vehicle operations will change drastically to a more supervisory and observatory role over the AV	
2. Conduct high level checks on ICE vehicle controls and on-board equipment to ensure that vehicle is ready for daily service commencement and termination	• Conduct high level checks on sensor perception systems, AV controls, network and vehicular communications and on-board equipment to ensure that bus/ vehicle is ready for daily service commencement and termination	
3. Provision of high quality customer service such as answering enquires, facilitating cash payment or card payment and assisting disabled or elderly passengers to board and alight	• Elimination of driving role, bus captains/ taxi drivers/ PHC drivers to provide higher quality of customer service to answer enquires, provide assistance and personable experience to passengers	
4. Execute crisis management procedures in emergencies or accidents such as ushering passengers to safe points or follow up of journey continuation methods to resume operations	• Human intervention and judgment remain critical in executing crisis management procedures and support for emergencies • Bus captain/ taxi driver/ PHC driver might require new AV diagnostic skills to identify vehicle faults and execute recovery or crisis management procedures to resolve the emergency or accident	

A SIGNIFICANT proportion of job tasks will be automated by key technologies, tasks performed will have a

HIGH degree of change

Within the next **20 years or beyond**, the job role(s) could potentially undergo

DISPLACEMENT

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Bus/ Car Vehicle Operations
- Bus/ Car Equipment and Systems Operation
- Bus/ Car Regulatory Compliance
- Service Excellence
- Workplace Traffic Safety Management
- Crisis Management
- Health and Fatigue Risk Management
- AV Dashboard Diagnostics
- Automatic Vehicle Control System
- Network and Vehicular Communications
- Perception System Sensor Diagnostics and Replacement

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- AV Onboard Safety Operator

4.5 Detailed analysis – P2P

4.5.1 Taxi/ PHC Drivers

Core job tasks of taxi/ PHC drivers such as:

1. Driving and operating of vehicles on planned routes according to GPS and within estimated time allocated;
2. Providing high quality customer service such as answering enquires, facilitating cash payment or card payment, assisting disabled or elderly passengers to board, alight or load baggage to the vehicle storage area; and
3. Working with the respective Associations and street-hail/ride-hail operators to handle accidents or emergencies such as ushering passengers to safe points or follow up of journey continuation methods to resume operations;

would observe a low degree of change. This is because driving, providing customer service, and crisis management will still be highly relevant core tasks and would remain largely similar regardless of whether the vehicles are ICE vehicles or EVs. The incremental change would arise from small changes in driving operations such as braking or accelerating and high-level diagnostics of vehicle fault.

In the longer term when AV arrives, job tasks of taxi/ PHC drivers such as:

1. Driving and operating of vehicles on designated routes and timings to transport passengers to destinations; and
2. Conduct high level checks on vehicle controls and on-board equipment to ensure that vehicle is ready for daily service commencement and termination;

may observe a high degree of change due to obsolescence of vehicle operations from driverless technology. Driving task is projected to shift to customer service, high level supervision and emergency and accident management.

With the impact of AV on job tasks, taxi and PHC drivers job roles may have high degree of obsolescence due to driverless technology in their core job tasks, which increases the possibility of job displacement and redundancy.

Please refer to Section 5.3.1 of this report for the evolution of job tasks for taxi and PHC drivers over 5, 10 and 20-year windows.

Taxi/ PHC Driver

Job description: The Taxi/ PHC Driver provides point-to-point services on taxis or passenger cars and performs pre-trip and post-trip vehicle checks to ensure vehicle readiness for daily service commencement and service termination respectively. He operates the devices and systems that receive rides and ensures adherence to pick up and drop off locations. He works with the unions and taxi/ ride hire companies to handle incidents and/or accidents if occurred during operations. He provides customer service to passengers in need of assistance, and contribute towards continuous improvement by providing feedback on gaps in service standards.

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Driving and operating of ICE vehicles on planned routes according to GPS and within estimated time allocated	• Car vehicle operations will remain similar, with slight changes to the way of acceleration and braking for an EV due to its regenerative braking process	
2. Conduct high level checks on vehicle controls and on-board equipment such as testing of mobile applications/ devices, meters and engine to ensure vehicle readiness for service commencement and termination	• High level checks on EV controls and devices such as EV diagnostic dashboard to ensure that vehicle is ready for daily service commencement and termination	
3. Provide high quality customer service such as answering enquires, facilitating cash payment or card payment, assisting disabled or elderly passengers to board, alight or load baggage to the vehicle storage area	• Customer service will remain an important characteristic of taxis and P2P ride hailing due to the highly individualised journeys and routes taken • Continue to provide high quality customer service such as answering enquires, facilitating cash payment or card payment, assisting disabled or elderly passengers to board and alight or load baggage to the vehicle storage area	
4. Work with Associations and street-hail/ ride-hail operators to handle accidents or emergencies such as ushering passengers to safe points or follow up of journey continuation methods to resume operations	• Human intervention and judgment remain critical in executing crisis management procedures and support for emergencies • Continue to perform under pressure in instances of crisis and select the best approach to resolve the situation	

A MINIMAL proportion of the job tasks will be impacted by the key trend, tasks performed will have a

LOW degree of change

Within the next **10 years**, the job role(s) could potentially undergo

INCREMENTAL CHANGE

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Car Vehicle Operations
- Car Equipment and Systems Operation
- Service Excellence
- Car Regulatory Compliance
- Service Orientation
- Workplace Traffic Safety Management
- Crisis Management
- Health and Fatigue Risk Management
- EV Dashboard Diagnostic
- Car EV Equipment and System Operation

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Bus Captain – 92.6
- Taxi/PHC Driver (EV based)[1]

Legend for job tasks & skills

High impact — Declining skills
Medium impact — Adjacent skills
Low impact — Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Note(s): 1. Pivot scores are not applicable for new job roles

BUS/ TAXI/ PHC DRIVERS

Bus Captain/ Senior Bus Captain/ Chief Bus Captain/ Master Bus Captain/ Taxi Driver/ PHC Driver

Job description: The Bus Captain operates various bus types on scheduled routes and timetables and performs pre-trip and post-trip bus checks to ensure bus readiness for daily service commencement and routine procedures upon service termination respectively. He works closely with the Bus Operations Control Centre (BOCC) to ensure adherence to scheduled journey timings and to seek support during incidents and/or accidents. He also provides customer service to passengers and contributes towards continuous improvement by providing feedback on gaps in service standards. The Senior Bus Captain assists in assessments for new bus service routes and provides coaching and briefings to guide junior bus captains. The Chief Bus Captain/ Master Bus Captain drives service culture and supports team performance.
The Taxi/PHC Driver provides point-to-point services on taxis or passenger cars and performs pre-trip and post-trip vehicle checks. He operates the devices and systems that receive rides and ensures adherence to pick up and drop off locations. He works with the unions and taxi/ ride hire companies to handle incidents and/or accidents if occurred during operations. He provides customer service to passengers in need of assistance, and contribute towards continuous improvement by providing feedback on gaps in service standards

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Driving and operating of ICE vehicle on designated routes and timings to transport passengers to destinations	• No driving of the vehicle required hence bus/ car vehicle operations will change drastically to a more supervisory and observatory role over the AV	
2. Conduct high level checks on ICE vehicle controls and on-board equipment to ensure that vehicle is ready for daily service commencement and termination	• Conduct high level checks on sensor perception systems, AV controls, network and vehicular communications and on-board equipment to ensure that bus/ vehicle is ready for daily service commencement and termination	
3. Provision of high quality customer service such as answering enquires, facilitating cash payment or card payment and assisting disabled or elderly passengers to board and alight	• Elimination of driving role, bus captains/ taxi drivers/ PHC drivers to provide higher quality of customer service to answer enquires, provide assistance and personable experience to passengers	
4. Execute crisis management procedures in emergencies or accidents such as ushering passengers to safe points or follow up of journey continuation methods to resume operations	• Human intervention and judgment remain critical in executing crisis management procedures and support for emergencies • Bus captain/ taxi driver/ PHC driver might require new AV diagnostic skills to identify vehicle faults and execute recovery or crisis management procedures to resolve the emergency or accident	

A SIGNIFICANT proportion of job tasks will be automated by key technologies, tasks performed will have a

HIGH degree of change

Within the next **20 years or beyond**, the job role(s) could potentially undergo

DISPLACEMENT

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Bus/ Car Vehicle Operations
- Bus/ Car Equipment and Systems Operation
- Bus/ Car Regulatory Compliance
- Service Excellence
- Workplace Traffic Safety Management
- Crisis Management
- Health and Fatigue Risk Management
- AV Dashboard Diagnostics
- Automatic Vehicle Control System
- Network and Vehicular Communications
- Perception System Sensor Diagnostics and Replacement

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- AV Onboard Safety Operator

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

4.6 Detailed analysis – Motor Workshops

4.6.1 Car Mechanics

Maintenance job tasks of car mechanics such as:

1. Coordinating routine scheduled vehicle maintenance operations based on last maintenance session and condition of car vehicles; ensure car vehicles completes routine maintenance sessions;
2. Supporting on-the-road vehicle breakdown assistance and recovery using diagnostic tools to identify faults, completing simple repairs on-site or transport vehicles to workshops for more complicated works; and
3. Providing technical advice to vehicle maintenances teams for complex issues and overseeing the maintenance works in complicated cases;

would also observe a medium degree of change. This is because the maintenance of EVs is vastly different from ICE vehicles in aspects of electric drivetrain, battery, charging components, cooling systems and sensors installed in the vehicle. Core tasks will be largely augmented by EV technologies, in which dashboard diagnostics and testing of electrical, high voltage systems, battery components and module and parts replacement are done rather than repairing works. Although there are repair works that are common in both ICE vehicle and EVs such as body works and tyre replacement, EVs generally have fewer components to maintain and would not require as frequent maintenance as ICE vehicles. Charging infrastructure is also necessary to support the charging of EV fleets which creates new job tasks such as charging infrastructure installation and maintenance.

In the longer term when AV arrives, maintenance job tasks of car mechanics such as:

1. Coordinating routine scheduled vehicle maintenance operations based on last maintenance session and condition of vehicles; ensure vehicles complete routine maintenance sessions
2. Performing general housekeeping of workshop tools and diagnostic equipment via a log system and maintenance scheduling system; and
3. Supporting on-the-road vehicle breakdown assistance and recovery using diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works;

would observe a medium degree of change. This is because these tasks will have to be altered to support AVs instead of ICE/EV vehicles, given that the maintenance of AVs would require deep expertise in AV related components and technology such as sensors, perception system, automatic general control system and network vehicular communication systems.

Given the impact of EVs on job tasks, based on preliminary qualitative analysis, the car mechanics / senior mechanics/ technical specialist job role would have medium degree of change in their core job tasks, which increases the possibility of job redesign while in the long term, the car mechanics / senior mechanics/ technical specialist would have a medium degree of change in their core job tasks to AV technology which increases the possibility of job redesign between 10 to 20 years or beyond.

Please refer to Section 5.4.1 of this report for the evolution of job tasks for car mechanics over 5, 10 and 20-year windows.

CAR MECHANICS

Technician/ Senior Technician/ Section Supervisor/ Foreman/ Workshop Supervisor/ Senior Foreman/ Technical Specialist/ Senior Technical Specialist/ Master Technical Specialist/ Deputy Workshop Manager/ Workshop Manager

Job description: The Technician/ Technical Specialist performs routine general and/or specific vehicle sub system servicing and preventive corrective maintenance activities. He prepares work activities, performs assigned servicing and maintenance tasks, performs general housekeeping of workshop tools and equipment and adheres to Workplace Safety and Health (WSH) procedures. He also supports on-the-road vehicle breakdown assistance and recovery. The seniors/ masters coordinate the routine scheduled vehicle maintenance operations of the team/ section, plan and assign daily work tasks, provide technical guidance and on-the-job coaching and propose workflow improvements. The managers support coordination of cross functional teams, supports budget forecasting and conducts engineering studies for improvement initiatives

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance such as oil, filter changing, tire rotations or specific vehicle sub system servicing such as air condition maintenance, engine system maintenance, mechanical drivetrain system and body work maintenance	• Utilize EV specific tools and diagnostics equipment to conduct inspection and maintenance for vehicles, interpret vehicle health data collected from various sensors such as temperature and voltage sensors • Replace electrical based components instead of mechanical components such as batteries and electrical drivetrain parts	
2. Coordinate routine scheduled vehicle maintenance operations based on last maintenance session and condition of vehicles; ensure vehicles complete routine maintenance sessions	• Frequency of maintenance will drop as EVs have less components which require repair work • Maintenance of specific EV parts which differ from ICE based vehicles will be allocated to specialists on the shop floor	
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment via a log system and maintenance scheduling system	• While the tools utilized for maintaining EVs are different from conventional ICE based vehicles, housekeeping remains a general task that must be performed by each technician in their work regime	
4. Support on-the-road vehicle breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	• EV diagnostic tools instead of ICE diagnostic tools will be used to ascertain if a fault is recoverable on–site • Less specialized repairs can be done on-site while more complicated repairs such as drive train faults will need to be conducted in the workshops with proper gears and equipment	

A MEDIUM proportion of the job tasks will be impacted by the key trend, thus minimising or changing the current job tasks

MEDIUM degree of change

Within the next **5 – 10 years**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Car Engine System Maintenance
- Car Drivetrain System Maintenance
- Car Regulatory Compliance
- Car Body Work Maintenance
- Workplace Facilities Safety Management
- Data and Statistical Analytics
- Internet of Things Application
- Robotics and Automation Application
- EV Dashboard Diagnostic
- Car Battery System Maintenance
- Car Electric Drivetrain System Maintenance
- Car High Voltage System Maintenance

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- Bus Technician
- EV Technician
- EV Bus Technician

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

CAR MECHANICS

Technician/ Senior Technician/ Section Supervisor/ Foreman/ Workshop Supervisor/ Senior Foreman/ Technical Specialist/ Senior Technical Specialist/ Master Technical Specialist/ Deputy Workshop Manager/ Workshop Manager

Job description: The Technician/ Technical Specialist performs routine general and/or specific vehicle sub system servicing and preventive corrective maintenance activities. He prepares work activities, performs assigned servicing and maintenance tasks, performs general housekeeping of workshop tools and equipment and adheres to Workplace Safety and Health (WSH) procedures. He also supports on-the-road vehicle breakdown assistance and recovery. The seniors/ masters coordinate the routine scheduled vehicle maintenance operations of the team/ section, plan and assign daily work tasks, provide technical guidance and on-the-job coaching and propose workflow improvements. The managers support coordination of cross functional teams, supports budget forecasting and conducts engineering studies for improvement initiatives

Current Job Tasks	Future view of job tasks	Impact at task-level
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance such as oil, filter changing, tire rotations or specific vehicle sub system servicing such as air condition maintenance, engine system maintenance, mechanical drivetrain system and body work maintenance	• Utilize AV specific tools and diagnostics equipment to conduct inspection and maintenance for vehicles • Replacement and repair of sensor perception systems, network and vehicular communications, vehicle control system and more	
2. Coordinate routine scheduled vehicle maintenance operations based on last maintenance session and condition of vehicles; ensure vehicles complete routine maintenance sessions	• Frequency of maintenance will drop as AVs are mostly electric and have less components which require repair work • Maintenance of specific AV parts which differ from ICE based vehicles will be allocated to specialists on the shop floor	
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment via a log system and maintenance scheduling system	• Housekeeping remains a general task that must be performed by each technician in their work regime for AV equipment and tools	
4. Support on-the-road vehicle breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	• AV diagnostic tools instead of ICE diagnostic tools will be used to ascertain if a fault is recoverable on–site • Less specialized repairs can be done on-site while more complicated repairs such as drive train faults will need to be conducted in the workshops with proper gears and equipment	

A SIGNIFICANT proportion of job tasks will be automated by key technologies, tasks performed will have a

MEDIUM degree of change

Within the next **20 years or beyond**, the job role(s) could potentially undergo

REDESIGN

Current/future skills

To take on adjacent/ new job role(s) the skills below will observe these changes:

- Car Engine System Maintenance
- Car Drivetrain System Maintenance
- Maintenance Scheduling
- Equipment Maintenance and Housekeeping
- Workplace Facilities Safety Management
- Car Electric Drivetrain System Maintenance
- Car High Voltage System Maintenance
- AV Dashboard Diagnostic
- Perception System Sensor Diagnostic and Replacement
- Remote Diagnostic Recovery Management

Job Adjacency

The job holder could potentially take on adjacent job roles as:

- AV Maintenance Technician

Legend for job tasks & skills

High impact
Medium impact
Low impact
Declining skills
Adjacent skills
Emerging skills

Legend for job adjacency

Pivot score shows job fit between current to future job role derived from Faethm. The higher the score, the easier the transition. A pivot score of >75 is deemed as a good fit for the future role.

Figure 11 below provides a summary on the projected impact of EVs on job roles in Bus, P2P and Motor Workshop segments, with 30 job roles projected to be redesigned, and 5 job roles projected to see incremental changes.

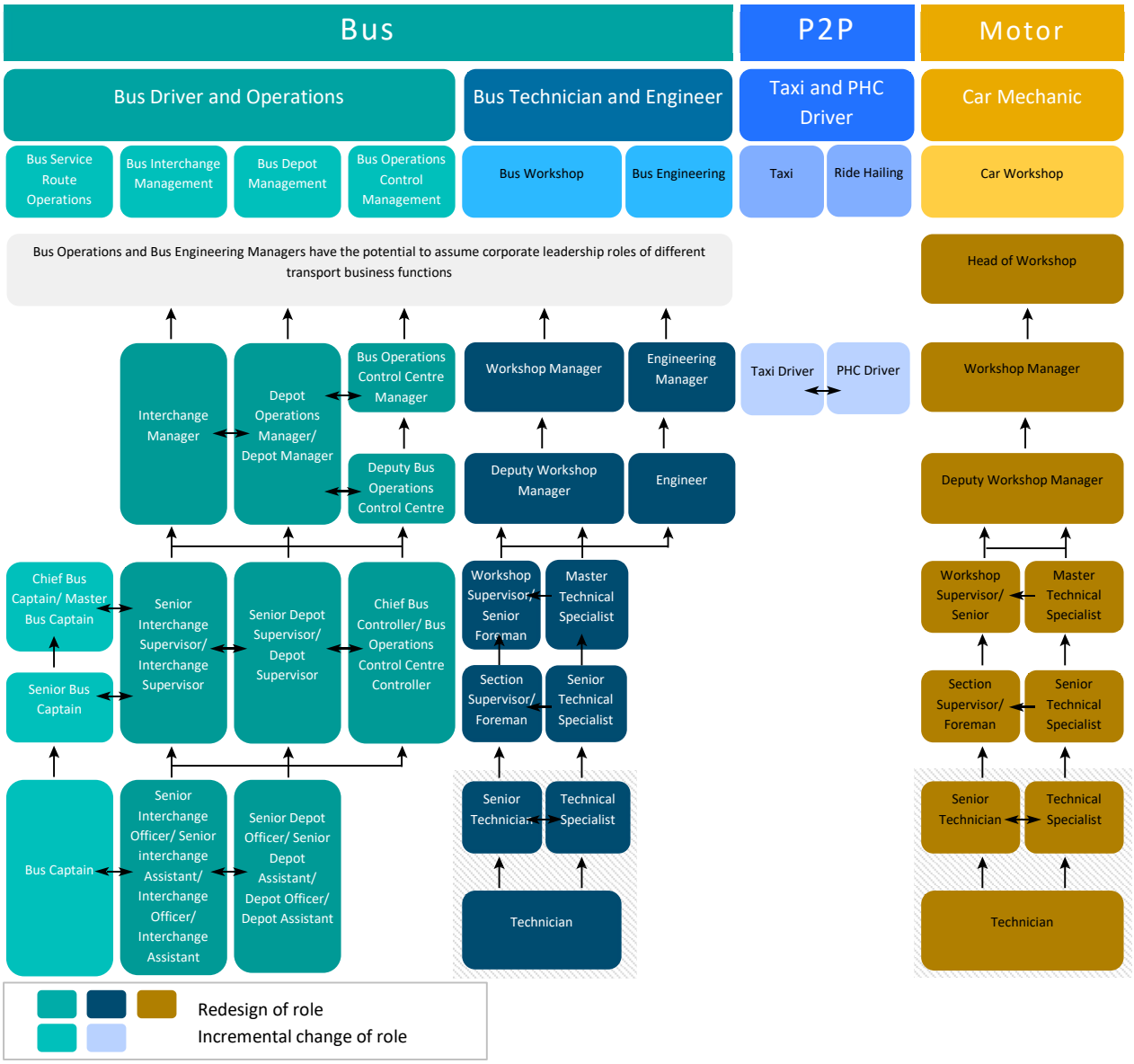


Figure 11: Identification of jobs impact in the bus, P2P and motor workshop segments due to EVs

4.7 Detailed analysis - New Job Roles

Overall, 6 new job roles will emerge across the short, medium to long term under I4.0, EVs and AVs (Figure 122):

1. Data Analyst
2. EV Technician
3. Charging Infrastructure Electrician
4. AV Onboard Safety Operator
5. AV Maintenance Technician
6. AV Fleet Manager

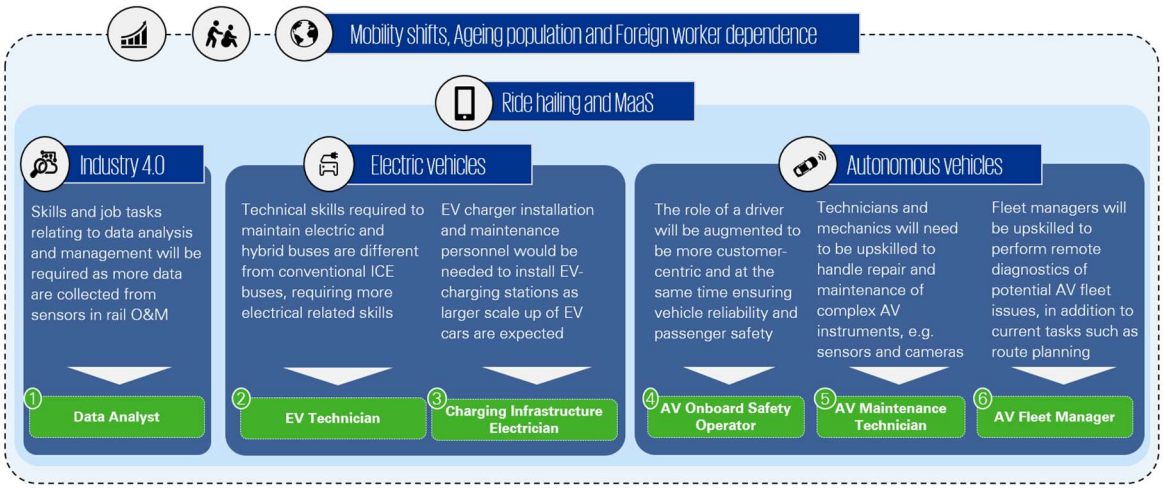


Figure 12: 6 emerging job roles in the Land Transport industry

These 6 new job roles will significantly affect the land transport industry specifically the rail segment that hires approximately 10,000 workers, public bus segment which currently employs approximately 13,000 of which about 10,000 are bus captains, P2P segment with approximately 59,000 taxi/PHC drivers and motor workshops segment that hires more than 10,000 car mechanics.

Rail segment

Most job roles in Rail are projected to remain relevant in the future with slight augmentation to I4.0 solutions in the operations and maintenance verticals.

As discussed previously, I4.0 will open up opportunities for automation of manual activities in the rail segment, thus eliminating the need for tasks that would traditionally be done physically. Rail companies are now looking to employ or train talents with the right capabilities either by way of CET or PET programmes to ensure a continuous pipeline of resources.

The proliferation of I4.0 in land transport has permeated many facets of existing job roles within the rail segment today, augmenting day-to-day tasks. For example, tasks performed by rolling stock technicians now incorporate some elements of data and statistical analytics in condition-based asset monitoring management work, monitoring "train health" through data collected from sensors installed on the rolling stock. Currently, majority of data-driven work are performed by engineers, but the roles of the technicians are expected to be augmented with more data-driven tasks as manual

inspection works are expected to reduce with the use of IoT. As such mobilized manhours will shift from labour intensive tasks to value-added work such as process improvement and preventive maintenance.

While I4.0 has reinvented day-to-day tasks of existing job roles, emerging job roles are expected to be derived from the application of I4.0. To identify these job roles, qualitative interviews and focus group discussions with 51 land transport players in Singapore coupled with data mining from online job postings from key rail operator and manufacturers globally were conducted between Dec 2020 to May 2021.

I4.0 will continue to create job opportunities in three main areas, namely data analytics and management, software and applications and robotics and robotics and system automation roles.

a. Data Analytics and Management

Data forms the backbone of I4.0 and a robust data governance and management framework is required for any organization, including land transport industry. Data analytics helps businesses in optimizing performance and allow for better decision making leading to productivity improvements and cost savings. Data is also an enabler for other core technologies such as Artificial Intelligence and predictive maintenance which relies heavily on data as foundation for its learning algorithms.

In the land transport industry, data-driven work such as providing inputs for collecting the right type of data, modelling, developing algorithms, synthesizing, and interpreting data with the assistance of visualization tools will be required as manual inspection works are expected to reduce with the use of robots and software. Mobilized manhours will shift from labour intensive tasks to value-added work such as process improvement and preventive maintenance.

Hence, an emerging role from this area, would be a Data Analyst/ Data Engineer with the following persona for illustration.

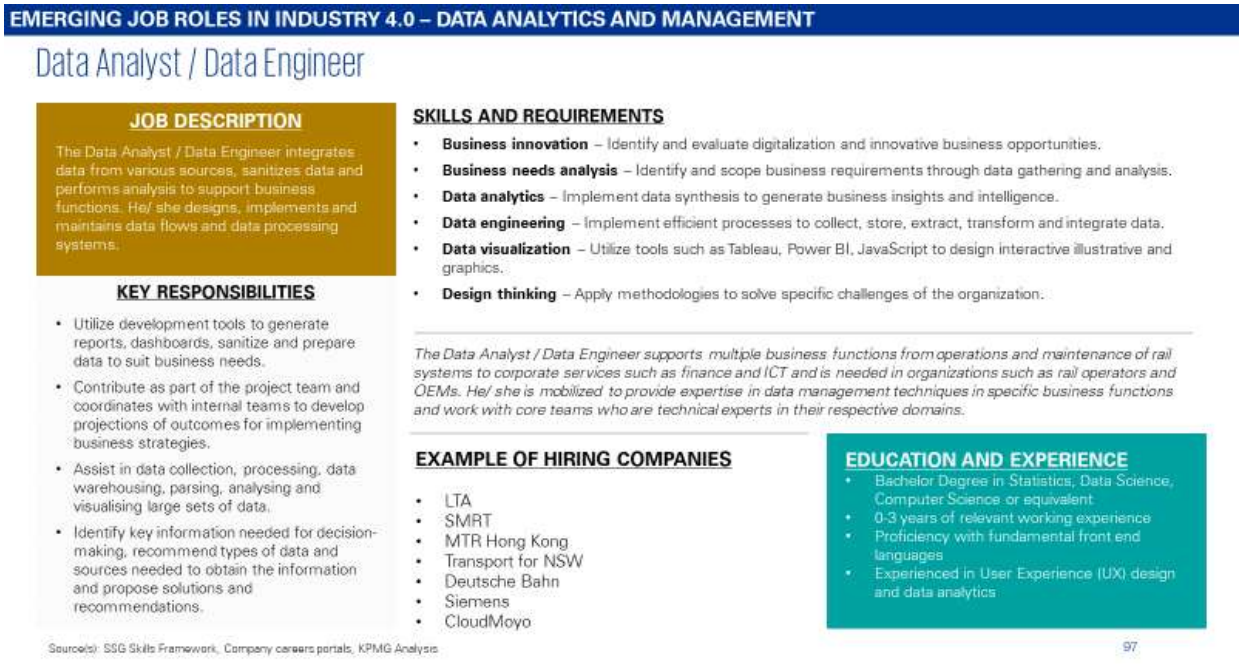


Figure 13 Data Analyst/ Data Engineer Persona

b. Software and applications

Software provides an interface between hardware solutions and the users. Software, to some degree, will require customization to suit each business application and the context of the organization which uses it. As such, the user becomes a critical stakeholder in which business rules defined in the software must cater to for it to be intuitive and easy to use.

In the land transport industry, tailoring and integration of software applications with existing transport systems, maintaining of software and redesigning of user interfaces and end-user experience will be required for optimal usage and application by employees and commuters. For example, the train dispatching software used in rail control centres should display details of service lines on a layout map for the ease of train controllers in dispatching trains effectively.

c. Robotics and Automation

Robotics and automation are key areas in operation and maintenance verticals. The use of robotics and automation will improve overall maintenance productivity and reliability by eliminating manual tasks that would traditionally be done by humans and providing increased accuracy in work activities. Given the diverse application of robotics and system automation, to cater for the different working environments and users, it is critical to apply procedural knowledge of robotic systems and automated technologies appropriately to execute tasks, supervise the use of such technology and review performance of automated workflows in order to adopt robotics and automation successfully.

In the land transport industry, particularly in the rail segment, autonomous mobile robots are used for track inspection works and cleaning. In operational work in trains and depots, video-based sensors are used for remote surveillance of passengers in stations.

These emerging job roles provide complementary functions to fundamental job roles in the rail segment such as rail engineers (e.g. rolling stock, power, p-way and others). Core tasks performed by the former revolves around providing expertise in ICT related functions while tasks performed by the latter are specific to rail technology. While these new roles form a small proportion of the workforce for rail operators but are fundamental to manufacturers and land transport technology providers.

Bus, P2P and motor workshops segments

As previously mentioned, EVs may bring about new employment opportunities in the bus, P2P and motor workshops segment, especially job roles that handle vehicles directly such as drivers and maintenance technicians. Companies in these segments are now looking to employ or train talents with the right capabilities either by way of CET or PET programmes to ensure a continuous pipeline of resources.

With Singapore's plans for decarbonization and wide use of sustainable and clean energy, the government has committed to installing 60,000 charging points by 2030 and phasing out of ICE vehicles in favour of EVs. The introduction of EVs in the land transport will permeate many facets of existing job roles within the bus, P2P and motor workshop segments today. For example, tasks performed by bus technicians/ technical specialist are expected to incorporate electrical elements instead of ICE based repairs and more diagnostic testing in condition-based maintenance.

While EVs will require existing job roles to evolve and adapt to the new technology, emerging job roles are expected to be derived from the advent of EVs in the bus, P2P and motor workshop segments.

The emerging job roles in the bus, P2P and motor workshop segments in the advent of Electric Vehicles were identified can be classified into two main areas:

a. EV Repair and Maintenance

The job roles/functions involved in servicing a car can be broadly categorised into 3 main domain areas, namely Diagnostics, Electrical/Electronics and Mechanical. The proportion mix of job roles within the 3 domains will shift as the vehicle populations transit to EVs. EVs are fundamentally different from ICE vehicles, with battery engine systems instead of fuel-based systems. Their components involve high voltage power and electrical circuit boards that require new sets of electrical skills to handle and understand.

Therefore, technicians that maintain and recover EVs will have to learn to isolate main electricity supply before working on the various components to ensure safety, understand the usage of diagnostic tools to read fault codes and comprehend OEMs' instructions for component replacement processes. The battery systems will be different from ICE systems such as the lack of requirement for oil changes and transmission fluid changes. Examples of job roles include EV technician, EV service recovery technician.

The relevant skills required to perform these tasks include battery system maintenance, electric drivetrain systems maintenance, high voltage system maintenance and some mechanical skills for body works, brakes, steering suspension system maintenance and others.

Given this niche set of skills needed, an emerging job role for would thus be an EV Technician/ EV Technical Specialist, with illustrative persona provided in Figure 14.

Figure 14: EV Technician/ EV Senior Technician/ EV Technical Specialist Persona

Particularly in the near term, impact on technicians and mechanics jobs is projected to be mostly from authorised workshops. EV OEMs will engage authorised workshops to offer exclusive maintenance and repair for their own cars. Due to strict repair and maintenance requirements by EV manufacturers, the growth of EV technicians and mechanics is expected to be at a slower pace until sufficient technicians are trained to handle EVs after which a wide-scale decentralization will occur. Hence, the proportion of EV-based technicians and mechanics out of the total population of technicians and mechanics (ICE + EV) will be low, as repair and maintenance will be provided by OEMs or authorised workshops only.

Eventually in the long term, with EVs becoming more prevalent, the impact on independent workshops is expected to be greater as they lack first-mover advantage and access to proprietary OEM technology. As such, were authorised workshops to see a reduction in the workforce needed to service EVs, there could potentially be a consolidation as well as a shift in business model in the independent workshop segment. Instead of many small full service independent workshops, we may see a much smaller number of big/medium independent workshops that provide specialised servicing and/ or are partners with authorised workshops/ OEMs/ Fleet owners.

b. EV Charging Infrastructure Construction and Maintenance

On the other hand, the wide availability of EV Charging Infrastructure nationwide is vital to support the adoption of EVs and to support domestic charging needs at steady-state. EV infrastructure such as charging points will need to be constructed and maintained regularly over the long term.

EV charging points will undergo the installation, operation and maintenance, and replacement or decommissioning lifecycle. Site works in general will include mechanical and electrical installations (including cable pulling and termination) with some sites requiring civil structural works such as those in bus depots (e.g. excavation works). Thereafter, routine maintenance and servicing will be conducted to comply to technical standards for charging points and to ensure the proper function and safety. An example of such an emerging role is the EV Charger Equipment Specialist. Supporting electrical infrastructure such as consumer switch rooms and substations will also need to be upgraded to provide for sufficient electrical capacity to support the installation of EV chargers.

The relevant skills required to perform these tasks include charging infrastructure maintenance, high voltage system maintenance and others, with the illustrative persona for EV Charging Infrastructure Electrician provided in Figure 15.

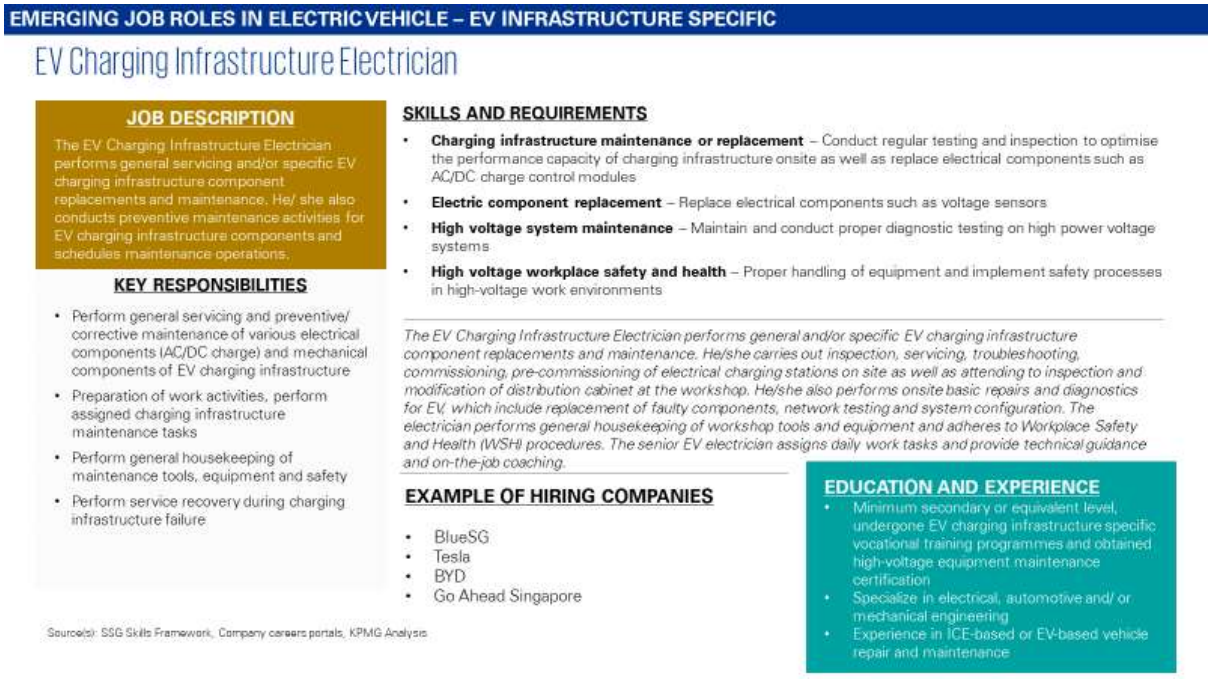


Figure 15: EV Charging Infrastructure Electrician Persona

These emerging job roles may be employed by bus operators, P2P fleet operators, motor workshop companies, OEMs and other land transport technology providers.

c. AV Repair and Maintenance

Technical skills to maintain autonomous cars are expected to be required such as AV dashboard diagnostic, perception system sensor diagnostic and replacement, network and vehicular communications, automatic vehicle control system and more. Core tasks performed by the AV maintenance technician revolves around providing expertise in AV related repair and maintenance and involves expertise around sensors, perception system, automatic general control system (see Figure 16 for illustrative persona).

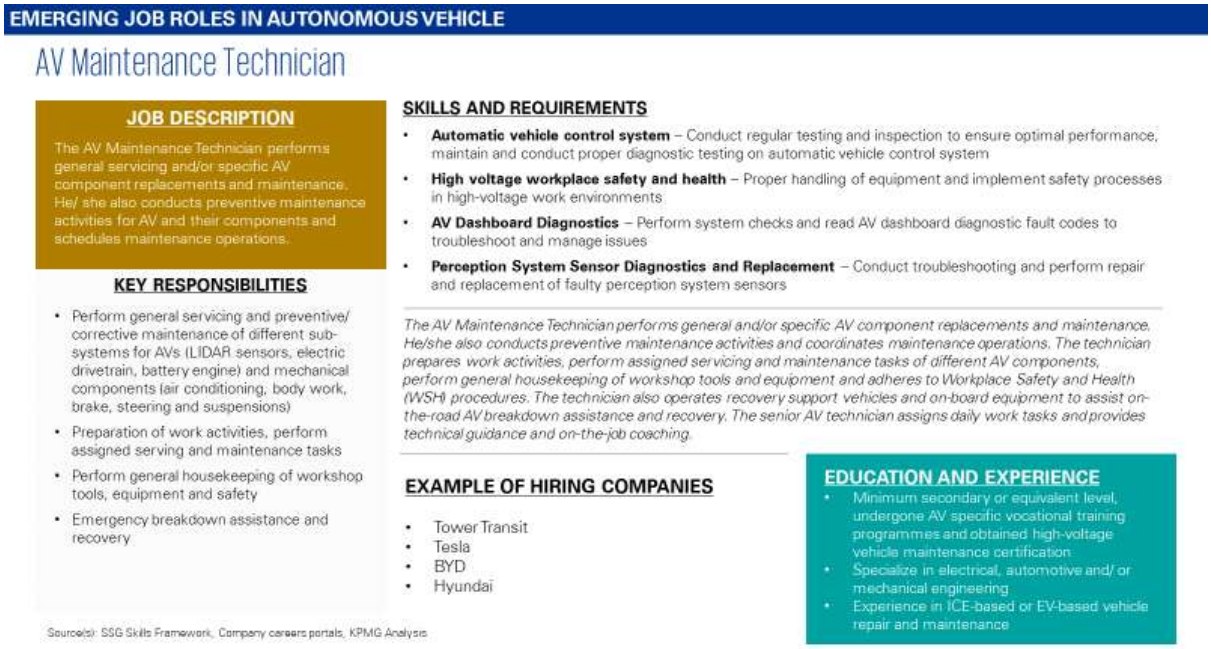


Figure 16: AV Maintenance Technician Persona

d. AV Onboard Safety Operator

Driving will no longer be required when AV arrives and skills will focus more on customer service, AV dashboard diagnostic, AV operations and AV equipment and system operation ensuring vehicle reliability and passenger safety. Core tasks performed by the AV onboard safety operator include supervision of AV, assistance to commuters, emergency and accident management.

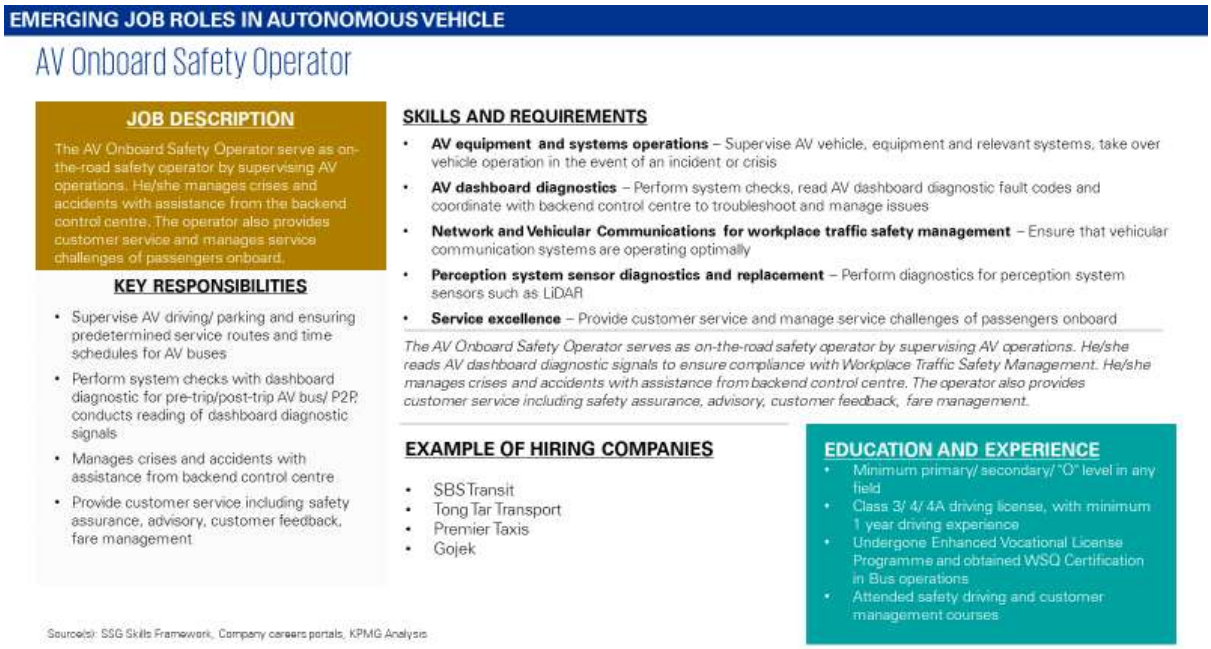


Figure 17: AV Onboard Safety Operator Persona

e. AV Fleet Manager

AV will be a driverless technology hence backend fleet operations and supervision will be essential to ensure service routes and time schedules of AV fleets are kept in order. Core tasks of an AV Fleet Manager includes supervising AV route planning and mobilisation and in the event of crisis or emergency will provide remote diagnosis of fleet issues ensuring reliability and passenger safety.

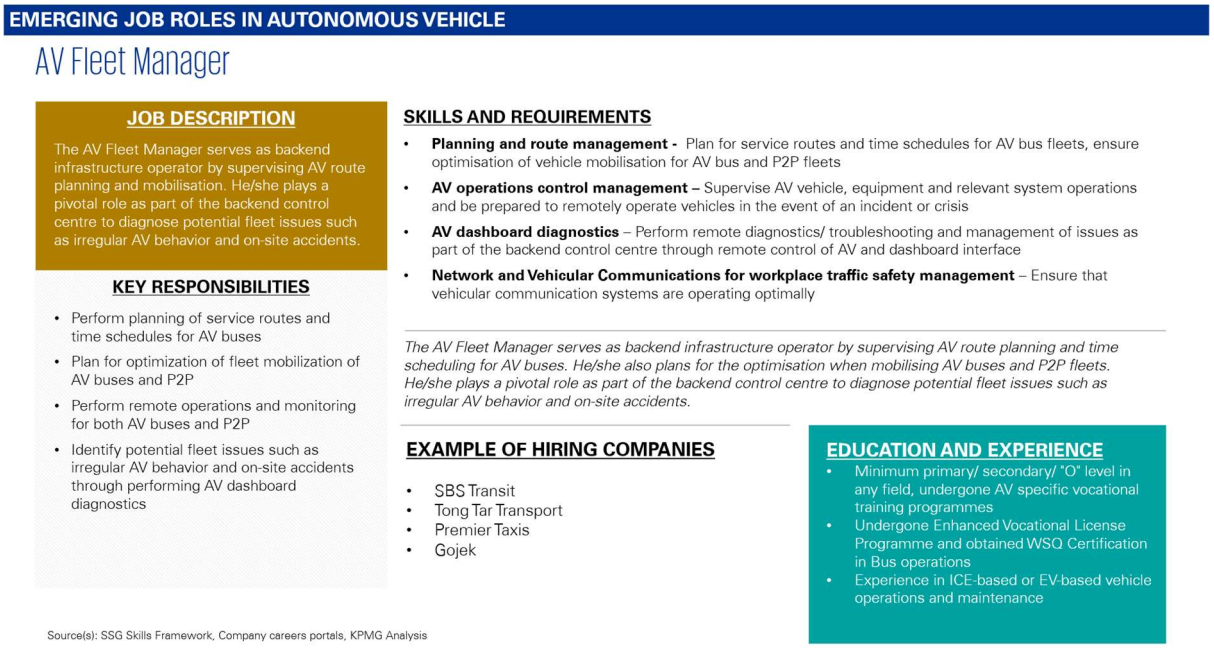


Figure 18: AV Fleet Manager Persona

4.8 Transition pathways

Workforce transition to adjacent land transport job roles within and beyond the transport industry would be expected to mitigate the potential impact of at-risk job roles as a result of I4.0, EVs and AVs. Transition pathways in this regard are analysed and summarized in Appendix C: Career Pathways Canvas**.** This section highlights the Taxi/ PHC driver job role which is projected to have greater impact.

Example: Taxi/PHC driver job roles within/ beyond the land transport industry

Within the transport industry, taxi/ PHC drivers can tap onto their expertise with vehicles and participate in upskilling initiatives to pivot into job roles within the land transport industry with stronger career progression opportunities, example Bus captain jobs.

Roles such as a Workshop Supervisor is a viable option. In this role, they will be required to coordinate the routine and schedule vehicle maintenance operations for technicians. In addition, they would also need to plan and assign daily work tasks, provide technical guidance and on-the-job coaching and propose workflow improvements. For this role, on the job training and experienced gained working as a technician in the short term can direct Taxi/ PHC drivers being equipped to tackle the challenges of the job.

On the other hand, beyond the transport industry, qualitative interviews indicated that drivers who were previously PMETs are inclined to re-enter their original industry. Some with higher qualifications and experience in other industries can re-join their career pathway through continued upskilling. Job support initiatives such as the Career Resilience Executive Workshop (e2i), Back to the Corporate Future (SSG/Ngee Ann Polytechnic) and National Silver Academy (NSA) – Job interview skills for Third Agers (SSG/Singapore Association for Continuing Education) are made available. Some drivers have also indicated an interest in urban farming and in facilities management roles.

Drivers can also pivot to other operational roles such as logistics operations. This job will require them to perform delivery work (i.e. parcel/logistics) on ad-hoc /shift work basis. In order to support the transition into such a role, job support initiatives such as the Win the Search (Employment and Employability Institute - e2i) and Win the Interview (e2i) is available.

5 Skills Impact Analysis

5. Skills Impact Analysis

5.1 Detailed analysis – Rail

5.1.1 Rail Engineers

Overall, I4.0 is projected to lead to a decline in skills associated with more manual, repetitive and labour-intensive tasks due to high automation such as data entry, documentation, report generation, supply chain management or ticketing.

In 5 years, rail engineers would likely see a decline in these skills:

1. Inventory Management – Automatic alert and inventory management system will automatically detect low availability of equipment, tools and materials for maintenance work and trigger purchase orders when threshold is hit

In 10 years, rail engineers would likely see a decline in these skills:

1. Inventory Management (as above).
2. Budgeting – Automatic set up of organisational budgets to support short-term and long- term business plans through pre-set forecasting algorithms, allocation, and financial policy setting.
3. Equipment Maintenance and Housekeeping – Robots used to maintain and upkeep tools and equipment such as sweeping, vacuuming, scrubbing, high pressure cleaning, and window and general cleaning.
4. Maintenance Scheduling – Automatic planning and scheduling of maintenance schedules in accordance with the organisational standards and Original Equipment Manufacturer recommendations.
5. Rail Track Inspection – Robots allow maintenance to be done remotely in inaccessible or high danger areas such as rail tracks in tunnels or high areas.
6. Report Writing – Machine generated reports automatically put together using terminologies and fields filled up in the system.

7. Track Access Management - Real time location sensing through biometrics for personnel identification for access control to confined spaces and restricted locations in accordance to organisational and regulatory requirements.

In 20 years, rail engineers would likely see a decline in these skills:

1. Inventory Management (as above)
2. Budgeting (as above)
3. Equipment Maintenance and Housekeeping (as above)
4. Maintenance Scheduling (as above)
5. Rail Track Inspection (as above)
6. Report Writing (as above)
7. Track Access Management (as above)
8. Engineering Train and Rolling Stock Operation – Remote operation of passenger train through communication-based control technology and new technology on-board equipment to support maintenance operations

I4.0 is anticipated to bring in these main areas of expertise:

a. Data usage and analytics – Data mining, cleansing, and modelling
b. Predictive maintenance – Condition monitoring to fix anomalies before they occur
c. Cyber security – Protection of computer systems and prevention of service disruption
d. Rail asset management – Management of systems, plant and equipment, infrastructure, operations, and maintenance, etc
e. Rail operations security – Assessment and mitigation of risks and threats to operations and infrastructure

Hence, the following skills are expected to emerge over the next 5 – 20 years:

1. Data and Statistical Analytics – Rise of big data from I4.0 will require analysis of data to identify trends or patterns, define new process improvement opportunities and integrate data to suit business needs.
2. Data Usage and Implementation – Data analysis and successful implementation into relevant areas to achieve workflow improvements.
3. Innovation Management – Continuous advancement of technology requires the necessary systems, processes, and cultures in place to embrace innovation to enhance functional performance.
4. Internet of Things Application – Rise of Internet of Things (IoT) through I4.0 will require proper implementation to drive efficiency and effectiveness of operations.
5. Robotics and Automation Application – Rise of automation technologies through I4.0 will require evaluation and proper implementation to reduce manual tasks, automate and drive desired efficiency.
6. Sensor Monitoring Management – Interpreting sensor data and using predictive technology and condition monitoring to improve systems and tackle faults effectively.
7. Technology Application – Proper technology implementation into business processes is needed to drive efficiency and effectiveness of operations.

5-year skills impact analysis for rail engineers

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Apply technical expertise by proposing recommendations for workflow improvements and supervising complex issues around design, fault analyses and testing	Technical expertise from engineers would be required to analyse data acquired from sensors and systems to develop workflow improvements.	Condition-Based Assets Monitoring Management Problem Solving	 Low degree of impact	 Incrementally change	1. Contract Engineer 2. Sales Engineer 3. Budget and Planning Manager
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on trains and rail systems	Continue to supervise maintenance work, with the support of predictive technology	Maintenance Scheduling Manpower Planning and Deployment			
3. Provide technical guidance and on-the-job coaching to the team	Human interaction would continue to be required to conduct on-the-job coaching	People Development			
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors	Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions	Strategy Planning Workplace Safety and Health for Confined Spaces Workplace Safety and Health for Electrical Safety			
Declining Functions	N/A				
Emerging Functions	Core tasks of rail engineers will remain relevant and complemented by data analytics functions				

Table 9: 5-year skills impact for rail engineers

10-year skills impact analysis for rail engineers

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Apply technical expertise by proposing recommendations for workflow improvements and supervising complex issues around design, fault analyses and testing	Technical expertise from engineers would be required to analyse data acquired from sensors and systems to develop workflow improvements.	Condition-Based Assets Monitoring Management Problem Solving	 Low degree of impact	 Incrementally change	1. Contract Engineer 2. Sales Engineer 3. Budget and Planning Manager
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on trains and rail systems	While supervision of maintenance work will remain a core task, predictive technology will automate other tasks such as budgeting and maintenance scheduling	Maintenance Scheduling Manpower Planning and Deployment Data Usage and Implementation Internet of Things Application			
3. Provide technical guidance and on-the-job coaching to the team	Human interaction would continue to be required to conduct on-the-job coaching	People Development			
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors	Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions	Strategy Planning Workplace Safety and Health for Confined Spaces Workplace Safety and Health for Electrical Safety			
Declining Functions	Manual inspection, documentation, report generation, data entry				
Emerging Functions	Core tasks of rail engineers will remain relevant and complemented by data analytics functions				

Table 10: 10-year skills impact for rail engineers

20-year skills impact analysis for rail engineers

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Apply technical expertise by proposing recommendations for workflow improvements and supervising complex issues around design, fault analyses and testing	Technical expertise from engineers would be required to analyse data acquired from sensors and systems to develop workflow improvements.	Condition-Based Assets Monitoring Management Problem Solving	Low degree of impact	Incrementally change	1. Contract Engineer 2. Sales Engineer 3. Budget and Planning Manager
2. Plan and schedule maintenance work activities and supervise team performing preventive and corrective maintenance work on trains and rail systems	While supervision of maintenance work will remain a core task, predictive technology will automate other tasks such as budgeting and maintenance scheduling	Maintenance Scheduling Manpower Planning and Deployment Data Usage and Implementation Internet of Things Application			
3. Provide technical guidance and on-the-job coaching to the team	Human interaction would continue to be required to conduct on-the-job coaching	People Development			
4. Establish and ensure engineering safety standards and competencies by leading and overseeing safety and work quality of cross-functional teams and external contractors	Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions	Strategy Planning Workplace Safety and Health for Confined Spaces Workplace Safety and Health for Electrical Safety			
Declining Functions	Manual inspection, documentation, report generation, data entry				
Emerging Functions	Core tasks of rail engineers will remain relevant and complemented by data analytics functions				

Table 11: 20-year skills impact for rail engineers

5.1.2 Rail Technicians

Overall, I4.0 is projected to lead to a decline in skills associated with more manual, repetitive and labour-intensive tasks due to high automation such as data entry, documentation, report generation, supply chain management or ticketing.

In 5 years, rail technicians would unlikely see a decline in core skills. This is because while I4.0 plays a critical role in automating manual works, in 5 years the degree of automation is not expected to drastically replace core functions of rail technicians.

In 10 years, rail technicians would likely see a decline in these skills:

1. Equipment Maintenance and Housekeeping – Robots used to maintain and upkeep tools and equipment such as sweeping, vacuuming, scrubbing, high pressure cleaning, window and general cleaning.
2. Report Writing – Machine generated reports automatically put together using terminologies and fields filled up in the system.
3. Maintenance Scheduling – Automatic planning and scheduling of maintenance schedules in accordance with the organisational standards and Original Equipment Manufacturer recommendations.
4. Rail Track Inspection – Robots allow maintenance to be done remotely in inaccessible or high danger areas such as rail tracks in tunnels or high areas.
5. Track Access Management - Real time location sensing through biometrics for personnel identification for access control to confined spaces and restricted locations in accordance with organisational and regulatory requirements.

In 20 years, rail technicians would likely see a decline in these skills:

1. Equipment Maintenance and Housekeeping (as above)
2. Maintenance Scheduling (as above)
3. Rail Track Inspection (as above)
4. Report Writing (as above)
5. Track Access Management (as above)
6. Engineering Train and Rolling Stock Operation – Remote operation of passenger train through communication-based control technology and new technology on-board equipment to support maintenance operations

I4.0 is expected to bring in these main areas of expertise:

a. Data usage and analytics – Data mining, cleansing, and modelling.
b. Predictive maintenance – Condition monitoring to fix anomalies before they occur.
c. Cyber security – Protection of computer systems and prevention of service disruption.
d. Rail asset management – Management of systems, plant and equipment, infrastructure, operations and maintenance, etc.
e. Rail operations security – Assessment and mitigation of risks and threats to operations and infrastructure.

Hence, the following skills are expected to emerge over the next 5 – 20 years:

1. Data and Statistical Analytics – Rise of big data from I4.0 would require analysis of data to identify trends or patterns, define new process improvement opportunities and integrate data to suit business needs.
2. Data Usage and Implementation – Data analysis and successful implementation into relevant areas to achieve workflow improvements.
3. Internet of Things Application – Rise of Internet of Things (IoT) through I4.0 would require proper implementation to drive efficiency and effectiveness of operations.
4. Robotics and Automation Application – Rise of automation technologies through I4.0 would require evaluation and proper implementation to reduce manual tasks, automate and drive desired efficiency.
5. Sensor Monitoring Management – Interpreting sensor data and using predictive technology and condition monitoring to improve systems and tackle faults effectively.

5-year skills impact analysis for rail technicians

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Perform preventive maintenance of trains and rail systems and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures	Continue to interpret system health data to identify potential failure modes, collected and analysed by RPA through centralized systems which will reduce the need for human intervention	Track Access Management Condition-Based Assets Monitoring Management Robotics and Automatic Application Data Usage and Implementation	 Medium degree of impact	 Redesign	1. Technician / Senior Technician (Permanent Way and Civil Structure) 2. Technician/ Senior Technician (Power) 3. Technician / Senior Technician (Rolling Stock/ Engineering Trains) 4. Technician / Senior Technician (Mechanical and Electrical) 5. Rail operations control management
2. Perform corrective maintenance through conducting repair and modifications of trains and rail systems	Continue to perform repair work but predictive technology such as condition monitoring and sensors can streamline the troubleshooting process and reduce manual effort	Problem Solving Sensor Monitoring Management Internet of Things Application			
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities	Continue to conduct visual checks on tools, vehicles and equipment to maintain working condition	Equipment Maintenance and Housekeeping Maintenance Scheduling Report Writing			
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards	Human intervention and judgment remain critical in overseeing operations and ensuring compliance but digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation as part of vendor and stakeholder management	Rail Regulatory Compliance Vendor Management Robotics and Automation Application Internet of Things Application			
Declining Functions	Manual inspection, documentation, report generation, data entry				
Emerging Functions	Predictive maintenance, implementation of RPA applications, data analytics (i4.0)				

Table 12: 5-year skills impact for rail technicians

10-year skills impact analysis for rail engineers

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Perform preventive maintenance of trains and rail systems and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures	Continue to interpret system health data to identify potential failure modes, collected and analysed by RPA through centralized systems which will reduce the need for human intervention	Track Access Management Condition-Based Assets Monitoring Management Robotics and Automation Application Data Usage and Implementation	 Medium degree of impact	 Redesign	1. Technician / Senior Technician (Permanent Way and Civil Structure) 2. Technician/ Senior Technician (Power) 3. Technician / Senior Technician (Rolling Stock/ Engineering Trains) 4. Technician / Senior Technician (Mechanical and Electrical) 5. Rail operations control management
2. Perform corrective maintenance through conducting repair and modifications of trains and rail systems	Continue to perform repair work but predictive technology such as condition monitoring and sensors can streamline the troubleshooting process and reduce manual effort	Problem Solving Sensor Monitoring Management Internet of Things Application			
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities	RPA will automate tasks such as equipment maintenance, maintenance scheduling and report writing, with the ability to store information on centralised systems to ensure accessibility	Equipment Maintenance and Housekeeping Maintenance Scheduling Report Writing Robotics and Automation Application			
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards	Human intervention and judgment remain critical in overseeing operations and ensuring compliance but digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation as part of vendor and stakeholder management	Rail Regulatory Compliance Vendor Management Robotics and Automation Application Internet of Things Application			
Declining Functions	Manual inspection, documentation, report generation, data entry				
Emerging Functions	Predictive maintenance, implementation of RPA applications, data analytics (i4.0)				

Table 13: 10-year skills impact for rail technicians

20-year skills impact analysis for rail engineers

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Perform preventive maintenance of trains and rail systems and assist in conducting fault analyses by collecting and analysing data to identify root causes of failures	Continue to interpret system health data to identify potential failure modes, collected and analysed by RPA through centralized systems which will reduce the need for human intervention	Track Access Management Condition-Based Assets Monitoring Management Robotics and Automation Application Data Usage and Implementation	 Medium degree of impact	 Redesign	1. Technician / Senior Technician (Permanent Way and Civil Structure) 2. Technician/ Senior Technician (Power) 3. Technician / Senior Technician (Rolling Stock/ Engineering Trains) 4. Technician / Senior Technician (Mechanical and Electrical) 5. Rail operations control management
2. Perform corrective maintenance through conducting repair and modifications of trains and rail systems	Continue to perform repair work but predictive technology such as condition monitoring and sensors can streamline the troubleshooting process and reduce manual effort	Problem Solving Sensor Monitoring Management Internet of Things Application			
3. Prepare tools, vehicles and equipment required by ensuring they are in working order, obtain the maintenance schedule and retain a proper record of maintenance activities	RPA will automate tasks such as equipment maintenance, maintenance scheduling and report writing, with the ability to store information on centralised systems to ensure accessibility	Equipment Maintenance and Housekeeping Maintenance Scheduling Report Writing Robotics and Automation Application			
4. Supervise work of contractors and external stakeholders and ensure adherence to safety requirements and operating standards	Human intervention and judgment remain critical in overseeing operations and ensuring compliance but digital tools such as ERP will generate standardized reports, conduct digital data logging and documentation as part of vendor and stakeholder management	Rail Regulatory Compliance Vendor Management Robotics and Automation Application Internet of Things Application			
Declining Functions	Manual inspection, documentation, report generation, data entry				
Emerging Functions	Predictive maintenance, implementation of RPA applications, data analytics (i4.0)				

Table 14: 20-year skills impact for rail technicians

5.1.3 Rail Operations

Overall, I4.0 would likely lead to a decline in skills associated with more manual, repetitive and labour-intensive tasks due to high automation such as data entry, documentation, report generation, supply chain management or ticketing.

In 5 years, rail operations would likely see a decline in these skills:

1. Inventory Management – Automatic alert and inventory management system will automatically detect low availability of equipment, tools and materials for maintenance work and trigger purchase orders when threshold is hit.
2. Train Fare and Ticket Management – Train fare and ticket collection will on backend-software, giving rise to remote access and management of train fare and ticket amounts in accordance to Fares and Tickets Regulations.

In 10 years, rail operations would likely see a decline in these skills:

1. Inventory Management (as above).
2. Train Fare and Ticket Management (as above).
3. Budgeting – Automatic set up of organisational budgets to support short- and long- term business plans through pre-set forecasting algorithms, allocation and financial policy setting.
4. Report Writing – Machine generated reports automatically put together using terminologies and fields filled up in the system.
5. Track Access Management - Real time location sensing through biometrics for personnel identification for access control to confined spaces and restricted locations in accordance with organisational and regulatory requirements.
6. Rail Operations Control Management – Manage rail operations and control to achieve and enhance rail service continuity and reliability through communication-based control technology where train transmits its exact position and direction to the control centre and receives movement authority, permissible speed and route data.
7. Train Depot Control Management – Depot automation of maintenance work by optimization of the entire maintenance process, on-site preventive maintenance, reporting and evaluations, acquisition of operating data and visualization.
8. Train Station Operations Management – Use of crowd management systems and passenger flow monitoring in stations and trains to achieve rail service continuity, safety and reliability.

In 20 years, rail operations would likely see a decline in these skills:

1. Inventory Management (as above).
2. Train Fare and Ticket Management (as above).
3. Budgeting (as above).
4. Report Writing (as above).
5. Track Access Management (as above).
6. Rail Operations Control Management (as above).

7. Train Depot Control Management (as above).
8. Train Station Operations Management (as above).
9. Passenger Train Operations – Remote operation of passenger train and response management to degraded and emergency train operations through communication-based control technology in accordance with regulatory and organisational requirements.
10. Crowd Management – Sensor technology will be used to conduct passenger flow monitoring, safety management, crowd control, traffic control in public transport premises to facilitate service continuity and reliability.

I4.0 is expected to bring in these main areas of expertise:

a. Data usage and analytics – Data mining, cleansing, and modelling.
b. Predictive maintenance – Condition monitoring to fix anomalies before they occur.
c. Cyber security – Protection of computer systems and prevention of service disruption.
d. Rail asset management – Management of systems, plant and equipment, infrastructure, operations and maintenance, etc.
e. Rail operations security – Assessment and mitigation of risks and threats to operations and infrastructure.

Hence, the following skills are projected to emerge over the next 5 – 20 years:

1. Data and Statistical Analytics – Rise of big data from I4.0 will require analysis of data to identify trends or patterns, define new process improvement opportunities and integrate data to suit business needs.
2. Data Usage and Implementation – Data analysis and successful implementation into relevant areas to achieve workflow improvements.
3. Innovation Management – Continuous advancement of technology requires the necessary systems, processes, and cultures in place to embrace innovation to enhance functional performance.
4. Sensor Monitoring Management – Interpreting sensor data and using predictive technology and condition monitoring to improve systems and tackle faults effectively.

5-year skills impact analysis for rail operations (incrementally changed roles)

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Monitor and control train services, station and depot operations	Continue monitoring and controlling station operations and train services with the support of vision-based sensors installed within station premises and on trains respectively	Track Access Management Rail Operations Control Management Train Depot Control Management Sensor Monitoring Management	 Low degree of impact	 Incrementally change	1. Operations Manager 2. Administrative Services manager 3. Venue Manager 4. Facilities Manager 5. Station manager
2. Implement and execute service recovery measures during rail emergencies and incidents	Continue to act under pressure in instances of crisis but digital communication tools and virtual signages would supplement service recovery activities	Rail Incident Management Rail Emergency Response Management Data Usage and Implementation			
3. Provide technical guidance and on-the-job coaching	Human interaction would continue to be required to conduct on-the-job coaching	People Development			
4. Establish and ensure workplace safety standards and competencies	Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions	Rail Regulatory Compliance Workplace Facilities Safety Management			
Declining Functions	N/A				
Emerging Functions	Core tasks will remain relevant and complemented by data analytics functions				

Table 15: 5-year skills impact for rail operations (incrementally changed roles)

5-year skills impact analysis for rail operations (redesigned roles)

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Implement and execute service recovery measures during rail emergencies and incidents	Continue to act under pressure in instances of crisis but digital communication tools and virtual signages would supplement service recovery activities	Rail Incident Management Rail Emergency Response Management Data Usage and Implementation	 Medium degree of impact	 Redesign	1. Company Secretaries 2. Customer Service Manager 3. Station manager 4. Bus Operations Control Centre Controller 5. Rail operations control management
2. Conduct recovery of train and station equipment in malfunction (For Customer Service Officer/ Rover)	Continue site mobilization for first-line recovery and close-up inspections of train and station equipment in malfunction with the support of IoT devices and sensors performing remote diagnostics	Train Station Operations Management Data Usage and Implementation			
3. Operate passenger trains and meet overall train service standards (For Train Captain)	Continue to operate manual trains while interpreting train dashboard data to manage exceptions on fully automated trains so as to ensure overall train service standards	Passenger Train Operations Data Usage and Implementation			
4. Oversee the performance and well-being of Train Captains (For Crew Manager)	Continue to manage the well-being and performance of Train Captains with the help of IoT sensors onboard trains to gather and centrally store performance data	People Development Data Usage and Implementation			
Declining Functions	Manual monitoring and regulating of rail operations at stations and onboard trains				
Emerging Functions	Use of data and interpretation of outputs from automated systems				

Table 16: 5-year skills impact for rail operations (redesigned roles)

10-year skills impact analysis for rail operations (redesigned roles)

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Monitor and control train services, station and depot operations	Focus will shift to crisis management of multiple stations via centralised control centres as service monitoring will be automated via vision based sensors installed within station premises and on trains.	Track Access Management Rail Operations Control Management Train Depot Control Management Sensor Monitoring Management	Medium degree of impact	Redesign	1. Operations Manager 2. Administrative Services manager 3. Venue Manager 4. Facilities Manager 5. Station manager
2. Implement and execute service recovery measures during rail emergencies and incidents	Continue to act under pressure in instances of crisis but digital communication tools and virtual signages would supplement service recovery activities	Rail Incident Management Rail Emergency Response Management Data Usage and Implementation			
3. Provide technical guidance and on-the-job coaching	Human interaction would continue to be required to conduct on-the-job coaching	People Development			
4. Establish and ensure workplace safety standards and competencies	Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions	Rail Regulatory Compliance Workplace Facilities Safety Management			
Declining Functions	Manual monitoring and regulating of rail operations				
Emerging Functions	Application of internet of things for consolidated service data management and centralized monitoring of station / depot operations				

Table 17: 10-year skills impact for rail operations (redesigned roles)

10-year skills impact analysis for rail operations (at-risk roles)

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Implement and execute service recovery measures during rail emergencies and incidents	Continue to act under pressure in instances of crisis but digital communication tools and virtual signages would supplement service recovery activities	Rail Incident Management Rail Emergency Response Management Data Usage and Implementation	 High degree of impact	 Displacement	1. Company Secretaries 2. Customer Service Manager 3. Station manager 4. Bus Operations Control Centre Controller 5. Rail operations control management
2. Conduct recovery of train and station equipment in malfunction (For Customer Service Officer/ Rover)	IoT devices and sensors will perform remote diagnostics of train and station system malfunctions and report incidences, shifting focus towards monitoring of sensor data and interpreting signals before site mobilization for first-line recovery and close-up inspections	Train Station Operations Management Data Usage and Implementation Sensor Monitoring Management			
3. Operate passenger trains and meet overall train service standards (For Train Captain)	Modern trains are highly automated, operate in confined environment and equipped robust signalling systems, shifting focus towards monitoring technology solutions and interpreting train dashboard data to manage exceptions	Passenger Train Operations Data Usage and Implementation Sensor Monitoring Management			
4. Oversee the performance and well-being of Train Captains (For Crew Manager)	Train Captain tasks being largely automated may lead a smaller pool being managed, while IoT sensors onboard trains will gather and centrally store performance data of Train Captains for processing and analysis	Data Usage and Implementation Sensor Monitoring Management			
Declining Functions	Train, station and depot operations that requires manual intervention such as onboard operating of trains and station patrolling				
Emerging Functions	Use of data and interpretation of outputs from automated systems				

Table 18: 10-year skills impact for rail operations (at-risk roles)

20-year skills analysis for rail operations (redesigned roles)

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Monitor and control train services, station and depot operations	Focus will shift to crisis management of multiple stations via centralised control centres as service monitoring will be automated via vision based sensors installed within station premises and on trains.	Track Access Management Rail Operations Control Management Train Depot Control Management Sensor Monitoring Management	 Medium degree of impact	 Redesign	1. Operations Manager 2. Administrative Services manager 3. Venue Manager 4. Facilities Manager 5. Station manager
2. Implement and execute service recovery measures during rail emergencies and incidents	Continue to act under pressure in instances of crisis but digital communication tools and virtual signages would supplement service recovery activities	Rail Incident Management Rail Emergency Response Management Data Usage and Implementation			
3. Provide technical guidance and on-the-job coaching	Human interaction would continue to be required to conduct on-the-job coaching	People Development			
4. Establish and ensure workplace safety standards and competencies	Continue to promulgate safety standards and develop initiatives to ensure compliance across rail functions	Rail Regulatory Compliance Workplace Facilities Safety Management			
Declining Functions	Manual monitoring and regulating of rail operations				
Emerging Functions	Application of internet of things for consolidated service data management and centralized monitoring of station / depot operations				

Table 19: 20-year skills impact for rail operations (redesigned roles)

20-year skills impact analysis for rail operations (at-risk roles)

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Implement and execute service recovery measures during rail emergencies and incidents	Continue to act under pressure in instances of crisis but digital communication tools and virtual signages would supplement service recovery activities	Rail Incident Management Rail Emergency Response Management Data Usage and Implementation	 High degree of impact	 Displacement	1. Company Secretaries 2. Customer Service Manager 3. Station manager 4. Bus Operations Control Centre Controller 5. Rail operations control management
2. Conduct recovery of train and station equipment in malfunction (For Customer Service Officer/ Rover)	IoT devices and sensors will perform remote diagnostics of train and station system malfunctions and report incidences, shifting focus towards monitoring of sensor data and interpreting signals before site mobilization for first-line recovery and close-up inspections	Train Station Operations Management Data Usage and Implementation Sensor Monitoring Management			
3. Operate passenger trains and meet overall train service standards (For Train Captain)	Modern trains are highly automated, operate in confined environment and equipped robust signalling systems, shifting focus towards monitoring technology solutions and interpreting train dashboard data to manage exceptions	Passenger Train Operations Data Usage and Implementation Sensor Monitoring Management			
4. Oversee the performance and well-being of Train Captains (For Crew Manager)	Train Captain tasks being largely automated may lead a smaller pool being managed, while IoT sensors onboard trains will gather and centrally store performance data of Train Captains for processing and analysis	Data Usage and Implementation Sensor Monitoring Management			
Declining Functions	Train, station and depot operations that requires manual intervention such as onboard operating of trains and station patrolling				
Emerging Functions	Use of data and interpretation of outputs from automated systems				

Table 20: 20-year skills impact for rail operations (at-risk roles)

5.2 Detailed analysis – Bus

5.2.1 Bus Engineers

Overall, the emergence of electric vehicles is expected to change the required maintenance and repair skills by shifting mechanical-based repair skills to electrical-based skills.

In 5 years, bus engineers would likely see a decline in these skills:

1. Inventory Management – Automatic alert and inventory management system will automatically detect low availability of equipment, tools and materials for maintenance work and trigger purchase orders when threshold is hit.

In 10 years, bus engineers would likely see a decline in these skills:

1. Inventory Management (as above).
2. Budgeting – Automatic set up of organisational budgets to support short- and long- term business plans through pre-set forecasting algorithms, allocation, and financial policy setting.
3. Bus Drivetrain Systems Maintenance – EV bus will have electrical drivetrain that would require different corrective and preventive maintenance.
4. Bus Engine System Maintenance – EV bus will have electrical engine that would require different corrective and preventive maintenance.

In 20 years, bus engineers would likely see a decline in these skills:

1. Inventory Management (as above)
2. Budgeting (as above)
3. Bus Drivetrain Systems Maintenance (as above)
4. Bus Engine System Maintenance (as above)

EVs would likely generate demand for operational and maintenance skills in these main areas:

a. Bus system Maintenance – Bus Battery System Maintenance, Bus Electric Drivetrain System Maintenance, Bus High Voltage System Maintenance.
b. Bus operations – Bus EV Equipment and Systems Operation, EV Fleet System Planning, EV Dashboard Diagnostic.

However, other general servicing skillsets for ICE vehicles are similar to that of EVs and would still remain relevant such as body works, tyres and brake systems. Given the less complex and modular nature of EV components, skillsets to repair and maintain EVs can potentially be developed through on job training, reskilling and short courses once the EV training landscape has been further developed.

In the long run, skills related to maintenance of AV systems and equipment would likely be focused on AV dashboard diagnostics and AV equipment and systems operations skills covering sensors and perception systems, network vehicular communication system and automatic control systems.

AVs would require operational and maintenance skills in these main areas:

a. Autonomous system – Perception System Sensor Diagnostic and Replacement, Network and Vehicular Communications, Autonomous Vehicle Control System.
b. Autonomous Vehicle Operations – Remote Diagnostic Recovery Management, AV Dashboard Diagnostic, AV Planning and Route Management, AV Remote Control and Management.
c. Technicians would need to increase their knowledge of sensor components for AVs, particularly in these areas:
   - Perception System Sensor Diagnostics and Replacement
   - Network and Vehicular Communications
   - Automatic Vehicle Control System
   - Software maintenance skillsets
   - Diagnostic and monitoring skillsets

AVs would also require usage and interpretation of data collected from diagnostic tools, hence a shift to data integration and analytics skills in these main areas:

a. Internet-of-things and Cybersecurity
b. Artificial intelligence
c. 5G Communication technologies
d. Data analysing
e. Machine learning
f. Robotics and automation

Hence, the following skills are projected to emerge over the next 5 – 20 years:

1. Data and Statistical Analytics – Rise of big data from I4.0 will require analysis of data to identify trends or patterns, define new process improvement opportunities and integrate data to suit business needs.
2. Innovation Management – Continuous advancement of technology requires the necessary systems, processes, and cultures in place to embrace innovation to enhance functional performance.
3. Internet of Things Application – Rise of Internet of Things (IoT) through I4.0 will require proper implementation to drive efficiency and effectiveness of operations.
4. Robotics and Automation Application – Rise of automation technologies through I4.0 will require evaluation and proper implementation to reduce manual tasks, automate and drive desired efficiency.
5. Technology Application – Proper technology implementation into business processes is needed to drive efficiency and effectiveness of operations.
6. EV Dashboard Diagnostic – New expertise and knowledge to understand EV technology and their vehicle dashboards that will show alerts and signals to fault codes.

7. Bus Battery System Maintenance – New expertise is required to maintain battery systems which have higher electrical voltage such as diagnostic testing, isolation of circuit board and replacement of battery modules for EVs/ AVs.
8. Bus Electric Drivetrain System Maintenance – New expertise is required to conduct inspection and maintenance for electrical drivetrain system for EVs/ AVs, including specific tools and diagnostics equipment that collects and interprets data, replacement of electrical based components.
9. Bus High Voltage System Maintenance – New expertise is required for handling high voltage system in EVs/ AVs such as wearing of suitable gear and equipment and isolation of electrical circuit board before inspection, testing and maintenance.
10. AV Dashboard Diagnostics – New expertise and knowledge to understand AV technology and their vehicle dashboards that will show alerts and signals to fault codes.
11. Automatic Vehicle Control System – Driverless technologies in AVs is based on automatic navigation techniques and algorithms built-in, deep understanding and technical expertise is required.
12. General Control System – Deep understanding and technical expertise is required for integration of all technologies in AVs to ensure effective AV operation.
13. Network and Vehicular Communications – New expertise is required to utilise AV specific tools and diagnostics equipment to conduct inspection and maintenance for vehicles and network and vehicular communications; deep understanding of new network and vehicular communications technology is required as well.
14. Perception System Sensor Diagnostics and Replacement – New expertise is required to utilise AV specific tools and diagnostics equipment to conduct inspection and maintenance for vehicles and sensor perception systems; deep understanding of new sensor technology is required as well.
15. Remote Diagnostics Recovery Management – Driverless technologies in AVs will require expert AV diagnostic skills to identify vehicle faults and execute recovery or crisis management procedures to resolve the emergency or accident remotely.

5-year skills impact analysis for bus engineers

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Diagnose root cause of bus system degradation through ICE vehicle tools, diagnostic equipment and ICE based engineering knowledge; implement improved maintenance or future mitigation actions to slow down system degradation	Utilize EV vehicle tools, diagnostics equipment and EV based engineering knowledge; implement improved maintenance or future mitigation actions to slow down system degradation	Bus Engine System Maintenance Bus Drivetrain System Maintenance Engineering Maintenance Management EV Dashboard Diagnostic Bus Battery System Maintenance Bus Electric Drivetrain System Maintenance	 Medium degree of impact	 Redesign	1. EV Bus Engineer
2. Provide technical advice to ICE bus maintenance team for complex issues and oversee the maintenance works in complicated cases	Provide technical advice to EV bus maintenance team for complex issues and oversee the maintenance works in complicated cases	Bus Regulatory Compliance Workplace Facilities Safety Management Bus Battery System Maintenance Bus Electric Drivetrain System Maintenance			
3. Conduct engineering studies for overall ICE equipment and vehicles; source for new technology application applicable to ICE maintenance work for increased efficiency and effectiveness	Conduct engineering studies for overall EV equipment and vehicles; source for new technology application applicable to EV maintenance work for increased efficiency and effectiveness	Systems Engineering Thinking Data and Statistical Analytics Internet of Things Application			
4. Review fleet performance audit data to establish standards that are relevant and applicable in today's context	Consistent review of fleet performance audit will remain similar to ensure improvements of bus operations and maintenance standards matching with the advancement of technology	Bus Regulatory Compliance Robotics and Automation Application			
Declining Functions	Diagnosis, provision of technical advice and conducting engineering studies of ICE vehicles and their components				
Emerging Functions	Diagnosis, provision of technical advice and conducting engineering studies of EV vehicles and their components				

Table 21: 5-year skills impact for bus engineers

10-year skills impact analysis for bus engineers

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Diagnose root cause of bus system degradation through ICE vehicle tools, diagnostic equipment and ICE based engineering knowledge; implement improved maintenance or future mitigation actions to slow down system degradation	Utilize EV vehicle tools, diagnostics equipment and EV based engineering knowledge; implement improved maintenance or future mitigation actions to slow down system degradation with more EVs on the road	Bus Engine System Maintenance Bus Drivetrain System Maintenance Engineering Maintenance Management EV Dashboard Diagnostic Bus Battery System Maintenance Bus Electric Drivetrain System Maintenance	 Medium degree of impact	 Redesign	1. EV Bus Engineer
2. Provide technical advice to ICE bus maintenance team for complex issues and oversee the maintenance works in complicated cases	Provide technical advice to EV bus maintenance team for complex issues and oversee the maintenance works in complicated cases	Bus Regulatory Compliance Workplace Facilities Safety Management Bus Battery System Maintenance Bus Electric Drivetrain System Maintenance			
3. Conduct engineering studies for overall ICE equipment and vehicles; source for new technology application applicable to ICE maintenance work for increased efficiency and effectiveness	Conduct engineering studies for overall EV equipment and vehicles; source for new technology application applicable to EV maintenance work for increased efficiency and effectiveness	Systems Engineering Thinking Data and Statistical Analytics Internet of Things Application Robotics and Automation Application			
4. Review fleet performance audit data to establish standards that are relevant and applicable in today's context	Consistent review of fleet performance audit will remain similar to ensure improvements of bus operations and maintenance standards matching with the advancement of technology	Bus Regulatory Compliance Robotics and Automation Application			
Declining Functions	Diagnosis, provision of technical advice and conducting engineering studies of ICE vehicles and their components				
Emerging Functions	Diagnosis, provision of technical advice and conducting engineering studies of EV vehicles and their components				

Table 22: 10--year skills impact for bus engineers

20-year skills impact analysis for bus engineers

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Diagnose root cause of bus system degradation through ICE vehicle tools, diagnostic equipment and ICE based engineering knowledge; implement improved maintenance or future mitigation actions to slow down system degradation	Utilize AV vehicle tools, diagnostics equipment and AV based engineering knowledge; implement improved maintenance or future mitigation actions to slow down system degradation	Bus Engine System Maintenance Bus Drivetrain System Maintenance Engineering Maintenance Management EV Dashboard Diagnostic Bus Battery System Maintenance Bus Electric Drivetrain System Maintenance	Medium degree of impact	Redesign	1. EV Bus Engineer
2. Provide technical advice to ICE bus maintenance team for complex issues and oversee the maintenance works in complicated cases	Provide technical advice to EV bus maintenance team for complex issues and oversee the maintenance works in complicated cases	Bus Regulatory Compliance Workplace Facilities Safety Management Bus Battery System Maintenance Bus Electric Drivetrain System Maintenance			
3. Conduct engineering studies for overall ICE equipment and vehicles; source for new technology application applicable to ICE maintenance work for increased efficiency and effectiveness	Conduct engineering studies for overall EV equipment and vehicles; source for new technology application applicable to EV maintenance work for increased efficiency and effectiveness	Systems Engineering Thinking Data and Statistical Analytics Internet of Things Application Robotics and Automation Application			
4. Review fleet performance audit data to establish standards that are relevant and applicable in today's context	Consistent review of fleet performance audit will remain similar to ensure improvements of bus operations and maintenance standards matching with the advancement of technology	Bus Regulatory Compliance Robotics and Automation Application			
Declining Functions	Diagnosis, provision of technical advice and conducting engineering studies of ICE vehicles and their components				
Emerging Functions	Diagnosis, provision of technical advice and conducting engineering studies of EV vehicles and their components				

Table 23: 20--year skills impact for bus engineers

5.2.2 Bus Technicians

Overall, the emergence of electric vehicles is expected to change the required maintenance and repair skills of bus technicians by shifting mechanical-based repair skills to electrical-based skills. Charging infrastructure installation and maintenance skills will be required as well but are expected to be filled by existing pool of electricians.

In 5 years, bus technicians would likely see a decline in these skills:

1. Inventory Management – Automatic alert and inventory management system will automatically detect low availability of equipment, tools and materials for maintenance work and trigger purchase orders when threshold is hit.

In 10 years, bus technicians would likely see a decline in these skills:

1. Inventory Management (as above)
2. Maintenance Scheduling – Automatic planning and scheduling of maintenance schedules in accordance with the organisational standards and Original Equipment Manufacturer recommendations.
3. Report Writing – Machine generated reports automatically put together using terminologies and fields filled up in the system.
4. Equipment Maintenance and Housekeeping – Robots used to maintain and upkeep tools and equipment such as sweeping, vacuuming, scrubbing, high pressure cleaning, window and general cleaning.
5. Budgeting – Automatic set up of organisational budgets to support short- and long- term business plans through pre-set forecasting algorithms, allocation, and financial policy setting.
6. Bus Drivetrain Systems Maintenance – EV bus will have electrical drivetrain that will require different corrective and preventive maintenance.
7. Bus Engine System Maintenance – EV bus will have electrical engine that will require different corrective and preventive maintenance.

In 20 years, bus technicians would likely see a decline in these skills:

1. Inventory Management (as above)
2. Maintenance Scheduling (as above)
3. Report Writing (as above)
4. Equipment Maintenance and Housekeeping (as above)
5. Budgeting (as above)
6. Bus Drivetrain Systems Maintenance (as above)
7. Bus Engine System Maintenance (as above)

EV's impact on skills required for bus technicians

EVs would generate demand for operational and maintenance skills in these main areas:

a. Bus system Maintenance – Bus Battery System Maintenance, Bus Electric Drivetrain System Maintenance, Bus High Voltage System Maintenance.

b. Bus operations – Bus EV Equipment and Systems Operation, EV Fleet System Planning, EV Dashboard Diagnostic.

However, other general servicing skillsets for ICE vehicles are similar to that of EVs and will remain relevant such as body works, tyres and brake systems. Given the less complex and modular nature of EV components, skillsets to repair and maintain EVs can potentially be developed through on job training, reskilling and short courses once the EV training landscape has been further developed.

Relevant EV training to support upskilling

These upskilling requirements are expected to be achieved through on-the job training and familiarization courses because most EV repairs are component based and proprietary in nature, hence trainings are mostly performed by OEMs.

Currently, the manufacturers of EVs (e.g. Hyundai and Tesla) do not provide any trainings to 3rd party workshops but only to specific authorised workshops. Technicians of these authorised workshops will have to go through the manufacturer's training and assessment programs and workshops must be willing to invest in proprietary tools which could costs a few hundred thousand Singapore dollars.

3rd party workshops servicing private cars in Singapore can proceed to the Singapore Motor Workshop Association (SMWA) Academy for recently launched training courses in EV repair and maintenance. They are currently offering level 1 courses on the introduction of hybrid and EV. Courses on vehicle sensors (cameras and sensors installed in EVs) conducted by trainers from manufacturers such as Robert Bosch. Moreover, Singapore Bus Academy (SGBA) has also recently begun offering introductory courses for EV bus maintenance.

On-the-job trainings and in-house training courses for technicians are implemented in some smaller workshops which provide EV and hybrid maintenance work. Examples of these courses include Basic level EV maintenance, safety protocol and isolation of batteries from main circuit board.

Furthermore, there are increasingly more partnerships with IHLs (e.g. NTU, NUS, Ngee Ann Polytechnic) and ITEs to bring in more work-study programmes, scholarships and internships for their technicians and mechanics to obtain hands-on experience in the early stages of their courses. IHLs such as ITE have started to incorporate more EV content such as high voltage system, safety management and battery handling into their curriculum.

AV's impact on skills required for bus technicians

In the long run, skills related to maintenance of AV systems and equipment are projected to be focused on AV dashboard diagnostics and AV equipment and systems operations skills covering sensors and perception systems, network vehicular communication system and automatic control systems.

AVs would require operational and maintenance skills in these main areas:

a. Autonomous system – Perception System Sensor Diagnostic and Replacement, Network and Vehicular Communications, Autonomous Vehicle Control System.
b. Autonomous Vehicle Operations – Remote Diagnostic Recovery Management, AV Dashboard Diagnostic, AV Planning and Route Management, AV Remote Control and Management.
c. Technicians would need to upskill their knowledge of sensor components for AVs, particularly in these areas:

- Perception System Sensor Diagnostics and Replacement
- Network and Vehicular Communications
- Automatic Vehicle Control System
- Software maintenance skillsets
- Diagnostic and monitoring skillsets

AVs would also require usage and interpretation of data collected from diagnostic tools, hence a shift to data integration and analytics skills in these main areas:

a. Internet-of-things and Cybersecurity
b. Artificial intelligence
c. 5G Communication technologies
d. Data analysing
e. Machine learning
f. Robotics and automation

Relevant AV training to support upskilling

Currently, there are no specific university courses and comprehensive curriculum that caters specifically to AVs except for post graduate courses which offer some topics related to AVs. Some examples of these courses include:

a. Artificial intelligence
b. Machine Learning
c. Cybersecurity
d. Robotics

Hence, there is a need for a combination of courses from several disciplines to culminate in the right expertise for AVs as this segment comprises of multi-faceted technologies. The realm of AV will have to address both technical and social aspects. Such disciplines include:

a. Engineering (Mechanical, Electrical, Software)
b. Computer science
c. Data analytics
d. Social science (Psychology, Sociology)

Advisory committees are already being set up in Institute of Higher Learnings (IHLs) to advise on the structure of courses and ensure that offerings remain up-to-date and relevant. Work Study Programmes and internships collaborations between IHLs and industry players are also on the rise to allow students to gain exposure and understand leading industries. This will help them garner interest in new sectors and enrich their learning experience. Regulators such as LTA will play an important role in driving collaborations between IHLs and industry players through scholarships and internships.

5-year skills impact analysis for bus technicians

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance	Utilize EV specific tools and diagnostics equipment to conduct inspection and maintenance for buses, interpret bus health data, replace electrical based components	Bus Engine System Maintenance Bus Drivetrain System Maintenance EV Dashboard Diagnostic Bus Battery System Maintenance	Medium degree of impact	Redesign	1. Car Mechanic 2. EV Bus Technician 3. EV Technician
2. Coordinate routine scheduled bus maintenance operations	Frequency of maintenance will drop as EVs have lesser repairs which require repair work and specific EV parts maintenance will be allocated to specialists	Maintenance Scheduling Bus Regulatory Compliance			
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment	Continue to perform general housekeeping of workshop ICE tools and diagnostic equipment	Workplace Facilities Safety Management Equipment Maintenance and Housekeeping			
4. Support on-the-road bus breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	Support on-the-road vehicle breakdown with EV diagnostic tools, only less specialized repairs can be done on-site, complicated repairs will require proper gears and equipment	Bus Recovery and Towing EV Dashboard Diagnostic			
Declining Functions	Repair and maintenance of ICE vehicles and their components				
Emerging Functions	Replacement and maintenance of EV vehicles and their components				

Table 24: 5-year skills impact for bus technicians

10-year skills impact analysis for bus technicians

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance	Utilize EV specific tools and diagnostics equipment to conduct inspection and maintenance for buses, interpret bus health data, replace electrical based components	Bus Engine System Maintenance Bus Drivetrain System Maintenance EV Dashboard Diagnostic Bus Battery System Maintenance	 Medium degree of impact	 Redesign	1. Car Mechanic 2. EV Bus Technician 3. EV Technician
2. Coordinate routine scheduled bus maintenance operations	Frequency of maintenance will drop as EVs have lesser repairs which require repair work and specific EV parts maintenance will be allocated to specialists	Maintenance Scheduling Bus Regulatory Compliance			
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment	Continue to perform general housekeeping of workshop ICE tools and diagnostic equipment; maintenance and housekeeping will be automated	Workplace Facilities Safety Management Equipment Maintenance and Housekeeping			
4. Support on-the-road bus breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	Support on-the-road vehicle breakdown with EV diagnostic tools, only less specialized repairs can be done on-site, complicated repairs will require proper gears and equipment	Bus Recovery and Towing EV Dashboard Diagnostic			
Declining Functions	Repair and maintenance of ICE vehicles and their components				
Emerging Functions	Replacement and maintenance of EV vehicles and their components				

Table 25: 10-year skills impact for bus technicians

20-year skills impact analysis for bus technicians

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance	Utilize AV specific tools and diagnostics equipment to conduct inspection and maintenance, replace and repair components such as sensors, network communication system and vehicle control system	Bus Engine System Maintenance Bus Drivetrain System Maintenance AV Dashboard Diagnostic Perception System Sensor Diagnostic and Replacement	Medium degree of impact	Redesign	1. AV Maintenance Technician
2. Coordinate routine scheduled bus maintenance operations	Frequency of maintenance will drop as AVs have less components which require repair work and specific AV parts maintenance will be allocated to specialists; scheduling will be automated	Maintenance Scheduling Bus Regulatory Compliance			
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment	Continue to perform general housekeeping of workshop EV/ AV tools and diagnostic equipment; maintenance and housekeeping will be automated	Equipment Maintenance and Housekeeping Workplace Facilities Safety Management			
4. Support on-the-road bus breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	Support on-the-road vehicle breakdown with AV diagnostic tools, only less specialized repairs can be done on-site, complicated repairs will require proper gears and equipment	Bus Recovery and Towing AV Dashboard Diagnostic			
Declining Functions	Repair and maintenance of ICE vehicles and their components				
Emerging Functions	Replacement and maintenance of EV and AV vehicles and their components				

Table 26: 20-year skills impact for bus technicians

5.2.3 Bus Operations

Overall, the emergence of electric vehicles would unlikely change operations drastically. However, there will be a need to incorporate more EV dashboard diagnostic and planning systems that takes into considerations the EV operational hours and bus arrival and departure times.

In the next 5 years, bus operations will unlikely see a decline in any skills. This is because while EV technologies become more prominent, its operational function remains largely similar to that of its ICE equivalent. Therefore, in 5 years, current skills will remain relevant, and retraining will be minimal.

In 10 years, bus operations would likely see a decline in these skills:

1. Report Writing – Machine generated reports automatically put together using terminologies and fields filled up in the system.
2. Budgeting – Automatic set up of organisational budgets to support short- and long- term business plans through pre-set forecasting algorithms, allocation, and financial policy setting.
3. Bus Interchange Operations – Automation will take over bus service frequency scheduling, bus inspection checks while sensors technology will be used to conduct passenger flow monitoring, safety management, crowd control, traffic control; robotics will optimise facilities maintenance process, on-site preventive maintenance, reporting and evaluations.
4. Bus Depot Operations – Automation will take over bus and bus captain allocation and despatch; robotics will optimise facilities maintenance process, on-site preventive maintenance, reporting and evaluations.
5. Bus Operations Control management – Sensor technology will be used to oversee designated service routes using real-time information on bus fleet management systems.

In 20 years, bus operations would likely see a decline in these skills:

1. Report Writing (as above).
2. Budgeting (as above).
3. Bus Interchange Operations (as above).
4. Bus Depot Operations (as above).
5. Bus Operations Control Management (as above).
6. Bus Garaging – Restoration of buses through garaging activities will decline due to fundamental changes in charging, handling, inspecting EVs/ AVs with more robot functions.
7. Bus Vehicle Operations – Operation of bus vehicular types and models (driving) will change with EVs due to regenerative braking and acceleration and will be obsolete with AVs driverless technology.
8. Crowd Management – Sensor technology will be used to conduct passenger flow monitoring, safety management, crowd control, traffic control in public transport premises to facilitate service continuity and reliability.

For the station and depot operations side, EV dashboard diagnostics, EV fleet system planning will be relevant for new interface fleet system and monitoring of bus arrival and departure times.

For station and depot operations, AV dashboard diagnostics, AV planning and route management will be relevant due to high level monitoring and supervision of AV arrival and departure time.

Hence, the following skills are projected to emerge over the next 5 – 20 years:

1. Data and Statistical Analytics – Rise of big data from I4.0 will require analysis of data to identify trends or patterns, define new process improvement opportunities and integrate data to suit business needs.
2. EV Dashboard Diagnostic – New expertise and knowledge to understand EV technology and their vehicle dashboards that will show alerts and signals to fault codes.
3. EV Fleet System Planning – Monitoring and regulating EV bus arrival and departure timings through intelligent transport systems such as computer aided dispatch, schedule adherence support, automated service compliance monitoring.
4. AV Dashboard Diagnostics – New expertise and knowledge to understand AV technology and their vehicle dashboards that will show alerts and signals to fault codes.
5. AV Planning and Route Management – Driverless technologies in AVs will require technical expertise to monitor and supervise arrival and departure times as well as route journeys.
6. AV Remote Control and Management – Driverless technologies in AVs will require technical expertise to control AVs remotely.

5-year skills impact analysis for bus operations

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Perform daily operations at bus interchange/ bus depot such as monitoring and regulating bus arrival and departure timings; driving buses within the interchange/ depot if required	Continue to perform daily operations at bus interchange/ bus depot such as monitoring and regulating bus arrival and departure timings; driving buses within the interchange/ depot if required (might include small pool of EV buses)	Bus Interchange Operations Bus Depot Operations Bus Operations Control Management	 Low degree of impact	 Incrementally change	1. Transportation manager 2. Bus Operations Control Centre Controller
2. Provide customer service in the interchange for commuters, conduct security checks, facilitate traffic and crowd control	Continue to provide customer service in the interchange for commuters, conduct security checks, facilitate traffic and crowd control	Service Excellence			
3. Provide support to emergencies, incidents, accidents in the interchange/ depot for vehicle-related and commuter-related	Continue to provide support to emergencies, incidents, accidents in the interchange/ depot for vehicle-related and commuter-related (might include small pool of EV buses)	Crisis Management Workplace Traffic Safety Management Workplace Safety and Health for Incident and Accident Investigation			
4. Support compliance to organisational and legislative requirements and improve ICE bus service performance standards	Continue to support compliance to organisational and legislative requirements and improve bus service performance standards	Bus Regulatory Compliance Continuous Improvement Management			
Declining Functions	N/A				
Emerging Functions	N/A				

Table 27: 5-year skills impact for bus operations

10-year skills impact analysis for bus operations

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Perform daily operations at bus interchange/ bus depot such as monitoring and regulating bus arrival and departure timings; driving buses within the interchange/ depot if required	Monitor and regulate EV and ICE bus arrival and departure timings through intelligent transport systems such as computer aided dispatch, schedule adherence support, service compliance which are highly automated	Bus Interchange Operations Bus Depot Operations Bus Operations Control Management EV Fleet System Planning	 Medium degree of impact	 Redesign	1. Transportation manager 2. Bus Operations Control Centre Controller 3. EV Fleet Manager
2. Provide customer service in the interchange for commuters, conduct security checks, facilitate traffic and crowd control	Continue to provide customer service in the interchange for commuters, conduct security checks, facilitate traffic and crowd control	Service Excellence			
3. Provide support to emergencies, incidents, accidents in the interchange/ depot for vehicle-related and commuter-related	Continue to provide support to emergencies, incidents, accidents in the interchange/ depot however vehicle-related service disruptions will need EV diagnostic	Crisis Management Workplace Traffic Safety Management Workplace Safety and Health for Incident and Accident Investigation EV Dashboard Diagnostic			
4. Support compliance to organisational and legislative requirements and improve ICE bus service performance standards	Continue to support compliance to organisational and legislative requirements and improve bus service performance standards	Bus Regulatory Compliance Continuous Improvement Management			
Declining Functions	Monitoring and regulating ICE buses – arrival and departure, scheduling, regulating and supervising operations				
Emerging Functions	Automated and advanced high level monitoring and regulating ICE and EV buses – arrival and departure, scheduling, regulating and supervising operations				

Table 28: 10-year skills impact for bus operations

20-year skills impact analysis for bus operations

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Perform daily operations at bus interchange/ bus depot such as monitoring and regulating bus arrival and departure timings; driving buses within the interchange/ depot if required	Monitor and regulate EV and AV bus arrival and departure timings through intelligent transport systems such as computer aided dispatch, schedule adherence support, service compliance which are highly automated	Bus Interchange Operations Bus Depot Operations Bus Operations Control Management EV Fleet System Planning AV Planning and Route Management	 Medium degree of impact	 Redesign	1. Transportation manager 2. Bus Operations Control Centre Controller 3. EV Fleet Manager 4. AV Fleet Manager
2. Provide customer service in the interchange for commuters, conduct security checks, facilitate traffic and crowd control	Continue to provide customer service in the interchange for commuters, conduct security checks, facilitate traffic and crowd control	Service Excellence			
3. Provide support to emergencies, incidents, accidents in the interchange/ depot for vehicle-related and commuter-related	Continue to provide support to emergencies, incidents, accidents in the interchange/ depot however vehicle-related service disruptions will need EV and AV diagnostic	Crisis Management Workplace Traffic Safety Management Workplace Safety and Health for Incident and Accident Investigation EV Dashboard Diagnostic AV Dashboard Diagnostic			
4. Support compliance to organisational and legislative requirements and improve ICE bus service performance standards	Continue to support compliance to organisational and legislative requirements and improve bus service performance standards	Bus Regulatory Compliance Continuous Improvement Management			
Declining Functions	Monitoring and regulating ICE buses – arrival and departure, scheduling, regulating and supervising operations				
Emerging Functions	Automated and advanced high level monitoring and regulating ICE and EV buses – arrival and departure, scheduling, regulating and supervising operations				

Table 29: 20-year skills impact for bus operations

5.2.4 Bus Captains

Overall, the emergence of electric vehicles would unlikely change driving tasks. However, some skills may need to be adapted to drive an EV. Drivers will need minimal upskilling when transitioning into EVs and involves areas such as braking, accelerating and high-level diagnostics of electric systems.

In 5 years, bus captains will likely see a decline in the skill below:

1. Bus Fare Management – Bus fare collection equipment will be on backend-software, giving rise to remote access and management of bus fares amounts.

In 10 years, bus captains will likely see a decline in the skill below:

1. Bus Fare Management (as above).

In 20 years, bus captains will likely see a decline in these skills:

1. Bus Fare Management (as above).
2. Bus Equipment and Systems Operation – Operation of EV/AV bus controls and on-board equipment including dashboard alerts and signals will be different from ICE bus.
3. Bus Vehicle Operations – Operation of bus vehicular types and models (driving) will change with EVs due to regenerative braking and acceleration and will be obsolete with AVs driverless technology.

Although there is unlikely to be drastic skill changes for bus vehicle operations, EV systems and diagnostics on dashboards will be relevant and required for the operation of electric buses.

In the long run with AV driverless technology, vehicle operations skills such as driving, will shift to new skills required to operate AVs involving high level supervision of AVs and AV dashboard diagnostics and AV equipment and systems operation.

Hence, the following skills are projected to emerge over the next 5 – 20 years:

1. EV Dashboard Diagnostic – New expertise and knowledge to understand EV technology and their vehicle dashboards that will show alerts and signals to fault codes.
2. Bus EV Equipment and System Operation – Operation of EV bus controls and on-board equipment including dashboard alerts and signals will be different from ICE bus.
3. AV Dashboard Diagnostics – New expertise and knowledge to understand AV technology and their vehicle dashboards that will show alerts and signals to fault codes.
4. Bus AV Operations (Supervision) – Driverless technologies in AVs will require technical expertise to conduct high level supervision and monitoring of AV buses.
5. Bus AV Equipment and System Operation – Operation of AV bus controls and on-board equipment including dashboard alerts and signals will be different from ICE vehicle.

5-year skills impact analysis for bus drivers

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Driving and operating of ICE buses on schedule routes and timetables to board and alight passengers at bus stops	Continue driving and operating of ICE buses on schedule routes and timetables to board and alight passengers at bus stops	Bus Vehicle Operations	 Low degree of impact	 Incrementally change	1. Taxi/ PHC Driver 2. Driving Instructor
2. Conduct high level checks on bus controls and on-board equipment to ensure vehicle readiness for service commencement and termination	Continue conducting high level checks on bus controls and on-board equipment to ensure vehicle readiness for service commencement and termination	Bus Equipment and System Operation (ICE) Bus Regulatory Compliance			
3. Provide high quality customer service to passengers boarding and alighting from the bus	Continue to provide high quality customer service to passengers boarding and alighting from the bus	Service Excellence			
4. Work with BOCC to execute crisis management procedures in emergencies or accidents	Continue to work with BOCC to execute crisis management procedures in emergencies or accidents	Workplace Traffic Safety Management Crisis Management			
Declining Functions	N/A				
Emerging Functions	N/A				

Table 30: 5-year skill impact for bus drivers

10-year skills impact analysis for bus drivers

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Driving and operating of ICE buses on schedule routes and timetables to board and alight passengers at bus stops	Driving and operating of buses will observe slight changes in acceleration and braking due to regenerative braking process in EVs	Bus Vehicle Operations	Low degree of impact	Incrementally change	1. Taxi/ PHC Driver 2. Driving Instructor 3. Bus Captain (EV based)
2. Conduct high level checks on bus controls and on-board equipment to ensure vehicle readiness for service commencement and termination	Conduct high level checks on EV bus controls and on-board equipment to ensure that bus is ready for service commencement and termination	Bus Regulatory Compliance Bus Equipment and System Operation (ICE) Bus EV Equipment and System Operation EV Dashboard Diagnostic			
3. Provide high quality customer service to passengers boarding and alighting from the bus	Continue to provide high quality customer service to passengers boarding and alighting from the bus	Service Excellence			
4. Work with BOCC to execute crisis management procedures in emergencies or accidents	Continue to work with BOCC to execute crisis management procedures in emergencies or accidents	Workplace Traffic Safety Management Crisis Management			
Declining Functions	While core tasks of bus drivers are expected to be relevant in 10 years, supporting tasks such as conducting inspection on ICE bus controls and on-board equipment is expected to decline with more EV buses on the road				
Emerging Functions	Core tasks of bus drivers will remain relevant however supporting tasks such as conducting inspection on EV bus controls and on-board diagnostic is expected to emerge with more EV buses on the road				

Table 31: 10-year skill impact for bus drivers

20-year skills impact analysis for bus drivers

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Driving and operating of ICE buses on schedule routes and timetables to board and alight passengers at bus stops	Occasional driving of the vehicle required hence bus/ car vehicle operations will shift primarily to a more supervisory and observatory role in AVs	Bus Vehicle Operations Bus AV Operations (Supervision)	 High degree of change	 Displacement	1. AV Onboard Safety Operator
2. Conduct high level checks on bus controls and on-board equipment to ensure vehicle readiness for service commencement and termination	Conduct high level checks on sensor perception systems, AV controls, network and vehicular communications and on-board equipment to ensure that bus/ vehicle is ready for daily service commencement and termination	Bus Equipment and System Operation (ICE) AV Dashboard Diagnostic Automatic Vehicle Control System Network and Vehicular Communications Perception System Sensor Diagnostics and Replacement			
3. Provide high quality customer service to passengers boarding and alighting from the bus	Elimination of driving role; provide higher quality of customer service to passengers	Service Excellence			
4. Work with BOCC to execute crisis management procedures in emergencies or accidents	Require new AV diagnostic skills to identify vehicle faults and execute recovery or crisis management procedures to resolve the emergency or accident	Workplace Traffic Safety Management Crisis Management AV Dashboard Diagnostics Automatic Vehicle Control System			
Declining Functions	Driving				
Emerging Functions	Supervision of AV operations				

Table 32: 20-year skill impact for bus drivers

5.3 Detailed analysis – P2P

5.3.1 Taxi/ PHC Drivers

Overall, the emergence of electric vehicles will unlikely change driving tasks. However, some skills may need to be adapted to drive an EV. Drivers will need minimal upskilling when transitioning into EVs and involves areas such as braking, accelerating and high-level diagnostics of electric systems.

In 5 years, taxi/ PHC drivers will unlikely see a decline in any skills. This is because while EV technologies become more prominent, the core function of a driver (i.e. driving) remains largely similar to that of its ICE equivalent. Therefore, in 5 years, current skills will remain relevant, and retraining will be minimal.

In 10 years, taxi/ PHC drivers would likely see a decline in these skills:

1. Car Equipment and Systems Operation (ICE) – Operation of EV car controls and on-board equipment including dashboard alerts and signals will be different from ICE vehicles.

In 20 years, taxi/ PHC drivers would likely see a decline in these skills:

1. Car Vehicle Operations (ICE) – Operation of car vehicular types and models (driving) will change with EVs due to regenerative braking and acceleration and will be obsolete with AVs driverless technology.
2. Car Equipment and Systems Operation (ICE).

Although there would unlikely be drastic skill changes for bus vehicle operations, EV systems and diagnostics on dashboards will be relevant and required for the operation of electric cars.

In the long run with AV driverless technology, vehicle operations skills such as driving, will shift to new skills required to operate AVs involving high level supervision of AVs and AV dashboard diagnostics and AV equipment and systems operation.

Hence, the following skills are projected to emerge over the next 5 – 20 years:

1. Mobility-as-a-service (MaaS) (mobile) Operations – Familiarity with MaaS systems is needed to receive and accept trip bookings, review customer feedback, report missing items or incidents to support ride-hailing experience.
2. EV Dashboard Diagnostic – New expertise and knowledge to understand EV technology and their vehicle dashboards that will show alerts and signals to fault codes.
3. Car EV Equipment and System Operation – Operation of EV car controls and on-board equipment including dashboard alerts and signals will be different from ICE vehicle.
4. AV Dashboard Diagnostics – New expertise and knowledge to understand AV technology and their vehicle dashboards that will show alerts and signals to fault codes.
5. Car AV Operations (Supervision) – Driverless technologies in AVs will require technical expertise to conduct high level supervision and monitoring of AVs.
6. Car AV Equipment and System Operation – Operation of AV controls and on-board equipment including dashboard alerts and signals will be different from ICE vehicle.

5-year skills impact analysis for taxi/ PHC drivers

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Driving and operating of ICE vehicles on planned routes according to GPS and within estimated time allocated	Continue driving and operating of ICE vehicles on planned routes according to GPS and within estimated time allocated	Car Vehicle Operations	 Low degree of impact	 Incrementally change	1. Bus Captain
2. Conduct high level checks on vehicle controls and on-board equipment to ensure vehicle readiness for service commencement and termination	Continue conducting high level checks on vehicle controls and on-board equipment to ensure vehicle readiness for service commencement and termination	Car Equipment and System Operation (ICE)			
3. Provide high quality customer service to passengers boarding and alighting from the vehicle	Continue to provide high quality customer service to passengers boarding and alighting from the vehicle	Service Excellence Service Orientation			
4. Work with unions and taxi/ ride hire companies to handle accidents or emergencies	Continue to work with unions and taxi/ ride hire companies to handle accidents or emergencies	Workplace Traffic Safety Management Crisis Management			
Declining Functions	N/A				
Emerging Functions	N/A				

Table 33: 5-year skills impact for taxi/ PHC drivers

10-year skills impact analysis for taxi/ PHC drivers

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Driving and operating of ICE vehicles on planned routes according to GPS and within estimated time allocated	Car vehicle operations for EVs will largely remain similar with that of ICE based vehicles	Car Vehicle Operations	 Low degree of impact	 Incrementally change	1. Bus Captain 2. Taxi/PHC Driver - (EV based)
2. Conduct high level checks on vehicle controls and on-board equipment to ensure vehicle readiness for service commencement and termination	High level checks on EV controls and devices such as EV diagnostic dashboard to ensure that vehicle is ready for daily service commencement and termination	Car Equipment and System Operation (ICE) Car EV Equipment and System Operation EV Dashboard Diagnostic			
3. Provide high quality customer service to passengers boarding and alighting from the vehicle	Continue to provide high quality customer service to passengers boarding and alighting from the vehicle	Service Excellence Service Orientation			
4. Work with unions and taxi/ ride hire companies to handle accidents or emergencies	Continue to work with unions and taxi/ ride hire companies to handle accidents or emergencies	Workplace Traffic Safety Management Crisis Management			
Declining Functions	While core tasks of taxi/ PHC drivers are expected to be relevant in 10 years, supporting tasks such as conducting inspection on ICE controls and on-board equipment is expected to decline with more EV on the road				
Emerging Functions	Core tasks of taxi/ PHC drivers will remain relevant however supporting tasks such as conducting inspection on EV controls and on-board diagnostic is expected to emerge with more EV on the road				

Table 34: 10-year skills impact for taxi/ PHC drivers

20-year skills impact analysis for taxi/ PHC drivers

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Driving and operating of ICE vehicle on designated routes and timings to transport passengers to destinations	Occasional driving of the vehicle required hence bus/ car vehicle operations will shift primary to a supervisory and observatory role in AVs	Car Vehicle Operations Car AV Operations (Supervision)	 High degree of change	 Displacement	1. AV Onboard Safety Operator
2. Conduct high level checks on ICE vehicle controls and on-board equipment to ensure that vehicle is ready for daily service commencement and termination	Conduct high level checks on sensor perception systems, AV controls, network and vehicular communications and on-board equipment to ensure that bus/ vehicle is ready for daily service commencement and termination	Car Equipment and Systems Operation (ICE) AV Dashboard Diagnostics Automatic Vehicle Control System Network and Vehicular Communications Perception System Sensor Diagnostics and Replacement			
3. Provision of high quality customer service to passengers boarding and alighting	Elimination of driving role; provide higher quality of customer service to passengers	Service Excellence			
4. Execute crisis management procedures in emergencies or accidents	Require new AV diagnostic skills to identify vehicle faults and execute recovery or crisis management procedures to resolve the emergency or accident	Workplace Traffic Safety Management Crisis Management AV Dashboard Diagnostics Automatic Vehicle Control System			
Declining Functions	Driving				
Emerging Functions	Supervision of AV operations				

Table 35: 20-year skills impact for taxi/ PHC drivers

5.4 Detailed analysis – Motor Workshops

5.4.1 Car Mechanics

Overall, the emergence of electric vehicles is expected to change the required maintenance and repair skills of car mechanics by shifting mechanical-based repair skills to electrical-based skills. Given the shift in skillsets required, mechanics would also be required to understand the basics of electrical and electronics engineering to appreciate the high-voltage contents within an EV.

In 5 years, car mechanics will likely see a decline in the skill below:

1. Inventory Management – Automatic alert and inventory management system will automatically detect low availability of equipment, tools and materials for maintenance work and trigger purchase orders when threshold is hit.

In 10 years, car mechanics will likely see a decline in these skills:

1. Inventory Management (as above).
2. Maintenance Scheduling – Automatic planning and scheduling of maintenance schedules in accordance to the organisational standards and Original Equipment Manufacturer recommendations.
3. Report Writing – Machine generated reports automatically put together using terminologies and fields filled up in the system.
4. Budgeting – Automatic set up of organisational budgets to support short- and long- term business plans through pre-set forecasting algorithms, allocation, and financial policy setting.
5. Car Drivetrain Systems Maintenance – EV car will have electrical drivetrain that will require different corrective and preventive maintenance.
6. Car Engine System Maintenance – EV bus will have electrical engine that will require different corrective and preventive maintenance.

In 20 years, car mechanics will likely see a decline in these skills:

1. Inventory Management (as above)
2. Maintenance Scheduling (as above)
3. Report Writing (as above)
4. Budgeting (as above)
5. Car Drivetrain Systems Maintenance (as above)
6. Car Engine System Maintenance (as above)

EVs will generate demand for operational and maintenance skills in these main areas:

a. Car system Maintenance – Car Battery System Maintenance, Car Electric Drivetrain System Maintenance, Car High Voltage System Maintenance.
b. Car operations – Car EV Equipment and Systems Operation, EV Dashboard Diagnostic.

However, other general servicing skillsets for ICE vehicles are similar to that of EVs and will still remain relevant such as body works, tyres and brake systems. Given the less complex and modular nature of

EV components, skillsets to repair and maintain EVs can potentially be developed through on job training, reskilling and short courses once the EV training landscape has been further developed.

In the long run, skills related to maintenance of AV systems and equipment will be focused on AV dashboard diagnostics and AV equipment and systems operations skills covering sensors and perception systems, network vehicular communication system and automatic control systems.

AVs would require operational and maintenance skills in these main areas:

a. Autonomous system – Perception System Sensor Diagnostic and Replacement, Network and Vehicular Communications, Autonomous Vehicle Control System.
b. Autonomous Vehicle Operations – Remote Diagnostic Recovery Management, AV Dashboard Diagnostic, AV Planning and Route Management, AV Remote Control and Management.
c. Mechanics will need to upskill their knowledge of sensor components for AVs, particularly in these areas:
   - Perception System Sensor Diagnostics and Replacement
   - Network and Vehicular Communications
   - Automatic Vehicle Control System
   - Software maintenance skillsets
   - Diagnostic and monitoring skillsets

AVs will also require usage and interpretation of data collected from diagnostic tools, hence there will be a shift to data integration and analytics skills in these main areas:

a. Internet-of-things and Cybersecurity
b. Artificial intelligence
c. 5G Communication technologies
d. Data analysing
e. Machine learning
f. Robotics and automation

Hence, the following skills are projected to emerge over the next 5 – 20 years:

1. Data and Statistical Analytics – Rise of big data from I4.0 will require analysis of data to identify trends or patterns, define new process improvement opportunities and integrate data to suit business needs.
2. Innovation Management – Continuous advancement of technology requires the necessary systems, processes, and cultures in place to embrace innovation to enhance functional performance.
3. Internet of Things Application – Rise of Internet of Things (IoT) through I4.0 will require proper implementation to drive efficiency and effectiveness of operations.
4. Robotics and Automation Application – Rise of automation technologies through I4.0 will require evaluation and proper implementation to reduce manual tasks, automate and drive desired efficiency.

5. Technology Application – Proper technology implementation into business processes is needed to drive efficiency and effectiveness of operations.
6. EV Dashboard Diagnostic – New expertise and knowledge to understand EV technology and their vehicle dashboards that will show alerts and signals to fault codes.
7. Car Battery System Maintenance – New expertise is required to maintain battery systems which have higher electrical voltage such as diagnostic testing, isolation of circuit board and replacement of battery modules for EVs/ AVs.
8. Car Electric Drivetrain System Maintenance – New expertise is required to conduct inspection and maintenance for electrical drivetrain system for EVs/ AVs, including specific tools and diagnostics equipment that collects and interpret data, replacement of electrical based components.
9. Car High Voltage System Maintenance – New expertise is required for handling high voltage system in EVs/ AVs such as wearing of suitable gear and equipment and isolation of electrical circuit board before inspection, testing and maintenance.
10. AV Dashboard Diagnostics – New expertise and knowledge to understand AV technology and their vehicle dashboards that will show alerts and signals to fault codes.
11. Automatic Vehicle Control System – Driverless technologies in AVs is based on automatic navigation techniques and algorithms built-in, deep understanding and technical expertise is required.
12. General Control System – Deep understanding and technical expertise is required for integration of all technologies in AVs to ensure effective AV operation.
13. Network and Vehicular Communications – New expertise is required to utilise AV specific tools and diagnostics equipment to conduct inspection and maintenance for vehicles and network and vehicular communications; deep understanding of new network and vehicular communications technology is required as well.
14. Perception System Sensor Diagnostics and Replacement – New expertise is required to utilise AV specific tools and diagnostics equipment to conduct inspection and maintenance for vehicles and sensor perception systems; deep understanding of new sensor technology is required as well.
15. Remote Diagnostics Recovery Management – Driverless technologies in AVs will require expert AV diagnostic skills to identify vehicle faults and execute recovery or crisis management procedures to resolve the emergency or accident remotely.

5-year skills impact analysis for car mechanics

Job tasks today	Job tasks in 5 years	Job skills in 5 years	Job task impact	Job role impact	Job role transition
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance	Utilize EV specific tools and diagnostics equipment to conduct inspection and maintenance for vehicles, interpret vehicle health, replace electrical based components	Car Engine System Maintenance Car Drivetrain System Maintenance EV Dashboard Diagnostic Car Battery System Maintenance	 Medium degree of impact	 Redesign	1. Bus Technician 2. EV Technician 3. EV Bus Technician
2. Coordinate routine scheduled vehicle maintenance operations based on last maintenance session and condition of vehicles; ensure vehicles complete routine maintenance sessions	Frequency of maintenance will drop as EVs have less components which require repair work and specific EV parts maintenance will be allocated to specialists	Maintenance Scheduling Car Regulatory Compliance			
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment	Continue to perform general housekeeping of workshop EV tools and diagnostic equipment	Workplace Facilities Safety Management Equipment Maintenance and Housekeeping			
4. Support on-the-road vehicle breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	Support on-the-road vehicle breakdown with EV diagnostic tools, only less specialized repairs can be done on-site, complicated repairs will require proper gears and equipment	Car Recovery and Towing EV Dashboard Diagnostic			
Declining Functions	Repair and maintenance of ICE vehicles and their components				
Emerging Functions	Replacement and maintenance of EV vehicles and their components				

Table 36: 5-year skills impact for car mechanics

10-year skills impact analysis for car mechanics

Job tasks today	Job tasks in 10 years	Job skills in 10 years	Job task impact	Job role impact	Job role transition
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance	Utilize EV specific tools and diagnostics equipment to conduct inspection and maintenance for vehicles, interpret vehicle health, replace electrical based components	Car Engine System Maintenance Car Drivetrain System Maintenance EV Dashboard Diagnostic Car Battery System Maintenance	 Medium degree of impact	 Redesign	1. Bus Technician 2. EV Technician 3. EV Bus Technician
2. Coordinate routine scheduled vehicle maintenance operations based on last maintenance session and condition of vehicles; ensure vehicles complete routine maintenance sessions	Frequency of maintenance will drop as EVs have less components which require repair work and specific EV parts maintenance will be allocated to specialists; scheduling will be automated	Maintenance Scheduling Car Regulatory Compliance			
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment	Continue to perform general housekeeping of workshop EV tools and diagnostic equipment; maintenance and housekeeping will be automated	Workplace Facilities Safety Management Equipment Maintenance and Housekeeping			
4. Support on-the-road vehicle breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	Support on-the-road vehicle breakdown with EV diagnostic tools, only less specialized repairs can be done on-site, complicated repairs will require proper gears and equipment	Car Recovery and Towing EV Dashboard Diagnostic			
Declining Functions	Repair and maintenance of ICE vehicles and their components				
Emerging Functions	Replacement and maintenance of EV vehicles and their components				

Table 37: 10-year skills impact for car mechanics

20-year skills impact analysis for car mechanics

Job tasks today	Job tasks in 20 years	Job skills in 20 years	Job task impact	Job role impact	Job role transition
1. Utilise ICE vehicle tools and diagnostic equipment to conduct routine preventive maintenance	Utilize AV specific tools and diagnostics equipment to conduct inspection and maintenance, replace and repair components such as sensors, network communication system and vehicle control system	Car Engine System Maintenance Car Drivetrain System Maintenance AV Dashboard Diagnostic Perception System Sensor Diagnostic and Replacement	 Medium degree of impact	 Redesign	1. AV Maintenance Technician
2. Coordinate routine scheduled vehicle maintenance operations based on last maintenance session and condition of vehicles; ensure vehicles complete routine maintenance sessions	Frequency of maintenance will drop as AVs have less components which require repair work and specific AV parts maintenance will be allocated to specialists; scheduling will be automated	Maintenance Scheduling Car Regulatory Compliance			
3. Perform general housekeeping of workshop ICE tools and diagnostic equipment	Continue to perform general housekeeping of workshop EV/ AV tools and diagnostic equipment; maintenance and housekeeping will be automated	Workplace Facilities Safety Management Equipment Maintenance and Housekeeping			
4. Support on-the-road vehicle breakdown assistance and recovery using ICE diagnostic tools to identify faults, complete simple repairs on-site or transport buses to workshops for more complicated works	Support on-the-road vehicle breakdown with AV diagnostic tools, only less specialized repairs can be done on-site, complicated repairs will require proper gears and equipment	Car Recovery and Towing AV Dashboard Diagnostic			
Declining Functions	Repair and maintenance of ICE vehicles and their components				
Emerging Functions	Replacement and maintenance of EV and AV vehicles and their components				

Table 38: 20-year skills impact for car mechanics

5.5 Skills Gaps and Training recommendation

Whilst technological trends are set to reshape the land transport industry, transport providers can future proof their talent requirements by devising skills development strategies to bridge potential skills gaps. A Learn, Practice, Review approach blending formal structured learning, on the job training and informal learning can be taken to upskill employees with the necessary knowledge skills and abilities to support the Land Transport industry. A list of training initiatives aligned to this approach can be found below:

Figure 19: Training initiatives through – Learn, Practice, Review approach

A number of training providers are present to support the abovementioned skills development initiatives. In addition, transport operators may explore partnerships with land transport training academies (e.g. Singapore Bus Academy (SGBA), Singapore Rail Academy (SGRA)) and Land Transport associations (e.g. SMWA, NTA) to develop their employees' skillsets.

Through identifying emerging technical skills and generic skills important for the Land Transport industry in future, structured training programmes can be developed based on the Learn, Practice, Review approach to ensure employees are capable of meeting future workforce requirements.

Skill specific training intervention for the different segments

Skills gaps for Rail, Bus, P2P and Car Mechanics job families can be addressed via training interventions and partnerships with training institutions.

1. Rail Segment

With Rail 4.0, the Rail segment is expected to see new emerging skills in the areas of Business Management, Technology management and Rail Operations. Individuals and companies may consider leveraging on government grants and support to attend relevant training programmes. The Rail Transport Operators may also train Rail workers through the Rail Manpower Development Initiative (RMDI) to expand and accelerate their training in future-relevant technologies and skillsets to enhance operational efficiency. Please see examples of potential training institutions in Table 39.

Category	Emerging Skills	Impacted Job Family	Training Interventions	Potential training institutions
Business Management	Data and Statistical Analytics	Rail Engineers, Rail Technicians, Rail Operations	— Instructor-led training — Vendor trainings and workshops — Certification programmes — Short courses — Coaching and mentoring — External forums	— Singapore Polytechnic (PACE Academy) - Statistics and Data Analysis course
	Innovation Management	Rail Engineers, Rail Operations		— SIT - Workplace Learning Project (Innovation Management)
Technology Management	Internet of Things Application	Rail Engineers, Rail Technicians		— SMU Academy - Internet of Things: Technology and Applications
	Robotics and Automation Application	Rail Engineers, Rail Operations		
	Technology Application	Rail Engineers		
Rail Operations	Data Usage and Implementation	Rail Engineers, Rail Technicians, Rail Operations		— Partnerships between SGRA (Singapore Rail Academy) and various institutes of higher learning can be sought to develop skillsets in these areas
	Sensor Monitoring Management			

Table 39: Training intervention for rail segment

2. Bus Segment

With the adoption of Electric Buses expected to rise, the Bus segment is expected to see new emerging skills in the areas of Automotive Maintenance and Bus Operations. Potential training institutions are expected to play a greater role in augmenting the skills of the workers. Please see examples of potential training institutions in Table 40.

Category	Emerging Skills	Impacted Job Family	Training Interventions	Potential training institutions
Automotive Maintenance	Bus Battery System Maintenance	Bus Technicians, Bus Engineers	— Instructor-led training — Vendor trainings and workshops — Certification programmes — Short courses — On-the-job training (OJT)	— Partnerships between SGBA (Singapore Bus Academy) and Institutes of Higher Learning (i.e. ITE, Polytechnics) can be sought to
	Bus Electric Drivetrain System Maintenance			
	Bus High Voltage System Maintenance			
	Perception System Sensor Diagnostic and Replacement			

Category	Emerging Skills	Impacted Job Family	Training Interventions	Potential training institutions
	Network and Vehicular Communications			develop skillsets in these areas — On-the-job training (OJT) and collaborations with OEMs (i.e. BYD) — SGBA to continue with the partnerships already formed with IHLs and OEMs to develop more courses and step up training for EVs.
	Automatic Vehicle Control System			
	General Control System			
	Remote Diagnostic Recovery Management			
Bus Operations	Bus EV Operations	Bus Drivers	— Instructor-led training — Vendor trainings and workshops — Certification programmes — Short courses — On-the-job training (OJT) — Coaching and mentoring	
	Bus EV Equipment and System Operation			
	EV Fleet System Planning	Bus Operations		
	EV Dashboard Diagnostic	Bus Technicians, Bus Engineers, Bus Drivers, Bus Operations		
	AV Dashboard Diagnostic			
	AV Planning and Route Management	Bus Operations		
	AV Remote Control and Management			

Table 40: Training intervention for bus segment

3. P2P

While the adoption of Electric Vehicle is expected to rise, driving task is expected to remain largely unchanged with a low degree of change over the next 10 years. To support the incremental change expected to reskill to drive an EV car, P2P drivers may consider developing the skillsets required with any of the potential training institutions. P2P drivers who wish to transit to other careers may also attend reskilling courses delivered by the Associations. Please see examples of potential training institutions in Table 41.

Category	Emerging Skills	Impacted Job Family	Training Interventions	Potential training institutions
Car Operations	MaaS (mobile) operations	Taxi/ private hire car (PHC) drivers	— Short courses — On-the-job training (OJT)	— Partnerships between SMWA (Singapore Motor Workshop Association) Training Academy and Institutes of Higher Learning (i.e. ITE, Polytechnics) can be sought to develop skillsets in these areas
	Car EV Operations			
	Car EV Equipment and System Operation			
	EV Dashboard Diagnostic	Taxi/ private hire car (PHC) drivers, Car Mechanic	— Instructor-led training — Vendor trainings and workshops — Short courses — On-the-job training (OJT)	

Table 41: Training intervention for P2P segments

4. Motor workshop segments

The adoption of Electric Vehicle is expected to rise. Maintenance tasks are expected to shift towards electrical-based skills over the next 5 years. To help workers acquires the new skills, SMWA and Institutions of Higher Learning has come together in partnership with the industry to develop baseline competencies and courses. Please see examples of potential training institutions in Table 42.

Category	Emerging Skills	Impacted Job Family	Training Interventions	Potential training institutions
Automotive Maintenance	Car Battery System Maintenance	Car Mechanic	— Instructor-led training — Vendor trainings and workshops — Certification programmes — Short courses — On-the-job training (OJT)	— Partnerships between SMWA and Institutes of Higher Learning (i.e. ITE, Polytechnics) can be sought to develop skillsets in these areas
	Car Electric Drivetrain System Maintenance			
	Car High Voltage System Maintenance			
	Perception System Sensor Diagnostic and Replacement			
	Network and Vehicular Communications			
	Automatic Vehicle Control System			
	General Control System			
	Remote Diagnostic Recovery Management			

Table 42: Training intervention for Motor Workshop

Appendix A: Skills Library

 Declining skills  Adjacent skills  Emerging skills

Category	Technical skill	Description	5 years	10 years	20 years
Automotive Maintenance	Bus Air-Conditioning Systems Maintenance	Implement preventive and corrective maintenance of bus air- conditioning systems			
	Bus Body Work Maintenance	Execute corrective and preventive maintenance of bus body work			
	Bus Brake Systems Maintenance	Implement corrective and preventive maintenance of bus brake systems			
	Bus Drivetrain Systems Maintenance	Implement corrective and preventive maintenance of bus drivetrain systems (ICE)			
	Bus Electrical and Electronic Systems Maintenance	Implement corrective and preventive maintenance of bus electrical and electronic systems (ICE)			
	Bus Engine System Maintenance	Implement preventive and corrective maintenance of bus engine system (ICE)			
	Bus Steering and Suspension Systems Maintenance	Implement corrective and preventive maintenance of bus steering and suspension systems			
Bus Operations	Bus Depot Operations	Manage bus depot operations through activities for bus allocation and despatch, Bus Captain duty allocation, and facilities maintenance			
	Bus Equipment and Systems Operation	Operate bus controls and on-board equipment			
	Bus Fare Management	Operate bus fare collection equipment to collect bus fares and maintain bus fare policy			
	Bus Garaging	Restore buses through garaging activities at the depot, which include refuelling, conducting bus inspections, parking buses, and managing coin boxes, to ensure organisational standards and bus service regulatory requirements are met			
	Bus Interchange Operations	Manage bus interchange operations through activities for bus service frequency regulation, bus readiness checks, safety management and crowd control, traffic control, customer service, and facilities maintenance			
	Bus Operations Control Management	Manage the operation of bus fleets according to designated service routes using real-time information obtained from bus fleet management systems			
	Bus Service Route	Provide coaching to facilitate learning of bus service route operations			

Category	Technical skill	Description	5 years	10 years	20 years
	Operations Training and Development				
	Bus Vehicle Operations	Operate various bus vehicular types and models in accordance with regulatory and operational requirements, including activities such as driving			

Category	Technical skill	Description	5 years	10 years	20 years
Business Management	Budgeting	Prepare organisational budgets to support short- and long- term business plans through forecasting, allocation and financial policy setting			
	Business Continuity Planning	Develop and implement business continuity plans for organisational preparedness of disruptive events			
	Change Management	Manage organisational change management systems to drive organisation success and outcomes by preparing, equipping and supporting adoption of change			
	Data and Statistical Analytics	Identify data sets for the application of statistical techniques to analyse and interpret large complex data to uncover trends or patterns in order to locate and define new process improvement opportunities			
	Innovation Management	Identify functional needs for innovation, establish systems and processes to cultivate an innovative culture that transforms ideas to realisation to enhance functional performance			
	Organisational Planning and Target Setting	Identify and prioritise strategic needs of the organisation to determine key performance indicators to achieve established goals			
	Project Management	Plan, execute, track and govern projects, including allocating and managing people resources, stakeholder engagement, time and budgets and problem resolution			
	Report Writing	Write reports using terminology appropriate to the reader as well as identify requirements for written reports			
	Strategy Planning	Develop organisational strategies and policies by analysing the impact of internal and external influencing factors and seeking consultation from relevant stakeholders			
Corporate Governance and Policies	Bus Regulatory Compliance	Comply with bus legislative and regulatory requirements by establishing and adhering to internal work procedures, to prevent incidents of non-compliance and regulatory oversight			
	Rail Regulatory Compliance	Adhere to rail legislative and regulatory requirements by establishing and developing internal work processes, to prevent incidents of non-compliance and regulatory oversight			
	Car Regulatory Compliance	Comply with car legislative and regulatory requirements by establishing and adhering to			

Category	Technical skill	Description	5 years	10 years	20 years
		internal work procedures, to prevent incidents of non-compliance and regulatory oversight			

Category	Technical skill	Description	5 years	10 years	20 years
Incident Management	Bus Recovery and Towing	Deploy on-the-road bus recovery procedures by implementing appropriate recovery actions and in coordination with the Bus Operations and Control Centre			
	Car Recovery and Towing	Deploy on-the-road car recovery procedures by implementing appropriate recovery actions			
	Civil Emergency Management	Facilitate civil emergency operations and exercises in accordance to operation standards and regulatory requirements			
	Crisis Management	Apply strategies designed to enable an organisation to deal with disruptive events by planning for responses to potential crises, establishing monitoring systems and training systems, communicating both internally and externally, and leading recovery processes			
	Rail Emergency Response Management	Respond to rail emergencies by executing and developing emergency response procedures as a countermeasure to rail operation disruptions			
	Rail Incident Management	Respond to rail incidents by investigating and implementing recovery plans to maintain rail service continuity and reliability			
Maintenance Management	Asset Management	Formulate and implement the organisation's asset management policies to optimise asset life-cycle and performance			
	Condition-based Assets Monitoring Management	Formulate and implement condition-based maintenance procedures to enhance organisation maintenance regimes and operational reliability			
	Engineering Maintenance Management	Implement engineering maintenance strategy to enhance performance level of public transport fleet			
	Equipment Maintenance and Housekeeping	Maintain and upkeep tools and equipment and implement organisational housekeeping practices			
	Maintenance Scheduling	Plan and manage maintenance schedules in accordance to the organisational standards and Original Equipment Manufacturer recommendations			

Category	Technical skill	Description	5 years	10 years	20 years
People Management	Learning and Development	Manage employees' learning and development activities to maximise employee' potential and capabilities to contribute to the organisation			

Category	Technical skill	Description	5 years	10 years	20 years
	Manpower Planning and Deployment	Develop and implement manpower plans to support and meet the organisation's strategic and operational needs	=	=	=
	People Development	Build a healthy pipeline of talent pool within the organisation, review talent capabilities, identify skill needs and encourage personal learning and development	=	=	=
	Staff Performance Management	Maximise employee performance to meet business goals by aligning organisational objectives with staff goals, creating learning and development opportunities to improve individuals, providing systems of feedback and support, and implementing an effective reward system for the employee	=	=	=
Process Improvement	Continuous Improvement Management	Apply continuous improvement processes to optimise operating cost, task efficiency and effectiveness in production, services, and processes	=	=	=
	Systems Engineering Thinking	Optimise inter-disciplinary engineering application by applying process knowledge and analytical techniques to provide engineering solutions and practices through an integrated and multidisciplinary approach	=	=	=
Rail Operations	Passenger Train Operations	Operate passenger train and respond to degraded and emergency train operations in accordance to regulatory and organisational requirements	=	▼	▼
	Rail Operations Control Management	Manage rail operations and control to achieve and enhance rail service continuity and reliability	=	▼	▼
	Rail Operations Enhancement Management	Formulate rail operations strategies built on rail systems fundamentals, principles, and knowledge to drive enhancement of service operations and performance excellence	=	=	=
	Track Access Management	Monitor and facilitate track access with relevant security and protection measures at appropriate zones in accordance to organisational and regulatory requirements	=	▼	▼
	Train Depot Control Management	Facilitate train depot activities through effective management of depot control operations	=	▼	▼
	Train Fare and Ticket Management	Implement fare and ticket management, operations and enforcement in accordance to Fares and Tickets Regulations	▼	▼	▼
	Train Station Operations Management	Manage the operations of train stations to achieve rail service continuity, safety, and reliability	=	▼	▼

Category	Technical skill	Description	5 years	10 years	20 years
Rail Operations (cont'd)	Automatic Fare Collection Auxiliary	Implement preventive and corrective maintenance activities of Automatic Fare Collection (AFC) auxiliary systems	=	=	=

Category	Technical skill	Description	5 years	10 years	20 years
	Systems Maintenance				
	Automatic Fare Collection Gate Maintenance	Implement preventive and corrective maintenance activities of Automatic Fare Collection gates			
	Automatic Fare Collection Sales Device Maintenance	Implement preventive and corrective maintenance activities of Automatic Fare Collection (AFC) sales devices			
	Civil Structure Maintenance	Implement preventive and corrective maintenance of civil structures			
	Communication Auxiliary Systems Maintenance	Implement preventive and corrective maintenance activities of communication auxiliary systems			
	Communication Backbone System Maintenance	Implement preventive and corrective maintenance activities of communication backbone system			
	Communication Power System Maintenance	Implement preventive and corrective maintenance activities of communication power system			
	Drainage, Plumbing and Sanitary Systems Maintenance	Implement preventive and corrective maintenance of drainage, plumbing and sanitary systems			
	Emergency and Security Communication Systems Maintenance	Implement preventive and corrective maintenance activities of emergency and security communication systems			
	Engineering Train and Rolling Stock Operation	Operate engineering train, rolling stock and on-board equipment to support maintenance operations			
	Escalator and Travellator Maintenance	Implement preventive and corrective maintenance of escalator and travelator			
	Fire Protection Systems Maintenance	Implement preventive and corrective maintenance of lift systems			
	Heavy Crane Vehicle Maintenance	Implement preventive and corrective maintenance activities of heavy crane vehicle			
	Heavy Lifting Machinery Operation	Operate heavy lifting machinery and the appropriate deployment of machinery for maintenance activities			
	High Voltage Power Systems Maintenance	Implement preventive and corrective maintenance activities of high voltage power systems			

Category	Technical skill	Description	5 years	10 years	20 years
Rail Operations (cont'd)	Lift Systems Maintenance	Implement preventive and corrective maintenance of lift systems			
	Locomotive Maintenance	Implement preventive and corrective maintenance activities of locomotive			
	Low Voltage Power Systems Maintenance	Implement preventive and corrective maintenance activities of low voltage power systems			
	Multi-Function Vehicle Maintenance	Implement preventive and corrective maintenance activities of multi-function vehicle			
	Network Systems Maintenance	Implement preventive and corrective maintenance activities of network systems			
	Platform Screen Door Maintenance	Implement preventive and corrective maintenance of Platform Screen Door			
	Radio System Maintenance	Implement preventive and corrective maintenance activities of radio system			
	Rail Grinding Vehicle Maintenance	Implement preventive and corrective maintenance activities of rail grinding vehicle			
	Rail Track Inspection	Plan, coordinate and perform inspection of rail tracks through on-site patrols			
	Rail Track Maintenance	Implement preventive and corrective maintenance activities of rail track			
	Rolling Stock Air Condition and Ventilation Systems Maintenance	Implement preventive and corrective maintenance activities of rolling stock air-conditioning and ventilation systems			
	Rolling Stock Auxiliary Systems Maintenance	Implement preventive and corrective maintenance activities of rolling stock auxiliary systems			
	Rolling Stock Bogie Maintenance	Implement preventive and corrective maintenance activities of rolling stock bogie			
	Rolling Stock Brake Systems Maintenance	Implement preventive and corrective maintenance activities of rolling stock brake systems			
	Rolling Stock Car Body Maintenance	Implement preventive and corrective maintenance activities of rolling stock car body			

Category	Technical skill	Description	5 years	10 years	20 years
	Rolling Stock On-Board Control	Implement preventive and corrective maintenance activities of rolling stock on-board control systems			

Category	Technical skill	Description	5 years	10 years	20 years
Rail Operations (cont'd)	Systems Maintenance				
	Rolling Stock Power Systems Maintenance	Implement preventive and corrective maintenance activities of rolling stock power systems			
	Rolling Stock Propulsion Systems Maintenance	Implement preventive and corrective maintenance activities of rolling stock propulsion systems			
	Signal Interlocking Systems Maintenance	Implement preventive and corrective maintenance activities of signal interlocking systems			
	Signalling Auxiliary Device and Equipment Maintenance	Implement preventive and corrective maintenance activities of signalling auxiliary devices and equipment			
	Station Air-Conditioning Systems Maintenance	Implement preventive and corrective maintenance of station air-conditioning systems			
	Supervisory Control and Data Acquisition System Maintenance	Implement preventive and corrective maintenance activities of Supervisory Control and Data Acquisition system			
	Third Rail Maintenance	Implement preventive and corrective maintenance activities of third rail system			
	Track Tamping Vehicle Maintenance	Implement preventive and corrective maintenance activities of track tamping vehicle			
	Trackside Automatic Train Control Equipment Maintenance	Implement preventive and corrective maintenance activities of Trackside Automatic Train Control equipment			
	Train Supervisory System Maintenance	Implement preventive and corrective maintenance activities of train supervisory system			
	Trainborne Automatic Train Control Equipment Maintenance	Implement preventive and corrective maintenance activities of trainborne Automatic Train Control equipment			
	Travel Information System Maintenance	Implement preventive and corrective maintenance activities of travel information system			
	Ventilation System Maintenance	Implement preventive and corrective maintenance of ventilation system			

Category	Technical skill	Description	5 years	10 years	20 years
	Video Surveillance System Maintenance	Implement preventive and corrective maintenance activities of video surveillance system			
	Wagon Maintenance	Implement preventive and corrective maintenance activities of wagons			

Category	Technical skill	Description	5 years	10 years	20 years
Stakeholder and Customer Management	Crowd Management	Manage and control commuter traffic in public transport premises through crowd management and control techniques to facilitate service continuity and reliability			
	Security Management	Develop and enforce security measures in public transport premises in accordance with organisational standards and regulatory requirements			
	Service Excellence	Develop a service framework to manage and address service challenges as well as collaborate with relevant partners to deliver service excellence			
	Stakeholder Management	Manage organisation's key stakeholders, strategic partners and investors to ensure continuous levels of engagement by identifying needs, setting service standards and resolving issues in accordance with organisational procedures			
Supply Chain Management	Inventory Management	Formulate and implement inventory management strategies targeted at ensuring availability of equipment, tools and materials for maintenance work			
	Vendor Management	Manage vendor by ensuring adherence to contract terms and organisational safety and operating requirements			
Technology Management	Internet of Things Application	Implement Internet of Things (IoT) technologies to drive efficiency and effectiveness of operations			
	Robotics and Automation Application	Apply and integrate evaluated technologies into organisation operations or processes to achieve desired outcomes and reduce reliance on manual tasks			
	Technology Application	Integrate technologies into operations of the organisation to optimise efficiency and effectiveness of processes			
Workplace Safety and Health	Health and Fatigue Risk Management	Identify and manage risks associated with fatigue within the work environment to ensure all personnel are fit to perform assigned duties			
	Work at Heights	Maintain Workplace Safety and Health (WSH) standards and practices when working at heights by establishing safety protocols and complying with regulatory and other Work at Height (WAH) and WSH requirements			

Category	Technical skill	Description	5 years	10 years	20 years
	Workplace Facilities Safety Management	Implement safety procedures and risk control measures in a public transport workplace environment and public access areas to ensure safety of staff and commuters			
	Workplace First-Aid	Assess casualties and apply first aid, Cardiopulmonary Resuscitation (CPR) and Automated External Defibrillator (AED) skills and abilities in the workplace			

Category	Technical skill	Description	5 years	10 years	20 years
Workplace Safety and Health (cont'd)	Workplace Safety and Health Culture Development	Create and maintain a Workplace Safety and Health culture based on a common set of attitudes, behaviours, and competencies			
	Workplace Safety and Health for Confined Spaces	Perform duties with proper supervision and safety precautions, when working in confined spaces			
	Workplace Safety and Health for Electrical Safety	Manage safety to minimise risks and hazards when performing electrical-related maintenance activities			
	Workplace Safety and Health for Fire Prevention and Fire Fighting	Formulate and execute fire safety protocols and processes to minimise risk posed to customers during emergency situations involving fire			
	Workplace Safety and Health for Incident and Accident Investigation	Investigate Workplace Safety and Health incidents and accidents based on root cause analysis and identification of corrective actions to prevent recurrences			
	Workplace Traffic Safety Management	Manage movement of bus/ car fleet and pedestrians at the workplace to minimise traffic risks and hazards			

Category	Technical skill	Description	5 years	10 years	20 years
Automotive Maintenance	Car Air-Conditioning Systems Maintenance	Implement preventive and corrective maintenance of car air- conditioning systems			
	Car Body Work Maintenance	Execute corrective and preventive maintenance of car body work			
	Car Brake Systems Maintenance	Implement corrective and preventive maintenance of car brake systems			
	Car Drivetrain Systems Maintenance	Implement corrective and preventive maintenance of car drivetrain systems (ICE)			
	Car Electrical and Electronic Systems Maintenance	Implement corrective and preventive maintenance of car electrical and electronic systems (ICE)			
	Car Engine System Maintenance	Implement preventive and corrective maintenance of car engine system (ICE)			

Category	Technical skill	Description	5 years	10 years	20 years
	Car Steering and Suspension Systems Maintenance	Implement corrective and preventive maintenance of car steering and suspension systems			
Car Operations	Car Equipment and Systems Operation	Operate car controls and on-board equipment			
	Car Vehicle Operations	Operate various car vehicular types and models in accordance with regulatory and operational requirements			

Category	Technical skill	Description	5 years	10 years	20 years
Automotive Maintenance (EV/AV)	Bus Battery System Maintenance	Implement corrective and preventive maintenance of electric bus battery systems			
	Bus Electric Drivetrain System Maintenance	Implement corrective and preventive maintenance of electric bus drivetrain systems			
	Bus High Voltage System Maintenance	Implement preventive and corrective maintenance activities of high voltage power systems for electric buses			
	Car Battery System Maintenance	Implement corrective and preventive maintenance of electric car battery systems			
	Car Electric Drivetrain System Maintenance	Implement corrective and preventive maintenance of electric car drivetrain systems			
	Car High Voltage System Maintenance	Implement preventive and corrective maintenance activities of high voltage power systems for electric cars			
	Perception System Sensor Diagnostic and Replacement	Diagnose any faults/ irregularities in perception sensor systems and implement suitable corrective and preventive maintenance and replacement	N/A	N/A	
	Network and Vehicular Communications	Understand network and vehicular communications and know how to operate or implement preventive and corrective maintenance for these communication devices	N/A	N/A	
	Automatic Vehicle Control System	Understand automatic vehicle control system and know how to operate or implement preventive and corrective maintenance for these automatic vehicle control system	N/A	N/A	
	General Control System	Understand general control system and know how to operate or implement preventive and corrective maintenance for these general control system	N/A	N/A	

	Remote Diagnostic Recovery Management	Diagnose any faults/ irregularities in components of autonomous vehicle for remote recovery during operations	N/A	N/A	
Rail Operations	Data Usage and Implementation	Interpret and analyse data sets for the actual application in processes or tasks for improvement opportunities			
	Sensor Monitoring Management	Manage and facilitate usage of sensor monitoring equipment and tools to inspect, monitor, observe certain components in dangerous, inconvenient, and small spaces			

Category	Technical skill	Description	5 years	10 years	20 years
Bus Operations (EV)	Bus EV Equipment and System Operation	Operate electric bus controls and on-board equipment			
	EV Fleet System Planning	Manage the operation of EV bus fleets according to designated service routes using real-time information obtained from EV bus fleet management systems			
Bus/ Car Operations (EV/AV)	EV Dashboard Diagnostic	Usage of dashboard diagnostic equipment to identify and investigate any faults in the electric vehicle, to link fault codes with manual and conduct corrective recovery to maintain electric vehicle service continuity and reliability			
	AV Dashboard Diagnostic	Usage of dashboard diagnostic equipment to identify and investigate any faults in the autonomous vehicle, to link fault codes with manual and conduct corrective recovery to maintain autonomous vehicle service continuity and reliability	N/A	N/A	
	AV Planning and Route Management	Manage and plan route for autonomous vehicle through activities for AV allocation and despatch, service frequency, readiness checks, safety management, crowd control, traffic control, customer service and facilities maintenance	N/A	N/A	
	AV Remote Control and Management	Control and manage autonomous vehicles from control centre in the event of interruption or disruption during service operations	N/A	N/A	
Car Operations (EV)	MaaS (mobile) operations	Operate mobile application to receive and accept trips booking, review customer feedback, report any missing items or incidents			
	Car EV Equipment and System Operation	Operate electric car controls and on-board equipment			
Bus Operations (AV)	Bus AV Operations	Supervise various autonomous bus vehicular types and models in accordance with regulatory and operational requirements; ensure passengers and vehicle safety during autonomous bus vehicle's journey	N/A	N/A	
	Bus AV Equipment and System Operation	Understand the know-hows to operate autonomous bus controls and on-board equipment in times of emergency or crisis which require overwrite or reboot	N/A	N/A	

Car Operations (AV)	Car AV Operations	Supervise various autonomous car vehicular types and models in accordance with regulatory and operational requirements; ensure passengers and vehicle safety during autonomous car vehicle's journey	N/A	N/A	
	Car AV Equipment and System Operation	Understand the know-hows to operate autonomous car controls and on-board equipment in times of emergency or crisis which require overwrite or reboot	N/A	N/A	

Appendix B: Summary of overall impact on job roles

Overall, on a job role level, we observe out of 27 current job roles, 4 will be displaced in the next 5-10 years and 2 others will undergo changes in the next 20 years. The remaining job roles will change incrementally and undergo redesigning depending on the impact of emerging trends in different timeframes.

Next 5 – 10 years: Replaced by automation | Augmented by technology | Marginal impact by technology

S/N	Job role	Job task 1	Job task 2	Job task 3	Job task 4	Summation	Job role impact
1	Technician (Rolling Stock / Engineering Train)					6	Redesign
2	Technician (Permanent Way and Civil Structure)					6	Redesign
3	Technician (Power)					6	Redesign
4	Technician (Mechanical and Electrical)					6	Redesign
5	Technician (Signal and Communications)					6	Redesign
6	Technician (Automatic Fare Collection)					6	Redesign
7	Engineer (Rolling Stock / Engineering Train)					0	Incremental Change
8	Engineer (Permanent Way and Civil Structure)					0	Incremental Change
9	Engineer (Power)					0	Incremental Change

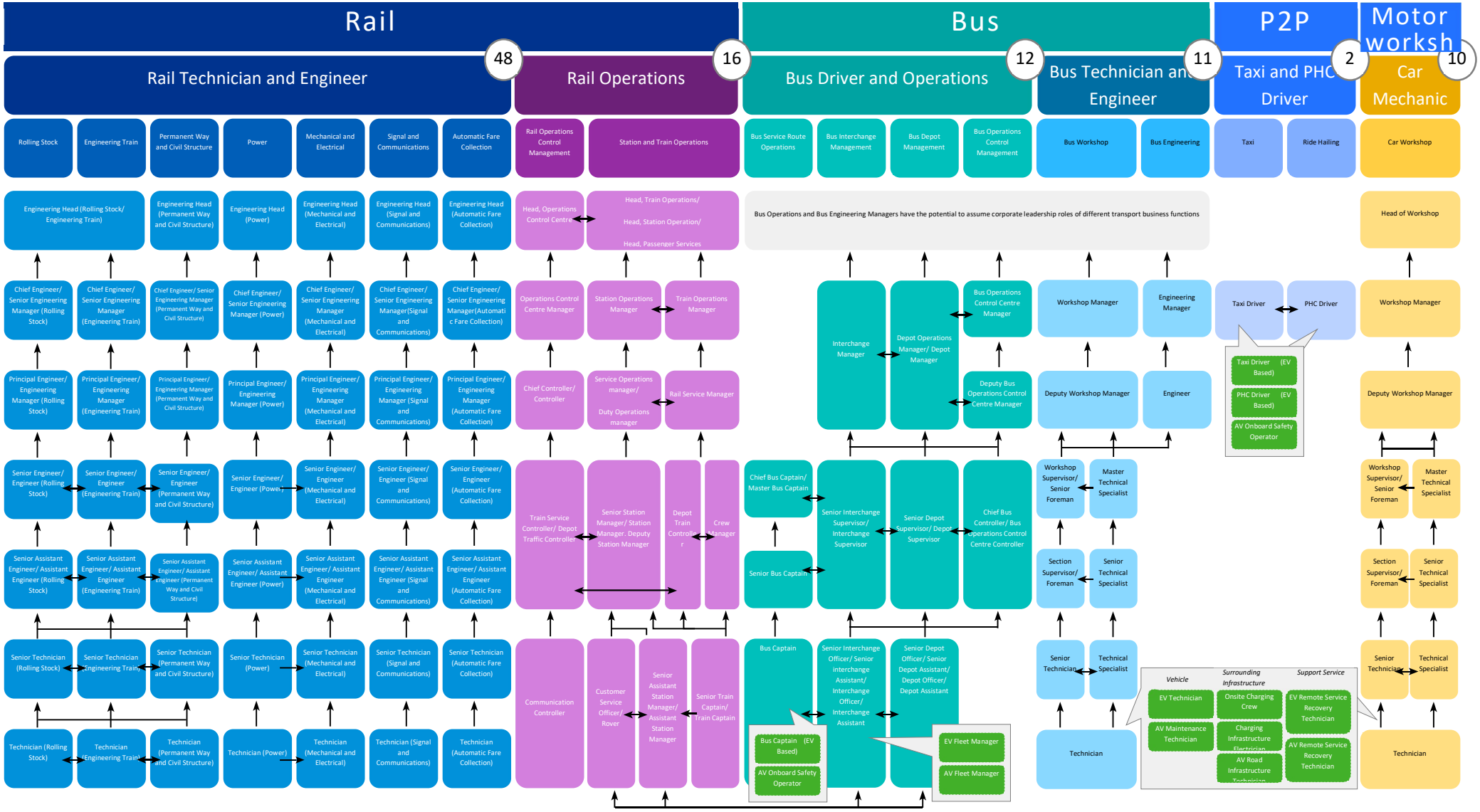
S/N	Job role	Job task 1	Job task 2	Job task 3	Job task 4	Summation	Job role impact
10	Engineer Head (Mechanical and Electrical)					0	Incremental Change
11	Engineer (Signal and Communications)					0	Incremental Change
12	Engineer (Automatic Fare Collection)					0	Incremental Change
13	Communication Controller					14	Displacement
14	Train Service Controller / Depot Traffic Controller / Operations Control Centre					6	Redesign
15	Customer Service Officer / Rover					12	Displacement
16	Station Manager					6	Redesign
17	Train Captain					14	Displacement
18	Crew Manager					12	Displacement
19	Bus Captain					2	Incremental Change
20	Bus Technician / Workshop Supervisor					6	Redesign

S/N	Job role	Job task 1	Job task 2	Job task 3	Job task 4	Summation	Job role impact
21	Bus Engineer / Engineering Manager					6	Redesign
22	Bus Interchange Officer / Depot Officer					6	Redesign
23	Chief Bus Controller / Bus Operations Control Centre Controller					6	Redesign
24	Taxi/ PHC Driver					2	Incremental Change
25	Car Mechanic					6	Redesign

In the next 20 years and beyond:

S/N	Job role	Job task 1	Job task 2	Job task 3	Job task 4	Summation	Job role impact
1	Bus Technician / Car Mechanic					10	Redesign
2	Bus Captain / Taxi Driver / PHC Driver					12	Displacement

Appendix C: Career Pathways Canvas



Appendix D: Tabulation of the job and skills analysis in CSV

S/N	Time horizon	Job role	Sub-sector/ Job family (applicable SSIC codes)	Job role (5D SSOC)	Type of impact	Level of impact	Skill required (Level of competency)	Top adjacent job role
1	Immediate (5 years)	Technician (Rolling Stock / Engineering Train)	SSIC 49101 - Railroad Services; SSIC 49102 - Mass rapid transit systems (including light rail)	SSOC 31214 - Rolling Stock Engineering Technician	Augmented	Medium	• Rolling Stock Auxiliary Systems Maintenance (1,2) • Propulsion Systems Maintenance (1,2) • Locomotive Maintenance (1,2)	• Technician (Permanent Way and Civil Structure)
2	Immediate (5 years)	Technician (Permanent Way and Civil Structure)		SSOC 31121 - Civil Engineering Technician	Augmented	Medium	• Rail Track Inspection and Maintenance (1,2) • Civil Structure and Third Rail Maintenance (1,2) • Condition-Based Assets Monitoring Management (1,2)	• Technician (Rolling Stock/ Engineering Trains)
3	Immediate (5 years)	Technician (Power)		SSOC 31131 - Electrical Engineering Technician	Augmented	Medium	• High Voltage Power Systems Maintenance (1,2) • Low Voltage Power Systems Maintenance (1,2) • Condition-Based Assets Monitoring Management (1,2)	• Rail Operations Control Mangement
4	Immediate (5 years)	Technician (Mechanical and Electrical)		SSOC 31151 - Mechanical Engineering Technician	Augmented	Medium	• Escalator and Travellator Maintenance (1,2)	• Technician (Power)

S/N	Time horizon	Job role	Sub-sector/ Job family (applicable SSIC codes)	Job role (5D SSOC)	Type of impact	Level of impact	Skill required (Level of competency)	Top adjacent job role
							• Air Conditioning Systems Maintenance (1,2) • Fire Protection Systems Maintenance (1,2)	
5	Immediate (5 years)	Technician (Signal and Communications)		SSOC 35220 -Technician (Signal and Communications); SSOC 83121 - Railway Brakemen/ Signalmen/ Shunter	Augmented	Medium	• Communication Auxiliary Systems Maintenance (1,2) • Communication Power System Maintenance (1,2) • Emergency and Security Communication System Maintenance (1,2)	• Technician (Power)
6	Immediate (5 years)	Technician (Automatic Fare Collection)		SSOC 31141 – Technician (Automatic Fare Collection)	Augmented	Medium	• Automatic Fare Collection Auxiliary Systems (1,2) • Automatic Fare Collection Gate Maintenance (1,2) • Automatic Fare Collection Sales Device Maintenance (1,2)	• Technician (Mechanical and Electrical) • Technician (Power)
7	Immediate (5 years)	Engineer (Rolling Stock / Engineering Train)		SSOC 21475 - Rolling Stock Engineer	Complemented	Low	• Rolling Stock Auxiliary Systems Maintenance (3,4)	• Contract Engineer (Train component) • Sales Engineer (Train component)

S/N	Time horizon	Job role	Sub-sector/ Job family (applicable SSIC codes)	Job role (5D SSOC)	Type of impact	Level of impact	Skill required (Level of competency)	Top adjacent job role
							• Locomotive Maintenance (3,4) • Systems Engineering Thinking	• Budget and Planning Manager (Train component)
8	Immediate (5 years)	Engineer (Permanent Way and Civil Structure)		SSOC 21421 - Civil Engineer	Complemented	Low	• Rail Track Inspection and Maintenance (3,4) • Civil Structure and Third Rail Maintenance (3,4) • Condition-Based Assets Monitoring Management (2,3,4,5)	• Contract Engineer (Structural) • Sales Engineer (Structure) • Budget and Planning Manager (Structural)
9	Immediate (5 years)	Engineer (Power)		SSOC 21512 - Power Generation and Distribution Engineer	Complemented	Low	• High Voltage Power Systems Maintenance (3,4) • Low Voltage Power Systems Maintenance (3,4) • Condition-Based Assets Monitoring Management (2,3,4,5)	• Contract Engineer (Voltage System) • Sales Engineer (Voltage System) • Budget and Planning Manager (Voltage System)
10	Immediate (5 years)	Engineer (Mechanical and Electrical)		SSOC 21441 - Mechanical Engineer; SSOC 21511 - Electrical Engineer	Complemented	Low	• Escalator and Travelletor Maintenance (3,4) • Air Conditioning Systems Maintenance (3,4)	• Contract Engineer (Mechanical) • Sales Engineer (Mechanical) • Budget and Planning Manager (Mechanical)

S/N	Time horizon	Job role	Sub-sector/ Job family (applicable SSIC codes)	Job role (5D SSOC)	Type of impact	Level of impact	Skill required (Level of competency)	Top adjacent job role
							• Fire Protection Systems Maintenance (3,4)	
11	Immediate (5 years)	Engineer (Signal and Communications)		SSOC 21532 – Signal and Communications Engineer	Complemented	Low	• Communication Auxiliary Systems Maintenance (3,4) • Communication Power System Maintenance (3,4) • Emergency and Security Communication System Maintenance (3,4)	• Contract Engineer (Comms System) • Sales Engineer (Comms Systems) • Budget and Planning Manger (Comms Systems)
12	Immediate (5 years)	Engineer (Automatic Fare Collection)		SSOC 21521 – Engineer (Automatic Fare Collection)	Complemented	Low	• Automatic Fare Collection Auxiliary Systems Maintenance (3,4) • Automatic Fare Collection Gate Maintenance (3,4) • Automatic Fare Collection Sales Device Maintenance (3,4)	• Contract Enigneer • Sales Engineer • Budget and Planning Manager
13	Immediate (5 years)	Communication Controller		SSOC 31596 – Communication Controller	At-Risk	High	• Rail Operations Control Management (2) • Rail Emergency Response Management (1)	• Station Manager

S/N	Time horizon	Job role	Sub-sector/ Job family (applicable SSIC codes)	Job role (5D SSOC)	Type of impact	Level of impact	Skill required (Level of competency)	Top adjacent job role
							• Security Management (1)	
14	Immediate (5 years)	Train Service Controller / Depot Traffic Controller / Operations Control Centre		SSOC 31572 - Train Service Supervisor; SSOC 31596 - Train Operations Officer	Augmented	Medium	• Civil Emergency Management (2,3,4) • Rail Emergency Response Management (2,3,5,6) • Rail Operations Control/ Train Depot Control Management (3,4,5,6)	• Station Manager
15	Immediate (5 years)	Customer Service Officer / Rover		SSOC 31596 - Customer Service Officer/ Rover	At-Risk	High	• Crowd Management (2) • Passenger Train Operations (2) • Service Excellence (1)	• Bus Operations Control Centre Controller • Company Secretaries • Customer Service Manager
16	Immediate (5 years)	Station Manager		SSOC 51121 - Rail Station Service Assistant; SSOC 51122 - Ticket Inspector	Augmented	Medium	• Rail Emergency Response Management (2,3,4,5,6) • Security Management (2,3,4,5) • Train Station Operations Management (2,3,4,5,6)	• Operations Manager • Administrative Services Manager • Venue Manager; Facilities Manager

S/N	Time horizon	Job role	Sub-sector/ Job family (applicable SSIC codes)	Job role (5D SSOC)	Type of impact	Level of impact	Skill required (Level of competency)	Top adjacent job role
17	Immediate (5 years)	Train Captain		SSOC 83110 - Train Operator	At-Risk	High	• Rail Emergency Response Management (1) • Security Management (1) • Passenger Train Operations (2)	• Bus Operations Control Centre Controller • Rail Operations Control Management
18	Immediate (5 years)	Crew Manager		SSOC 31572 – Crew Manager	At-Risk	High	• Rail Emergency Response Management (2) • Innovation Management (2,3) • Service Excellence (2)	• Bus Operations Control Centre Controller • Company Secretaries • Customer Service Manager
19	Medium (10 years from now)	Bus Captain	SSIC 49211 - Public bus services (scheduled services); SSIC 49212 - Chartered bus services (including school buses); SSIC 49213 - Intercountry bus services	SSOC 83311 - Bus Driver	Complemented	Low	• Bus Vehicle Operations (2) • Bus Equipment and Systems Operation (2) • Bus Service Route Operations Training and Development (3)	• Taxi/PHC Driver • Driving Instructor • Bus Captain (EV-based)
	Long (20 years from now)				At-Risk	High		• AV Onboard Safety Operator

S/N	Time horizon	Job role	Sub-sector/ Job family (applicable SSIC codes)	Job role (5D SSOC)	Type of impact	Level of impact	Skill required (Level of competency)	Top adjacent job role
20	Medium (10 years from now)	Bus Technician / Workshop Supervisor	SSIC 95301 - Repair and maintenance of motor vehicles (including installation of parts & accessories)	SSOC 31131 - Electrical Engineering Technician; SSOC 31151 - Mechanical Engineering Technician; SSOC 31212 - Automotive Engineering Technician	Augmented	Medium	• Bus Engine System Maintenance (1,2) • Bus Drivetrain Systems Maintenance (1,2) • Bus Recovery and Towing (2)	• Car Mechanic • EV Bus Technician • EV Technician
	Long (20 years from now)				Augmented	Medium		• AV Maintenance Technician
21	Medium (10 years from now)	Bus Engineer / Engineering Manager		SSOC 21472 - Automotive Engineer; SSOC 21441 - Mechanical Engineer; SSOC 21511 - Electrical Engineer; SSOC 21521 - Electronics Engineer	Augmented	Medium	• Bus Engine System Maintenance (4) • Bus Drivetrain Systems Maintenance (4) • Engineering Maintenance Management (4)	• EV Bus Engineer
22	Medium (10 years from now)	Bus Interchange Officer / Depot Officer	SSIC 49211 - Public bus services (scheduled services);	SSOC 42245 Customer Service Officer/ Clerk; SSOC 51122 Ticket Inspector; SSOC 212141 Customer Service Manager	Augmented	Medium	• Bus Interchange/ Bus Depot Operations (2) • Crisis Management (2) • Service Excellence (1)	• Bus Operations Control Centre Controller EV Fleet Manager
23	Medium (10 years from now)	Chief Bus Controller / Bus Operations Control Centre Controller	SSIC 49212 - Chartered bus services (including school buses); SSIC 49213 - Intercountry bus services	SSOC 31597 - Road Transport Operations Officer	Augmented	Medium	• Bus Operations Control Management (3) • Continuous Improvement Management (3) • Staff Performance Management (4)	• Transport Manager • EV Fleet Manager

S/N	Time horizon	Job role	Sub-sector/ Job family (applicable SSIC codes)	Job role (5D SSOC)	Type of impact	Level of impact	Skill required (Level of competency)	Top adjacent job role
24	Medium (10 years from now)	Taxi / PHC Driver	SSIC 49214 - Street-hail and ride-hail service providers	SSOC 83221 Taxi Driver; SSOC 83226 Private-Hire Driver	Complemented	Low	• Car Vehicle Operations (2) • Car Equipment and Systems Operation (2) • Service Excellence (1)	• Bus Captain • Taxi/PHC Driver (EV-based)
	Long (20 years from now)				At-Risk	High		• AV Onboard Safety Operator
25	Medium (10 years from now)	Car Mechanic	SSIC 95301 - Repair and maintenance of motor vehicles (including installation of parts & accessories)	SSOC 72310 Automotive Mechanic; SSOC 21472 Automotive Engineer; SSOC 31212 Automotive Engineering Technician	Augmented	Medium	• Car Engine System Maintenance (1,2) • Car Drivetrain Systems Maintenance (1,2) • Car Recovery and Towing (2)	• Bus Technician • EV Technicia • EV Bus Technician
	Long (20 years from now)				Augmented	Medium		• AV Maintenance Technician

Note(s):

— Most relevant time period for each job role is identified here

— Competency Levels:

- Low (Level 1- 2)
- Medium (Level 3 - 4)
- High (Level 5 - 6)

Appendix E: EV related Government policies and trends

Government policy

Government advocacy through EV policy measures act as good enablers to encourage the adoption of EVs. These EV policy measures range from monetary and non-monetary incentives, to set targets and regulations.

As of Budget 2021, the Singapore government has introduced the use of tax benefits, purchase subsidies, parking priorities, zero emission vehicles mandates, fuel economy standards and set targets as their choice of national EV measures.

The five main schemes and incentives laid out to encourage purchase of EVs include the following:

1. Enhanced Vehicular Emissions Scheme (VES)

Under this enhanced version of the regulatory scheme set out in 2018, which takes effect from 1 Jan 2021 till 31 December 2022, vehicles are categorised into different bands and given varying rebates and surcharges depending on the level of emissions they produce.

This was initiated to encourage drivers to select vehicles which produce lower emissions across the different pollutants, by bringing down the cost of purchase through rebates (Table 43**Error! Reference source not found.**). Hence, consumers may be more incentivised to buy cleaner energy vehicles.

Band	Current Rebate/Surcharge (-/+) for Cars	Increased Rebate/Surcharge	Current Rebate/Surcharge (-/+) for Taxis	Increased Rebate/Surcharge
A1	-20,000	-25,000*	-30,000	-37,500*
A2	-10,000	-15,000*	-15,000	-22,500*
B	0	0	0	0
C1	+10,000	+15,000^	+15,000	+22,500^
C2	+20,000	+25,000^	+30,000	+37,500^
*Increased rebate with effect from 1 Jan 2021 ^Increased surcharge with effect from 1 Jul 2021				

Table 43: Changes to the rebates and surcharges under the Enhanced VES

2. Electric Vehicle Early Adoption Incentive (EEAI)

In conjunction with the Enhanced VES, the EEAI allows for rebates of 45%, capped at $20,000 off the Additional Registration Fee (ARF) for the purchase of a new fully electric car or taxi. This will take effect from 1 Jan 2021 to 31 Dec 2023.

These complementary schemes will thus help to bring down the cost of purchasing and owning an electric vehicle, narrowing the differences in total cost between EVs and ICE cars.

3. Additional Registration Fee (ARF)

From Jan 2022 to Dec 2023, the floor will be lowered from S$5,000 to $0 for electric cars, which will enable mass-market EV buyers to maximise tax rebates.

4. Road taxes

The consumer tax payable for electric cars will be revised to be comparable with an ICE equivalent.

5. Certificate of Entitlement (COE) Category A: Revised Maximum Power Output (MPO) Threshold for Electric Cars

To support the adoption of electric cars, the COE Category A Maximum Power Output for electric cars has been revised from 97kW to 110kW. This will allow more mass-market electric cars to come under the lower COE category. This change will take effect from the first COE bidding exercise in May 2022.

During COS 2022, the Government announced the extension of statutory lifespan for e-taxis from 8 to 10 years, which will give operators more time to optimise their e-taxis investments.

However aside from government policies and incentives that provide mostly monetary support, there are concerns over the availability of EV charging infrastructure and whether the number of charging points planned can support the take up of EVs over time.

EV charging infrastructure and rates

There are 2 main types of charging infrastructure available for EVs namely Slow Chargers take approximately 6-7 hours for a full charge and Fast Chargers take approximately 1-2 hours for a full charge. Super Chargers such as Tesla's 250-kW Supercharger can charge an EV from 0% to 80% in 20 – 30 minutes. Currently, Singapore has estimated 2,000 charging points across the island. Type 2 AC and Combo-2 DC charging systems have been adopted as Singapore's National Public Charging Standards. The CHAdeMO charging system is an Optional Public Charging Standards for EVs.

In APAC, the total number of charging points increased from 73,137 in 2015 to 620,031 in 2019, with fast-charging infrastructure experiencing more extensive expansion (CAGR 87%) than slow charging infrastructure (CAGR 64%) (Figure 20**Error! Reference source not found.**). Overall, normal charging infrastructure make up the majority of the charging composition in APAC.

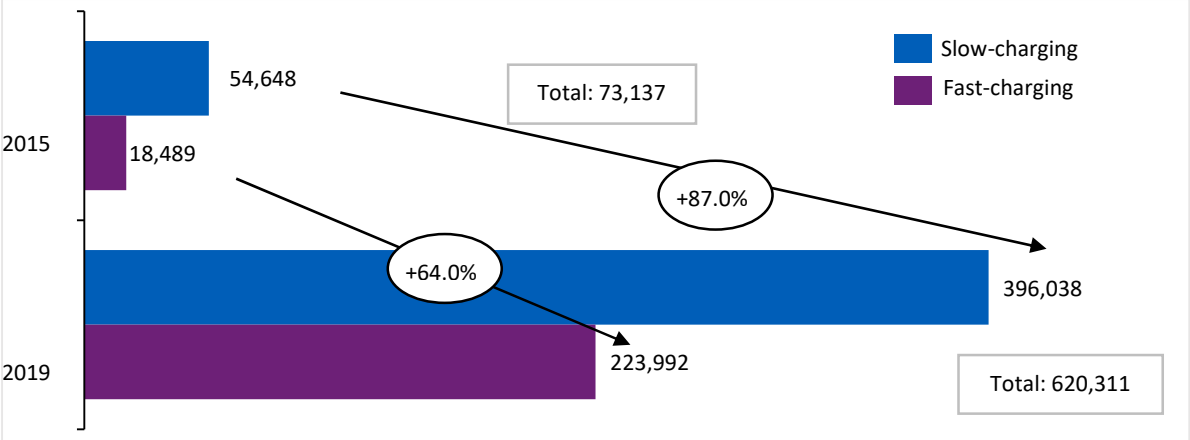


Figure 20 Growth in charging infrastructure 2015 – 2019 (APAC)

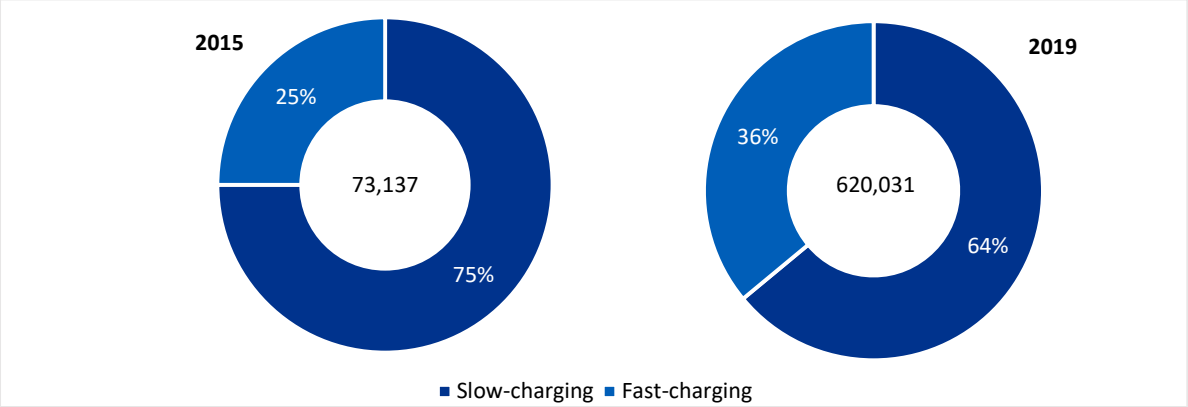


Figure 21: Change in composition of charging networks (APAC)

The government has a target to grow Singapore's charging network to 60,000 charging points by 2030 (40,000 in public carparks and 20,000 in private premises). For public car parks, the government plans to deploy a minimum of 3 charging points in all public housing car parks by 2025. To encourage the installation of shared charging infrastructure in non-landed private residences, the government had rolled out the Electric Vehicle Common Charger Grant (ECCG) which will co-fund the installation of up to 2000 smart charging points in these residences from 1 July 2021 to 31 Dec 2023.

By increasing the number of public and private charging points and providing consumers with wide accessibility of charging infrastructure, consumers' "range anxiety" can be alleviated. This will hence help to further boost the number of EV cars ownerships.

As Singapore is a small and densely populated city, most charging points will be slow chargers that support overnight charging at shared residential carparks, because it provides convenience to drivers and its much lower burden on electrical infrastructure. Although fast chargers may reduce the number of charging points needed, extensive and costly electrical infrastructure upgrades will be required. The Government, however, will facilitate the installation of fast chargers where existing electrical infrastructure allows for it and where required by taxis and heavier vehicle fleets that incur high mileages.

Specifically, EV charging Infrastructure for private bus and P2P segments will be essential to support larger scale EV fleet operations in the future. However, there are some challenges that will have to be addressed before EVs can be fully adopted commercially.

Lastly, charging rates remain a concern amongst consumer especially since it is observed that Singapore's EV charging rates exceed other benchmarked countries due to higher base electricity tariffs. However, electricity charging remains cheaper than petrol refuelling which provides a lower per km refuelling rate, reducing the long-term cost of ownership of EVs as compared to conventional ICE-based equivalents. This signifies a positive impact on consumer demand for EVs.

Battery cost and technology advancement

The declining cost of battery and renewables, alongside the advancement of battery technology, provide a positive outlook in matching the interest levels and sales of EVs moving forward.

Globally, lithium-ion battery pack prices fell 87% from 2010 to 2019, with the volume-weighted average hitting $156/kWh. By 2024, battery pack prices will go below $100/kWh on a volume-weighted average basis, driven in part by the introduction of new cell chemistries, manufacturing equipment and techniques and simplified pack designs.

Coupled with a fall in battery prices, battery technology has also seen improvements over the years. The average battery energy density is rising at 4-5% per year and new chemistries are hitting the market. Similarly, maximum EV charging speeds are also rising to match up with increased capacity of batteries. As a result, improved battery technology will extend the driving range of electric cars.

These breakthroughs and decreasing cost of batteries will be passed down to the final consumer prices of EVs and hence further reducing the cost of EVs. Industry estimates point to 2026 where upfront cost parity between EVs and ICE vehicles would be achieved, as a result of battery pack prices falling to US$80/kWh in 2016.

Barriers for EV adoption

Despite Singapore's push for EV adoption, there still exists significant barriers.

1. High costs of larger EVs

The cost of EVs is still largely higher than ICE vehicles. For example, electric buses (e.g. BYD/Volvo Electric Bus), which cost around S$220,000 – S$500,000 cost up to 3 times more than an equivalent ICE Single Decker Euro 6 bus, which price around S$150,000 – S$200,000. With the significant price disparity between EVs and ICEs vehicles, it will be difficult for EVs to be fully assimilated into Singapore's transportation network.

2. Limited charging infrastructure

While there are plans to grow Singapore's EV charging infrastructure network, charging infrastructure used by public, private buses, taxis and PHCs and rest of the EV population are different. As demand for electric vehicles grows in Singapore, there may be insufficient availability of EV charging points for each of the land transport related segments. Moreover, in comparison to petrol fuelling which takes 15 min, EV charging is still relatively inefficient, taking 1-2 hours for DC charging and 6-7 hours for AC charging.

3. Operational Challenges

Operational changes due to fleet turnaround time (e.g. charging time and operational-ready shifts) will affect revenue and costs.

Global case studies

Case Study 1: Norway

As of 2020, 52% of the total vehicles in Norway are fully electric, and only 19% are not at least partially run on renewable energy (Figure 22). The total number of electric cars and hybrid cars in Norway stands at almost 500,000, a 63.8% increase since 2010 (Figure 23**Error! Reference source not found.**).

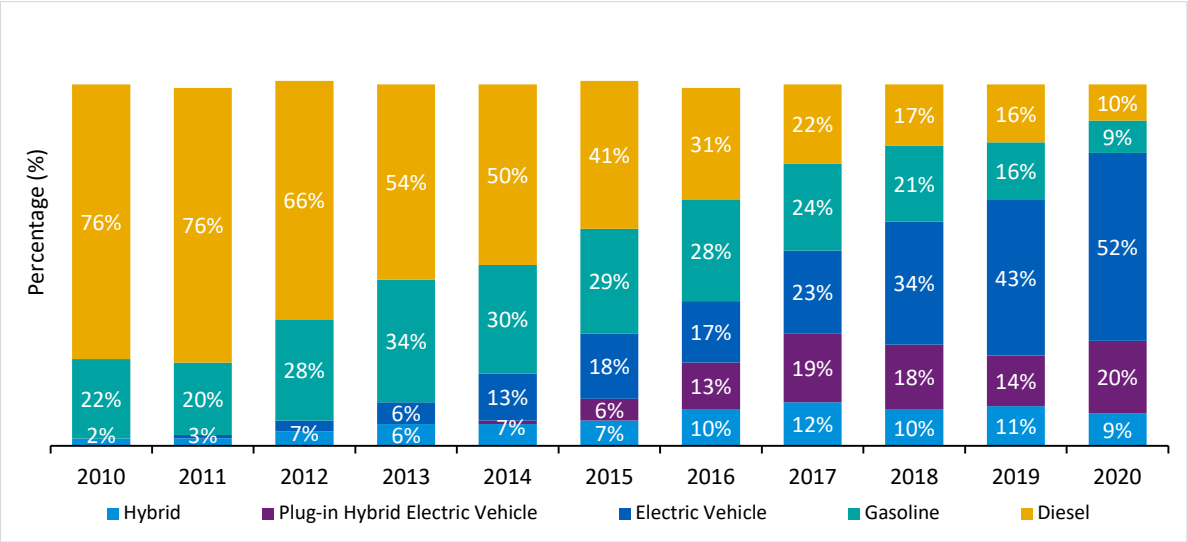


Figure 22: Changes in proportion on vehicles in Norway from 2010 – 2020

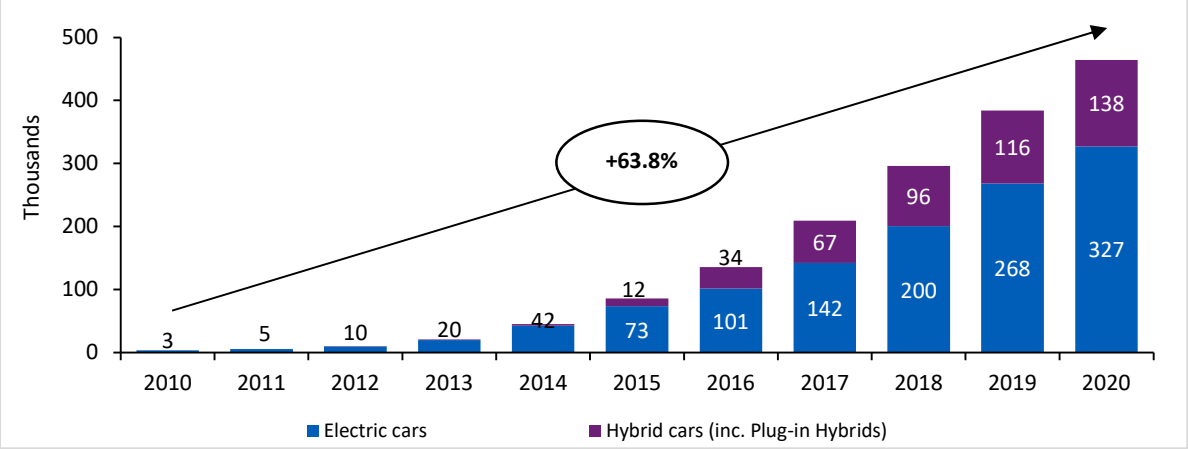


Figure 23: Rise in EVs in Norway

With Norway as a global best practice for electric car adoption, it is critical to understand the enablers of this rapid adoption of EVs. Insights from Norway indicates that zero emission goals and infrastructure and EV related policies are the main pillars driving the change.

Norway set four main zero emission goals to be achieved in the next 5-10 years:

1. All new passenger cars and light vans sold should be zero-emission by 2025.
2. All new city buses should be zero-emission or use biogas by 2025.
3. All new heavy vans, 75% of new long-distance buses and 50% of new lorries sold should be zero-emission by 2030.

4. Distribution of most goods in major city areas should be emission free by 2030.

Moreover, it also has implemented a wide range of policy measures to encourage consumers to purchase EVs. These include:

1. Exemptions from the high VAT and import tax when purchasing vehicles.
2. No toll-gate fee on all highways.
3. Free or reduced price on ferries.
4. Access to public transport lanes to avoid congestion.
5. Free parking.
6. At least two fast-charging stations every 50 km on all main roads.

Case Study 2: China

China is leading the global EV scene making up 45% of the global EV cars on the road in 2018 (Figure 24). As of 2020, China has approximately 5 million EVs on the road and in addition has the most electric vehicle (EV) charging stations in the world, with over 1.2 million in 2019 (Figure 25), and they are looking to add around 600,000 more through an infrastructure stimulus package announced by the Central Government in March 2020.

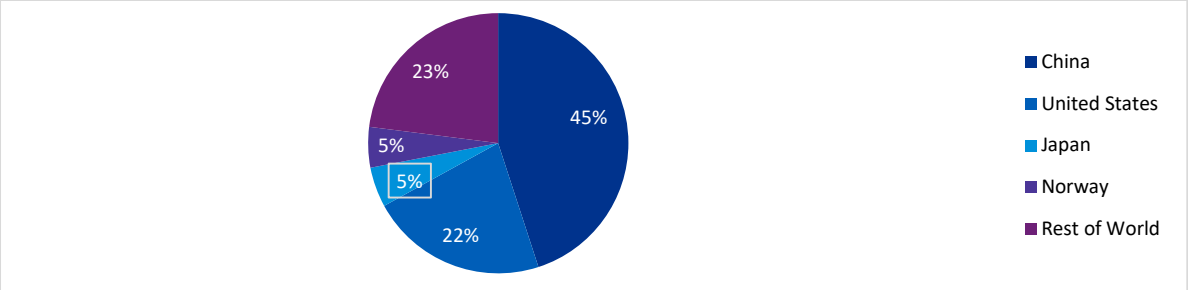


Figure 24: China's proportion of the world 2018 EV market (5.1m vehicles total)

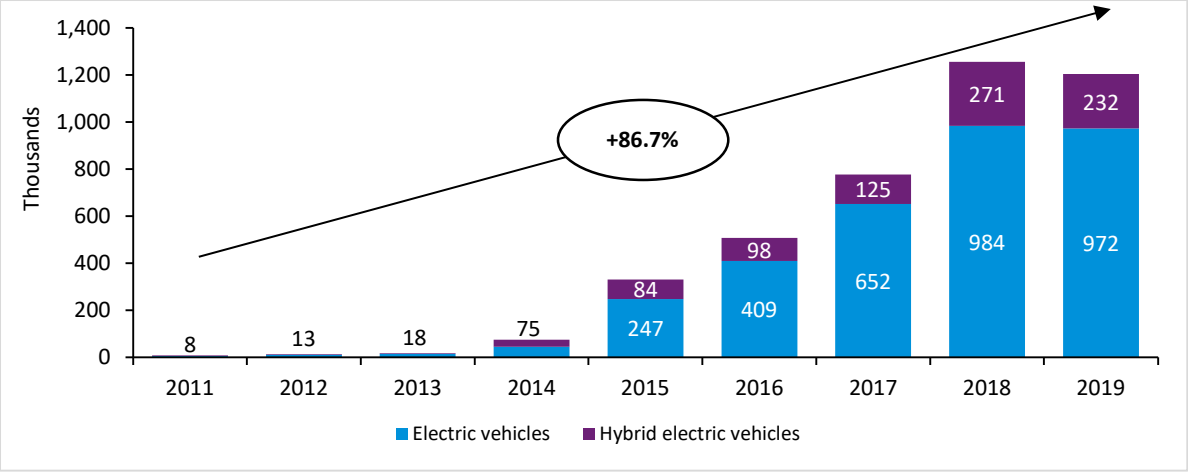


Figure 25: Annual sales volume of new energy vehicles in China from 2010 – 2019

China has invested in the following various government policies which has been the driving force for EV adoption:

1. Zero emissions vehicle mandate – In 2020, each Chinese vehicle manufacturer and importer is required to make or import at least 12% electric vehicles.
2. Subsidies – Subsidies are provided to manufacturers of electric vehicles, including all-electric plug-in cars and plug-in hybrid cars.
3. Tax exemptions – Electric vehicles are exempted from consumption and sales taxes, 50% of their vehicle registration fees waived.
4. Procurement – China's central government uses its procurement power in the May 2016 order to mandate that half of new vehicles purchased have to be new energy vehicles within five years.

Appendix F: AV Technologies, related Government policies and trends

In this appendix, we will look at AV technologies today and the infrastructure required to support the implementation of AV, the type of supportive policies implemented globally and in Singapore, and corporate investment into AV technologies. We will discuss the barriers to AV adoption and case studies of limited AV implementation from U.S.A, Norway, and China.

AV technologies and supporting infrastructure

1. Lidar sensors – Lidar sensors allow for the scanning of surroundings to perceive objects in front of the vehicle. Commercial lidar sensors are either 905nm or 1,550nm. AV specific lidars will have to perceive surroundings more than the standard lidar sensors to better read road signs 300m or 400m ahead (or 5-6 cars ahead). Paint used for road markings, traffic lights, road signs and parking lots will have to be suitable for optimal sensors detection. Lidar sensors will have to work with audio sensors to listen to surroundings (e.g. ambulance sounds, police cars, people) and provide better perception.
2. Navigation technologies – Navigation technologies and Global Positioning System (GPS) help AVs to map out the exact routes from point to point. Under this system, 3D maps must be refreshed consistently to reflect the live situation of the traffic and infrastructure. Technologies must be robust enough to counter poor connection areas such as in tunnels or underground.
3. Communication technologies – Vehicle-to-infrastructure (V2I) or vehicle-to-everything (V2X) communication allows interaction between multiple infrastructure components on the roads (e.g. ERP 2.0, traffic lights, speed cameras). This wireless exchange of data between vehicles and road infrastructure is bi-directional and allows improved mapping and information flow.

However, certain physical infrastructures have to be available to support these technologies and uptake of AVs.

1. Road – Road quality and maintenance are prerequisite for AV introduction to ensure that road conditions are suitable for the safe movement of AVs on their routes. According to the World Economic Forum, Singapore is Ranked 1st in the world for road quality. This is necessary in reducing potential issues when it comes to the testing and deployment of AVs as poor road quality can impact accuracy of mapping and cause safety issues
2. Supporting road infrastructure – Lane markers, traffic lights, road signs, parking lots will have to be repainted with suitable coating paint that will aid more accurate reflection of objects into the sensor's receptors
3. Designated lane and pick up points – Designs of bus stops, taxi stands, and pick-up drop-off points need to be adequately modified to prepare for AVs to easily fetch commuters. The possibility of dedicated lanes for AVs to drive on to prevent obstructions from surrounding vehicles could be considered.
4. High quality mobile internet – Singapore possesses high quality mobile internet through the availability of high-performance mobile internet network coverage, speed, number of servers and network bandwidth. This digital infrastructure is necessary to lay the foundation for Vehicle-to-everything (V2X) communication technologies, faster data transmission and reduced latency.

5. Extensive 4G networks – Apart from its present 4G network, Singapore is currently developing and launching 5G networks. Extensive network coverage is important to ensure there is proper coverage of internet to allow the vehicles to communicate and stay connected.

Government policy incentives

Global government legislation and initiatives have played a part in paving the way for AVs. Dubai, China, South Korea, and Germany are amongst the countries with favourable legislation to accelerate the adoption of AVs.

1. Dubai - In February 2020, Dubai's Roads and Transport Authority has introduced new legislations to streamline trial runs of AVs in Dubai. The legislations define the roles and responsibilities of government entities involved. These rules will help achieve Dubai's Smart Mobility goals of having 25% of transportation trips be smart and driverless by 2030.
2. China - In March 2020, China is evolving quickly on national level policies for AVs with a digital transport construction strategy ready. The government has also made it easier to test AVs on public roads with fewer controls.
3. China released their Intelligent Vehicle Innovation and Development Strategy with a blueprint to provide an ecosystem for intelligent vehicles to develop in China. The goal is to have level 3 AVs in mass production and level 4 AVs in specific environments by 2025.
4. South Korea – In July 2020, South Korea's Ministry of Land, Infrastructure and Transport has set safety standards for level 3 self-driving vehicles which will pave the way for manufacturing safe autonomous vehicles. The new safety standards allow the sale and manufacturing of level 3 AVs. One major characteristic includes allowing the car to run only when there is a driver in the driver's seat to control the car in emergency situations.
5. Germany – In September 2020, the German government is planning to be the first in the world by having plans to draft legislations to permit self-driving vehicles on roads across the country. The transport ministry believes that AVs are safer as the majority of traffic accidents in Germany are caused by human error. As a result, Germany has set a goal to get autonomous cars onto the regular roads from 2022.

In Singapore, the government's developed policy and technical specification guidelines which form the foundation for future AV development.

a. Technical Reference 68 (TR 68) – This encompasses the National standards for the development and roll out of AVs, related to vehicle behaviour, functional safety, cybersecurity, and data formats.
b. 2nd Edition: AI Governance Framework – This regulation elaborates on the compliance measures, ethical principles and governance considerations and recommendations for AI solution adoption.
c. Extension of test beds for AVs – Extensive testing areas in Buona Vista, Jurong Island, NTU and Sentosa and all public roads in Western Singapore, with the Centre of Excellence for Testing and Research of Autonomous Vehicles (CETRAN).
d. Amendments to Road Traffic Act – Firstly, there have been amendments made to recognise that motor vehicles need not necessarily have human drivers to facilitate AV trials in Singapore.

Moreover, regulations governing AV developers when undergoing on-the-road trials and data sharing with LTA have been edited into the Road Traffic Act.

Corporate Investments

In addition to government policy measures and initiatives, corporate investments have further provided a foundation for progress in research and development of AVs.

1. General Motors' Cruise and Microsoft – General Motors' Cruise announced a new deal with Microsoft to speed up the commercialisation of autonomous vehicles. The software giant will contribute an undisclosed amount to a $2 billion funding round.
2. Tesla – Tesla released a beta version of its "full self-driving" (FSD) driver assistance software to select Tesla owners. The FSD system does not give cars full autonomy and is currently a USD 10'000 add-on.
3. Intel and Moovit – US technology company Intel buys Moovit, an Israeli start-up which provides an urban mobility app, for around US$900 million, to support its Israeli-based AV unit Mobileye
4. Amazon and Zoox – Amazon announces its USD 1.3b acquisition of Zoox, a Silicon Valley company which has plans to design and build AVs from scratch. It is estimated that Amazon will likely have to spend $2 billion a year in ongoing development to get Zoox into the market.
5. Ouster Inc and Colonnade Acquisition Corp – Ouster Inc, a U.S. start-up that makes lidar sensors for AV and smart cities agreed to go public through a merger with a Special Purpose Acquisition Company (SPAC) Colonnade Acquisition Corp. Valuing Ouster at USD 1.9b.
6. Uber and Aurora – Uber announces the sale of its autonomous driving unit Uber Advanced Technologies Group (ATG) to self-driving car start-up Aurora for USD 4b while also investing USD 400m into Aurora. This puts Aurora's valuation at USD 10b

In Singapore, corporate interest is also seen through collaborations between private and public sectors and through its various key partnerships and agendas.

a. Cetran – The $3.6 million AV test centre was jointly developed by Nanyang Technological University (NTU), Land Transport Authority (LTA) and JTC Corporation, as part of the Centre of Excellence for Testing and Research of AVs – NTU in late 2017.
b. ST Engineering – ST Engineering invested an undisclosed amount in Israel-based SafeRide Technologies which provides cybersecurity solutions for AVs; First commercial AV bus trials partnership with MaaS apps, Zipster and SWATRide, and public transport operators, SBS and SMRT to run these commercial AV trials in Science Park 2 and Jurong Island until end-April 2021
c. ComfortDelGro – ComfortDelGro invested in Israel-based autonomous vehicle safety testing and compliance technology company Foretellix's US$14 million Series A round which closed in January 2019, then an undisclosed amount again subsequently.
d. Volvo – Volvo invested $4 million in AV trials in Singapore and has spent an additional amount of more than $4 million on technology development for AVs.
e. A*STAR – Singapore Autonomous Vehicle Initiative (SAVI) with LTA to provide a technical platform for conducting RandD and test-bedding of AV technology, applications, and solutions

f. Hyundai – Mobility Global Innovative Centre opening in 2022 with the support of EDB to explore business ideas and technologies in the future mobility solutions space.
g. Volvo, NTU and LTA collaboration – NTU-LTA-Volvo Level 4 AV Bus which the Volvo 7900 Electric bus is fitted with numerous sensors and navigation controls managed by an artificial intelligence (AI) system. The AI system is protected with industry-leading cybersecurity solutions to prevent risks of cyber-attacks. The bus comes with LIDAR sensors, stereo-vision cameras to capture 3D images, advanced GPS system which uses real-time kinematics to provide accuracy of up to one centimetre. The system is attached to an "inertial management unit" which acts as a gyroscope and accelerometer to improve navigations on uneven terrain or sharp bends to provide a more comfortable ride. The sensors are also able to navigate through dense traffic and tropical weather conditions

Barriers to AV adoption

However, complex challenges in implementation are still being addressed as AVs enter a critical period of pilot tests.

1. Safety concerns

WHO estimates out of 1.35 million road deaths annually, 95% are due to human error. However, while AVs have the potential to reduce casualties dramatically, drivers of AVs may engage in potentially riskier behaviour due to an overreliance on its autonomous systems. In March 2018, a Tesla crashed into a concrete barrier as the driver was always distracted despite manufacturer's warnings to be attentive and to keep hands on the wheel when the vehicle is on Autopilot mode.

Moreover, as with all technology, there are always limitations such as the possibility of sensors malfunctioning in detecting objects like pedestrians, other vehicles, or obstacles.

As such, the public's perception towards AV remains uncertain due to safety issues from a fully autonomous vehicle. They are concerned about whether AVs will be able to respond to sudden changes on the roads (e.g. swerving of other vehicles, pedestrian jay walking) or properly navigate in unpredictable conditions (e.g. heavy rain, hazy, crowded surroundings, bad network area under tunnels). In the event of an accident, liability will be an issue as there are no drivers behind the wheel. Having dedicated lanes (e.g. AV lane which is similar to a bus lane) to reduce uncertainties of surrounding drivers will enhance operational safety and potentially speed up the process of introducing AVs into the market.

2. Privacy concerns

Privacy also remains a critical challenge as connected vehicles allow for optimization of road capacity but infringes on data privacy. In May 2020, there were reports of hackers buying old Tesla parts on eBay which contain sensitive user data. Hence, tighter regulations need to be put in place to prevent instances of hacking associated with AVs.

3. Lack of suitable Infrastructure

There are various components to the AV infrastructure, and thus there needs to be substantial innovative technology in place to meet these infrastructure demands.

Critical digital infrastructure technologies for AVs are still in the early development stage where level 5 autonomous driving is not available. Lidar sensors and navigation technologies will be essential for AVs while more complex technologies such as vehicle-to-everything (V2X) communications will be critical until a truly autonomous solution is available.

Moreover, investments in IT and communications infrastructure are necessary to handle the flow of data from AVs. An example would be 5G infrastructure which speeds up data transmission and reduces latency, which is essential for AV adoption.

Establishment of critical physical infrastructure is also needed to allow for AV vehicle testing and adoption (e.g. Charging stations, Trial areas, etc.). LTA had a recent grant call for designing bus stops, taxi stands and pick-up or drop-off points to prepare for the transition towards AVs. However, road signs and lane markings need to be designed to ensure that the cameras and sensors on AVs can detect the surrounding environment.

4. Lack of legislations

Legislation is a complex challenge, given the scope and applicability of certain regulations which may impact the demand for AVs.

For example, international standardization of AV regulations would be pertinent to allow AVs to operate in different countries. As such, within the European Union, some basic automation will become mandatory in all new vehicles under the Advanced Driver Assistance Systems (ADAS) from 2022.

Moreover, regulations are both prescriptive as well as experimental hence covering all key aspects such as safety, privacy, cybersecurity, liability, and impact on incumbent industry is necessary.

5. Nascent training landscape

Industry professionals and academics have an indication on relevant courses and skills required to maintain and operate AV's. However, training pathways and courses must be formalised to support workforce reskilling/upskilling in AV maintenance and operations.

Global case studies

Case Study 1: United States (US)

A closer look into the US shows that technology, innovation, and industry partnerships have paved the way for AVs, making it a best practice for adoption of AVs.

In the US, technology-focused companies and established vehicle makers continue to dominate AV development worldwide. This has allowed the country to be ranked 1st in Huawei's 2020 Global Connectivity Index which ranks 79 nations based on ICT investment, ICT maturity and digital economic performance.

Moreover, the US has 420 AV-related technology companies' headquarters in the country, which is the highest in the world. Some key investments include Ford's investment of US$1 bill into Argo AI, a US-based self-driving car startup. In 2020, the company is now valued at US$7.5 billion. More recently, Apple acquired Drive.ai in 2019 and is currently in talks with Hyundai to sign a partnership agreement to work on AVs and start production in 2024 in the US.

Given these key enablers of AV adoption, the US autonomous car market is expected to see a CAGR of 46.4% for the forecast period between 2019 to 2024 (Figure 26**Error! Reference source not found.**).

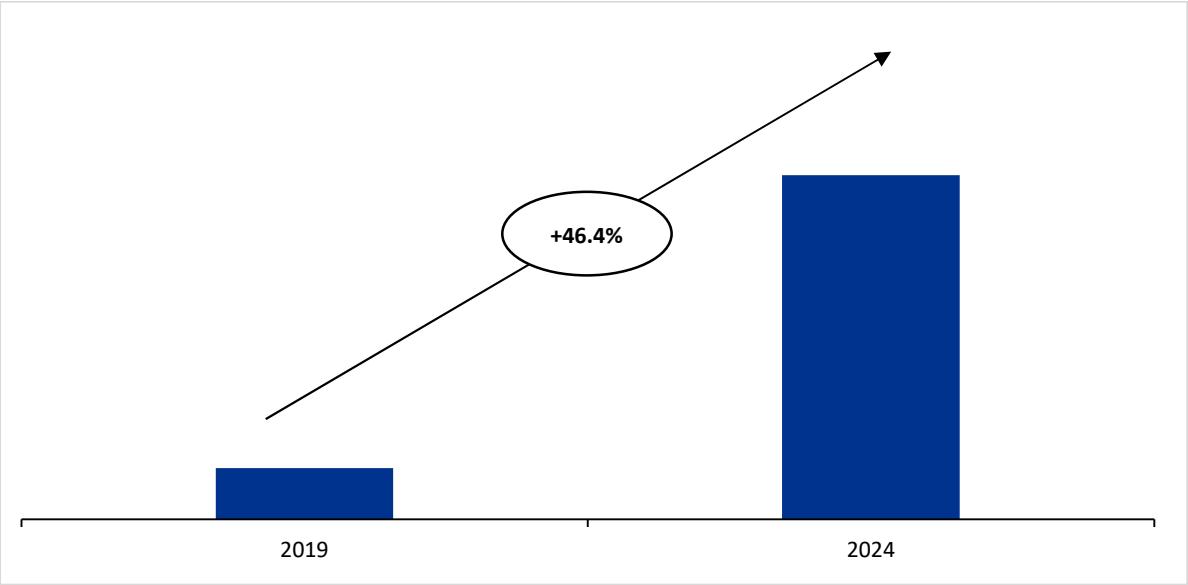


Figure 26: Anticipated US autonomous car market CAGR from 2019 to 2024

While level 4 and level 5 AVs are not expected to reach wide acceptance by 2030, it is anticipated that there will be rapid growth for level 2 and level 3 AVs which have advance driver assistance systems. Nevertheless, the US has commenced commercial deployments of level 4 and 5 AVs, setting the stage for other countries.

One example of such an AV would be Waymo's Robotaxi. In Dec 2018, Waymo launched a commercial self-driving car service called "Waymo One". Users in the Phoenix metropolitan area use a mobile application to request a pick-up. By Nov 2019, the service was operating AVs without a safety backup driver, the first service worldwide operating without safety drivers. In Oct 2020, Waymo became the first service provider to offer robotaxi rides to the general public.

Another such example would be Nuro's cargo delivery service. In Dec 2020, Nuro was issued a deployment permit in California for their electric self-driving local commerce delivery vehicle. Nuro already had operations in Arizona, partnering with companies like Dominos, CVS and Walmart. This vehicle is designed to carry only cargo, with space for 12 grocery bags in the first model and has a maximum speed of 25 miles per hour.

Case Study 2: Norway

In another case study, Norway has trialled and tested AVs in the transportation and logistics sectors.

One major trial conducted was for the EasyMile Self-Driving Bus. Trialled on the roads of Trondheim, with 20 bus stops at 200m distance apart, the buses sit 6 passengers together with a safety operator on board. It travels at a speed of 16km/h and uses GPS and Lidar to navigate. Passengers can call for the bus via a mobile application. This trial generated a good supply of test riders for the project while making sure the service itself is useful.

Another similar AV trialled was the Ruter and Holo public bus trials in Oslo. These automated buses were trialled in 3 areas of Oslo and 1 on the outskirts. As a successful project, the bus services have

served 29,000 passengers and driven more than 33,000 km as of Dec 2020. Ruter's self-driving vehicle project is carried out in collaboration with Norwegian Public Roads Administration and Oslo municipality's Agency for City Environment, as part of a joint initiative titled "Smarter Transport in the Oslo Region" (STOR).

Finally, a subsidiary of the automobile company Volvo, Volvo Trucks, initiated its first autonomous solution under their hub-to-hub service, transporting limestone from an open pit mine to a nearby port. These trucks drive 5km in both tunnels and outdoor environment before dumping the load, all on their own. The autonomous Volvo FH trucks are managed by the operator of a wheel loader.

Case Study 3: China

In China, AV projects are seen in P2P services for private guests and logistics business.

One such project would be the AutoX RoboTaxi trials. In Dec 2020, Alibaba backed, AV start-up AutoX launched 25 fully driverless robotaxis in Shenzhen, available only to employees and private guests. Rides are booked through Alibaba's AutoNavi mapping and navigation app and Leztgo, a Shanghai-based taxi fleet service. Expanding into the US, AutoX is the third company after Waymo and Nuro to obtain a permit from the California DMV to fully test self-driving vehicles on streets within San Jose.

Another example of a successful project was the JD.com Inc. Autonomus Delivery Robots which integrated AVs into the logistics transportation segment. In Feb 2020, JD.com's logistics arm deployed its inhouse level 4 autonomous delivery robots to deliver goods in Wuhan during the COVID-19 lockdown period. These robots can carry up to 30 parcels each and travel up to 50 km with one battery charge. Users can pick up their package with a retrieval code when a delivery vehicle arrives at the designated location. The robots travelled 6,800 km to deliver more than 13,000 packages in Wuhan.