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EXPLORING THE SOCIAL SUSTAINABILITY IMPLICATIONS OF
AUTONOMOUS VEHICLE ADOPTION IN SUPPLY CHAINS

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August 2023



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This thesis is submitted in partial fulfilment of the requirements for
the degree of Doctor of Philosophy

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Academic integrity declaration

I declare that:

- the thesis submitted has been written by me alone.
- the thesis submitted has not been previously submitted to this university or any other.
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Abstract

Adopting autonomous vehicles (AVs) in supply chains has shown significant potential for economic and environmental benefits, however, they are still not widely deployed in supply chains. In order to gain social approval for wider AV adoption in supply chains, it is crucial to understand the social implications. Currently, there is a lack of comprehensive discussion about the social impacts of AV adoption, and how to improve the social sustainability performance in this scenario. Therefore, this thesis aims to explore the social impacts and social sustainability aspects of deploying AVs in supply chains, and the actions organisations enact to improve social sustainability performance and hence achieve wider social approval for adopting AVs in supply chains. Using the paper-based structure, this thesis comprises three interconnected papers which collectively fulfil this overall research aim: the first paper systematically reviews the literature in this research domain, and papers two and three present empirical studies that discuss supply chain social sustainability (SCSS) implications and the actions needed to improve the SCSS performance of AV adoption in supply chains.

Paper one titled “Exploring the Social Impacts of Autonomous Vehicle adoption in Supply Chains: a systematic literature review” aims to identify the positive and negative social impacts of AV adoption in supply chains as well as the actions taken by organisations that address the impacts enabling wider AV adoption in supply chains based on a systematic literature review (SLR). Through reviewing 58 identified papers, this paper identified 13 positive and 7 negative social impacts of AV adoption in the supply chain. Based on these impacts, a conceptual model categorising the social impacts under six context-specific SCSS indicators that are derived from seminal social sustainability literature is formed to measure the social sustainability performance of AV adoption in supply chains in aspects including Health and safety, customer satisfaction, employment, transparency, diversity and equality, and welfare. Stakeholder as an essential element in analysing SCSS received limited focus in this context, which serves as a research gap for the second paper to fill. In addition, this paper identifies 20 suggested

actions for organisations to enact for wider AV adoption. These actions are synthesised into four groups including pilot experiments, regulation improvement, chain-wide considerations, and education, promotion, and training. However, wider AV adoption requires wide social approval, which requires the social impacts to be addressed for improved SCSS performance. The actions are mentioned to facilitate wider AV adoption, but the existing literature does not clarify how to address the social implications of achieving wider AV adoption in supply chains. This means that the actions taken by organisations to address social implications are currently missing. Therefore, the actions organisations employ to address social impacts for wider AV adoption serve as the research gap for the third paper to fill.

Paper two titled “Investigating the Social Sustainability of Autonomous Vehicle Adoption in Supply Chains: A Delphi Study” refines the social implications identified from the literature, and discusses stakeholder roles in the AV adoption context. Based on a three-round Delphi study with 39 experts, 19 positive and 15 negative social impacts are identified and their importance is ranked. In addition to the existing six identified indicators, “Reputation” is recognised, extending the concept of SCSS to the AV adoption context. This study also identifies 9 internal and 17 external stakeholders and evaluates the degree to which they affect or are affected by AV adoption in supply chains. This finding fulfils the first research gap of this thesis.

Paper three titled “Improving Supply Chain Social Sustainability in the Autonomous Vehicle adoption context: A Delphi study with expert interviews” empirically investigates the actions that organisations take to address the social impacts of AV adoption in supply chains. The three-round Delphi study suggests eight categories of actions, which are further validated through 14 follow-up interviews to evaluate the key SCSS indicators these actions address. Identifying these actions fills the second research gap of this thesis. To understand how the organisations at various stages of AV adoption act to improve SCSS performance, this paper adopts the Diffusion of Innovations (DOI) theory to align the action categories with the organisational innovation process. This theory structures the actions on the basis of the AV adoption stages of the organisations

in a logical sequence. The eight categories of actions provide organisations at various innovation adoption levels with an action plan to address the social impacts of AV adoption to improve their SCSS performance.

This thesis contributes to knowledge regarding SCSS concepts through an in-depth investigation of context-specific SCSS indicators and actions for organisations to enact to improve SCSS performance. It defines the SCSS of AV adoption in supply chains with a conceptual framework, highlights the degree of influence of internal and external stakeholders in this context, and defines and evaluates the actions that address the social impacts for improved SCSS performance in the AV adoption context. This thesis provides a novel use of the DOI theory by tailoring the Innovation Process (IP) model with the identified action categories that apply to the AV adoption context, a continuous improvement cycle, and the inclusion of the internal/external stakeholders that enact the actions to improve SCSS.

This thesis contributes to practice by offering an overview of social issues and a structured action plan to address these issues to improve SCSS performance when adopting AVs in supply chains. First, the identified social impacts and stakeholders support organisations in the development of social indices for the performance measurement of their operations when adopting AVs. Then, the action plan guides organisations to develop tailored business models to improve SCSS performance when adopting AVs. Regulators can use the action plan as a trail of evidence to check whether the organisations achieve SCSS performance improvement in the AV adoption context by actually implementing the actions or not.

Keywords:

Supply chain management, social sustainability, autonomous vehicles, social impacts, actions, Delphi method.

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Table of Contents

Academic integrity declaration.....	i
Abstract	ii
Acknowledgements	v
List of Figures.....	xi
List of Tables	xiii
List of Abbreviations	xvii
1 Introduction.....	1
1.1 Research Background and Rationale	1
1.2 Research context.....	5
1.3 Personal motivations.....	11
1.4 Research Questions, Aim, and Objectives.....	13
1.5 Research Paradigm and method	14
1.5.1 Philosophical perspective	14
1.5.2 Research strategy	16
1.5.3 Research Method Overview	17
1.6 Thesis structure outline.....	18
1.6.1 Description of each chapter.....	19
1.6.2 Logic flow of the main papers and research objectives.....	21
1.6.3 Overall positioning of the thesis and each chapter	22
1.7 Research Dissemination	24
References	25
2 Paper 1: Exploring the Social Impacts of Autonomous Vehicle adoption in Supply Chains: a systematic literature review	34
2.1 Introduction	34
2.2 Methodology	38
2.3 Descriptive analysis	42
2.4 Thematic Analysis.....	45
2.4.1 Positive social impacts	45
2.4.2 Negative social impacts.....	49
2.4.3 Current social barriers to a wider AV Adoption.....	56
2.4.4 Key stakeholders identified	57
2.4.5 Suggested actions and categorisation.....	58
2.5 Discussion	62
2.5.1 Contextual SCSS indicators	63
2.5.2 Potential research directions suggested.....	67
2.5.3 Two perspectives of the empirical studies.....	73
2.6 Conclusion	74
2.6.1 Contributions	74
2.6.2 Research limitations and future research suggestions.....	75
References	77

3 Paper 2: Investigating the Social Sustainability of Autonomous Vehicle Adoption in Supply Chains: A Delphi Study.....	88
3.1 Introduction	88
3.2 Review of the literature	90
3.2.1 Social impacts and supply chain social sustainability	91
3.2.2 Autonomous vehicles in the supply chain.....	95
3.3 Methodology	98
3.3.1 Delphi method	99
3.3.2 Pilot study.....	104
3.3.3 Consensus	105
3.3.4 Termination of the Delphi study.....	106
3.3.5 Delphi Process	107
3.3.6 Participant average deviation	112
3.4 Findings	113
3.4.1 Stakeholders	113
3.4.2 Social impacts	123
3.5 Discussion	135
3.5.1 Stakeholder grouping	135
3.5.2 Social impacts and SCSS: Model Validation	142
3.5.3 Refined model and Proposed mapping of stakeholders with the relevant social impacts	144
3.6 Conclusion	147
3.6.1 Contributions to knowledge	147
3.6.2 Managerial implications.....	149
3.6.3 Limitations	150
3.6.4 Future research directions.....	151
References	153
4 Paper 3: Improving Supply Chain Social Sustainability in the Autonomous Vehicle adoption context: A Delphi study with expert interviews	165
4.1 Introduction	165
4.2 Literature review and Underpinning theories	168
4.2.1 Supply chain social sustainability	168
4.2.2 Suggested actions from the existing literature.....	171
4.2.3 Theoretical frameworks	173
4.3 Research design and methodology	177
4.3.1 Delphi Approach.....	178
4.3.2 Follow-up Interviews.....	183
4.4 Findings from the Delphi study	188
4.4.1 Actions to improve positive impacts	188
4.4.2 Actions to mitigate negative impacts	193
4.4.3 The combined action categories from the two lists.....	197
4.5 Discussion	200

4.5.1 Action category refinement: combining and synthesising.....	200
4.5.2 Defining the eight categories of actions.....	203
4.5.3 Validating the actions: actions and action categories addressing SCSS	207
4.5.4 Action categories aligned with the Innovation Process.....	217
4.6 Conclusion	227
4.6.1 Contributions to knowledge	227
4.6.2 Managerial impacts	228
4.6.3 Limitations and future research directions.....	229
References	231
5 Conclusion.....	247
5.1 Achievement of research objectives	248
5.2 Contributions.....	253
5.2.1 Theoretical contributions	253
5.2.2 Methodological considerations	257
5.2.3 Practical contributions	258
5.3 Limitations.....	261
5.3.1 The limitations in the use of theory.....	261
5.3.2 The limitations of the research method of this thesis	262
5.4 Future Research Suggestions	263
5.4.1 The identified 14 research directions from literature and the Delphi study	263
5.4.2 The research suggestions derived from the limitations	264
References	267
Appendices.....	270

List of Figures

Figure 1-1 Five stages in the Innovation Process in Organisations (Rogers, 2003)	11
Figure 1-2 Overall Thesis structure	19
Figure 1-3 Logical flow of the three papers	21
Figure 2-1 Paper searching and screening process	41
Figure 2-2 Distribution of publications by year	43
Figure 2-3 Links between social impacts and SCSS indicators in the AV adoption context	67
Figure 2-4 Two perspectives of understanding the SCSS of AV adoption	74
Figure 3-1 Links between social impacts and SCSS indicators	98
Figure 3-2 Delphi study process and timeline	107
Figure 3-3 Participant Average Deviation	112
Figure 3-4 Internal stakeholder positions	138
Figure 3-5 External stakeholder positions	142
Figure 3-6 Refined links between social impacts and SCSS indicators	145
Figure 4-1 Links between social impacts and SCSS indicators	170
Figure 4-2 Overall structure and timeline for the two-phase study	178
Figure 4-3 Participant Deviation	183
Figure 4-4 Proposed alignment of action categories with IP	221
Figure 4-5 Refined model and Action plan for improving SCSS performance in the AV adoption context	227
Figure A-1 SAE Levels of Driving Automation	272
Figure F-1 Low agreement items	320
Figure F-2 Answer distribution for Q3	321
Figure H-1 Organisational IP to be presented	332
Figure H-2 CSI for evaluation	332
Figure H-3 CI for evaluation	333
Figure H-4 CSR focus for evaluation	333

Figure H-5 EMP for evaluation 334

Figure H-6 PL for evaluation..... 334

Figure H-7 PRM for evaluation 335

Figure H-8 RWE for evaluation..... 335

Figure H-9 RI for evaluation 336

List of Tables

Table 1-1 Dissemination of the papers.....	24
Table 2-1 Search strings	39
Table 2-2 Inclusion and Exclusion criteria	39
Table 2-3 Descriptive analysis of the literature review	44
Table 2-4 Theoretical frameworks identified from the literature.....	44
Table 2-5 Positive social impacts of AV adoption in SC	52
Table 2-6 Negative social impacts of AV adoption in SC	54
Table 2-7 Stakeholders identified in the AV adoption context concerning SCSS	58
Table 2-8 Actions and Action categories	61
Table 2-9 Definitions of SCSS indicators in the conceptual literature.....	64
Table 2-10 Research directions suggested in the literature	71
Table 3-1 SCSS indicators in the general context.....	96
Table 3-2 Key social implications in this context	96
Table 3-3 Delphi Panellists.....	104
Table 3-4 5-point Likert Rating Scale	110
Table 3-5 Internal stakeholders' degrees of being affected	115
Table 3-6 Internal stakeholders' degree of affecting.....	115
Table 3-7 External stakeholders' degrees of being affected.....	119
Table 3-8 External stakeholders' degrees of affecting.....	120
Table 3-9 Social impacts of AV adoption ranked with importance.....	124
Table 3-10 Positive impact rating Part A	132
Table 3-11 Positive impact ratings Part B	133
Table 3-12 Negative impact ratings.....	134
Table 3-13 Stakeholder series.....	135
Table 3-14 Mapping the stakeholders and social impacts.....	146
Table 4-1 Actions suggested from the literature	172
Table 4-2 Rating Scale	181

Table 4-3 Participant distributions	182
Table 4-4 Actions addressing positive implications	189
Table 4-5 Actions addressing negative impacts	194
Table 4-6 Combining actions for two lists of implications	199
Table 4-7 Action refinement	202
Table 4-8 Finalised eight categories of actions	205
Table 4-9 Actions addressing SCSS indicators	208
Table 5-1 Results against the questions and objectives.....	250
Table 5-2 Research directions identified from the studies	263
Table A-1 Quality Assessment Criteria.....	271
Table B-1 Pilot testers Round 1.....	275
Table B-2 Pilot test feedback Round 1	275
Table B-3 Synthesised feedback.....	277
Table B-4 Pilot testers Round 2.....	279
Table B-5 Pilot test feedback Round 2	280
Table B-6 Synthesised pilot test feedback Round 2	281
Table B-7 Pilot testers Round 3.....	283
Table B-8 Pilot test feedback Round 3	283
Table B-9 Synthesised pilot feedback Round 3.....	285
Table D-1 Internal stakeholders extracted from Round 1	293
Table D-2 External stakeholders extracted from Round 1	294
Table D-3 Positive impacts extracted from Round 1	295
Table D-4 Negative impacts extracted from Round 1	296
Table D-5 Social motivators extracted from Round 1	297
Table D-6 Social barriers extracted from Round 1	297
Table D-7 Actions addressing positive impacts from Round 1	299
Table D-8 Actions addressing negative impacts from Round 1	300
Table D-9 Communication category	302

Table D-10 Continuous improvement category	303
Table D-11 CSR focus category	303
Table D-12 Human resource management category.....	304
Table D-13 Planning category	304
Table D-14 Promotion category.....	305
Table D-15 Regulation improvement category	305
Table D-16 Real-world experiments category	306
Table D-17 Stakeholder involvement category.....	306
Table E-1 Actions reached a consensus at Round 2.....	315
Table E-2 Agreement evaluation for the model	317
Table G-1 Delphi Participant Round 1.....	324
Table G-2 Academic participant information - Round 1.....	325
Table G-3 Delphi Participant Round 2.....	325
Table G-4 Academic participant information - Round 2.....	326
Table G-5 Delphi Participant Round 3.....	327
Table G-6 Academic participant information – Round 3	328
Table G-7 Practitioner information - Round 1	329
Table G-8 Practitioner information - Round 2	329
Table G-9 Practitioner information - Round 3	330
Table H-1 Eight action categories for evaluation	331
Table I-1 CSI evidence	337
Table I-2 CI evidence	339
Table I-3 CSR focus evidence	340
Table I-4 EMP evidence	341
Table I-5 PL evidence	342
Table I-6 PRM evidence	344
Table I-7 RWE evidence	345
Table I-8 RI evidence	347
Table I-9 IP alignment evidence	348

Table J-1 Interviewee profiles..... 350

List of Abbreviations

Abbreviations for the thesis

AM	Additive Manufacturing
AGVs	Automated Guided Vehicles
AMRs	Autonomous Mobile Robots
AVs	Autonomous Vehicles
CAQDAS	Computer-assisted qualitative data analysis software
CC	Cloud Computing
CSR	Corporate Social Responsibility
DOI	Diffusion of Innovations
ERP	Enterprise Resource Planning
ESG	Environmental, Social, Governance
F&A	Financial and Accounting
GRC	Governance, Risk, Compliance
HR	Human Resource
IA	Innovation Adoption
IoT	Internet of Things
IP	Innovation Process
IT	Information Technology
LSP	Logistics Service Providers
M	Mean Value
NGOs	Non-Government Organisations
RFID	Radio Frequency Identification
RO	Research Objectives
RQ	Research Questions
R&D	Research and Development
SAE	Society of Automotive Engineers
SD	Standard Deviation
SC	Supply Chain
SCM	Supply Chain Management

SCSS	Supply Chain Social Sustainability
SDGs	Sustainable Development Goals
SLR	Systematic Literature Review
TOE	Technology-organisation-environment
UN	United Nations
UNGC	United Nations Global Compact
UAVs	Uncrewed Aerial Vehicles
UGVs	Uncrewed Ground Vehicles
VMI	Vendor-Managed Inventory

Abbreviations for Chapter 3 (SCSS Indicators)

CS	Customer Satisfaction
DE	Diversity and Equality
EMP	Employment
H&S	Health and Safety
RPT	Reputation
TSP	Transparency
WF	Welfare

Abbreviations for Chapter 4 (Action Categories)

CI	Continuous Improvement
CSI	Communications and Stakeholder Involvement
HRM	Human Resource Management
PL	Planning
PRM	Promotion
RI	Regulation Improvement
RWE	Real World Experiment

1 Introduction

1.1 Research Background and Rationale

Sustainability is defined as the capability to use the resources to meet the needs of the present generation without compromising the ability of future generations to meet their needs (WCED, 1987). Supply chain management is defined as the integration of the flows of materials and information for the transformation of goods among the involved entities to achieve improved supply chain relationships and as sustainable competitive advantage (Handfield and Nichols, 1999; Seuring and Müller, 2008). When integrating sustainability with supply chain management, various aspects are involved, as concluded by Linton et al. (2007): the environmental impacts of the whole product life-cycle, the reduced wastes during manufacturing processes, the sustainability considerations when managing and supporting the use of the products, product life extension, product end-of-life management, and the recovery process of the end-of-life products. In this case, environmental perspectives are especially emphasised – waste reduction, clean production, emissions, noise pollution, recycling or even circularity (Linton et al., 2007; Ahi and Searcy, 2015). In addition to these environmental issues, the social implications in the supply chain cannot be ignored – health and safety in the working environment, diversity, human rights etc. (Carter and Rogers, 2008). These issues represent the pressures from multiple relevant entities (e.g., employees, customers, and non-governmental organisations) (Seuring and Müller, 2008).

Hence, definitions of sustainable supply chain management captured by seminal authors contain the following main elements: the management of material, information, and capital flows; the cooperation among the companies or the nodes along the supply chain; satisfying the stakeholders' requirements; improving the short- and long-term profitability, competitiveness, and resilience; integrating the economic, environmental, and social considerations (Ahi and Searcy, 2013; Seuring and Müller, 2008; Carter and Rogers, 2008). The definitions vary slightly among the sequence of these elements, however, the three aspects, or “three pillars” – economic, environmental, and social are

essential in the definitions. These three pillars are also called the “triple bottom lines” (Elkington, 1997). As one of the three pillars of sustainability, social sustainability should be as important as the other two dimensions when discussing sustainability performance. However, the conceptualisation of social sustainability is lagging behind the other two, especially in the development of performance measurement, due to the difficulty in quantifying and measuring the social issues in the supply chain (Ahi and Searcy, 2015; Dai and Tang, 2022).

There is a well-accepted argument that supply chain social sustainability (SCSS) is rooted in the corporate social responsibility (CSR) concept (Mani et al., 2016). CSR covers both the environmental and social aspects of the duties of corporations with regard to society (Klassen and Vereecke, 2012). Regarding the social aspects, CSR calls for the organisation to be ethically and socially accountable to a series of entities such as customers, employees, unions, government, non-government organisations (NGOs), communities, regulators, and media (Maloni and Brown, 2006). In the supply chain management domain, CSR emphasises more on social responsibility in procurement activities, including the assessment of the responsibility of suppliers (Mani et al., 2018), and developing a sustainable buyer-supplier relationship (Yawar and Seuring, 2017). When expanding this to the chain-wide context, ethical and social benefits are to be gained within the whole supply chain, by collaborating with various supply chain partners and relevant entities (Spense and Bourlakis, 2009; Yu et al., 2023). Social sustainable supply chain management, therefore, represents the management of social issues in supply chains (Hohn and Durach, 2023). Hence, in order to achieve SCSS, supply chain managers need to understand the various issues, demands and enquiries from the relevant groups, and behave socially responsibly to create social value for them (Mani et al., 2018; Hussain et al., 2018). According to some of the seminal authors who have contributed to the SCSS discussion (Carter and Rogers, 2008; Ahi and Searcy, 2015; Yawar and Seuring, 2017; Mani et al., 2016; 2018; Klassen and Vereecke, 2012), health and safety, human rights, employment, equality, welfare, reputation, customer satisfaction, philanthropy, community development, housing, etc. are involved.

All these aspects relate to different groups of people and entities who affect or are affected by supply chain operations.

In parallel with the important role of SCSS concepts in academia, it is also closely related to the United Nations Sustainability Development Goals (UN SDGs) for global sustainability goals, and the Environmental, Social, and Governance (ESG) concepts for organisational level performance. In 2015, the United Nations (UN) proposed 17 sustainability development goals (SDGs) that balance social, economic, and environmental priorities – these goals aim to end poverty, protect the planet, and ensure peace and prosperity by 2030 (UN, 2023). Since SCSS calls for the supply chain to be ethically and socially accountable to relevant stakeholder groups on the environmental and social outcomes of operations under the chain-wide considerations (Maloni and Brown, 2006; Spense and Bourlakis, 2009), and relating to the various key aspects of SCSS in academia, it is valid to argue that investigating SCSS contributes to the realisation of SDGs (Fernando et al., 2022). The potential contributions of research in SCSS to the SDGs involve but are not limited to, health and safety for SDG 3 (Good health and Well-being); diversity and equality for SDG 5 (Gender equality) and SDG 10 (Reduced Inequalities); employment and working environment for SDG 8 (Decent work and economic growth); and enhanced collaboration and partnerships along supply chain nodes for SDG 17 (Partnerships for the goals) (ElAlfy et al., 2020; UN, 2023).

Meanwhile, at the corporate level, ESG has achieved increasing attention as a measurement tool for the firm's social impacts and sustainability performance (Dai and Tang, 2022; Atkins, 2020). Similar to the arguments that SCSS concepts are developed from CSR, ESG is also rooted in CSR in that when corporations take actions, they need to consider the environment, ethics, health and safety, and labour aspects of outcomes (Dai and Tang, 2022). In addition, the ESG rating for a single company can be misleading, if the ESG of the holistic supply chain of the company is not assessed – the measures regarding discrimination, human rights, fair labour and pay etc. of the up-and downstream of the company (Dai and Tang, 2022). Also, supply chain external entities such as the customers who care about social responsibility put pressure on their suppliers to adopt better

ESG/CSR policies (Gillan et al., 2021). Unlike the CSR and SCSS, which are normally accompanied by pressures from multiple entities, the ESG ratings are used by the major institutional investors as the reference for financial funding provision (Atkins, 2020). The investors judge whether the companies act consistently with the ESG criteria to decide whether to sponsor the companies or not (Dai and Tang, 2022; Atkins, 2020). This suggests that ESG investment requires organisations and the wider supply chains to take sustainability issues into account. Companies with a positive ESG assessment benefit from improved financial performance not only from external investment but also from their own profit growth, mostly in the long term (Li and Wu, 2020). Hence, reducing ESG risks and incidents is incrementally crucial for successful supply chain management. Research into SCSS and the social aspects of CSR strengthens the conceptualisation of the “S” of ESG, since this aspect is not as well defined and understood compared to “E” and “G” (Dai and Tang, 2022).

The SCSS aspects mentioned above form the definition of the SCSS concept under the general conditions, however, there is no single definition of SCSS that covers a holistic image (Hussain et al., 2018). Unlike the measures for economic (monetary costs) and environmental dimensions (green-house gas emission, energy consumption) that present sustainability performance in various scenarios, there is no such set of standards measuring the social sustainability performance that suits all supply chain contexts (Ahi and Searcy, 2013; 2015). Hence, in order to understand what aspects of social sustainability are covered in a particular supply chain scenario, and how they perform in that scenario, it is crucial to develop context-specific indicators (Ahi and Searcy, 2015; Denu et al., 2023). In addition, social sustainability concerns the human side of sustainability (Huq et al., 2014), so it is critical to identify the relevant involved groups in the specific context, and the social sustainability issues relating to these groups. These groups are known as “stakeholders” (Freeman, 1984). Various stakeholders place different demands involved in the supply chain into various perspectives (Carter and Rogers, 2008), which means that one group can have requirements on multiple social indicators, depending on the organisation’s operations (Yawar and Seuring, 2017). In order to operate socially sustainably,

all the relevant stakeholders along the supply chain should be taken into account and treated responsibly (Hussain et al., 2018). Therefore, in order to further conceptualise social sustainability, two main requirements were raised – developing context-specific indicators (Ahi and Searcy, 2015; Denu et al., 2023), and focusing on the specific stakeholder groups in the context (Hussain et al., 2018).

With these aforementioned considerations, the author considers SCSS a valuable and crucial topic to discuss and explore. Contributing to conceptualising social sustainability on the one hand benefits the managerial perspectives: further developing the ESG frameworks and realising UN SDGs within the agenda. In the meantime, the research into social sustainability strengthens the social dimension within the three-pillar framework of supply chain sustainability conceptualisation in academia.

1.2 Research context

Regarding SCSS, various topics and challenges are attracting academia: traffic safety improvement of long-haul freight transportation – more than 90% of fatal accidents are human-error-led (Fagnant and Kockelman, 2015; Gružasuskas et al., 2018); reduced availability of the labour force in the logistics sectors – decline in the number of young labourers due to low birthrate, and experienced employees retiring (Hwang et al., 2019; Kim et al., 2022; Engholm et al., 2021); and the increased customer-oriented delivery services and visibility due to the rapid development in online shopping (Sellevold et al., 2020; Kapser and Abdelrahman, 2020). In addition, human employees need to take rests, rather than work 24/7 which robotics can do (Monios and Bergqvist, 2020), and fatigue also leads to accidents in the operations, especially long-haul freight transport (Nikitas et al., 2021). Furthermore, the COVID-19 pandemic and consequent lockdown policies have caused severe supply chain risks – the lack of a healthy workforce for supply chain operations is one of the main reasons (Sodhi and Tang, 2021). These challenges are proposed to be addressed by autonomous technologies, for their capabilities in conducting logistics-related tasks with reduced human intervention in supply chains (Soni and Soni, 2019). This means

that challenges from human-related errors and the shortage of a human workforce in the logistics sectors can be mitigated by adopting autonomous technologies (Hopkins and Schwanen, 2023). Likewise, the digitalised processes in the logistics operations empowered by autonomous technologies strengthen efficiency, accuracy, and visibility, so as to improve customer satisfaction (Sellevold et al., 2020). Such autonomous technologies to be adopted in supply chains with these aforementioned features, are mainly autonomous vehicles (AVs).

The deployment of AVs requires the maturity of Information and Communication Technologies (ICTs) as the key technological prerequisite to provide a software infrastructure for the Internet of Things (IoT) (Mohamed et al., 2020; Schwab, 2016; Ding, 2018). These technologies experienced a significant evolvement after the rise of Industry 4.0 in 2011, which stands for the comprehensive transformation of industrial production through the internet of physical products and assets, with a capability to process massive data rapidly, so as to improve productivity (Schwab, 2016; Siltori et al., 2021).

The scope of AVs includes uncrewed ground vehicles (UGVs) and uncrewed aerial vehicles (UAVs) (Rai et al., 2022). Automated guided vehicles (AGVs) are the first form of UGVs that have served the logistics sectors for half a century in designated areas such as harbours, warehouses, and manufacturing plants (Flämig, 2016; DHL, 2020). Autonomous Mobile Robots (AMRs) are more advanced AGVs with more sensors and computer technologies that can operate wider ranges of tasks in both indoor and outdoor spaces and avoid physical obstacles (DHL, 2020). Driverless vehicles, on the other hand, are vehicles controlled by systems and sensors and make route decisions based on the environment with no human interference, although they can be remotely controlled by human operators when an emergency occurs. The Society of Automotive Engineers (SAE) published a well-accepted standard of automated driving levels categorising the vehicles in level 3 (conditional automation), level 4 (high automation), and level 5 (full automation) as AVs (Klumpp and Zijm, 2019; SAE, 2021; Wang and Li, 2019). Compared to AMRs, driverless trucks are more suitable for long-haul road freight transport, and a large deployment of

autonomous long-haul heavy-loaded trucks is expected on the highway soon, since the highway traffic is much simpler to manage than in a city scenario (Gružauskas et al., 2018).

Apart from the UGVs, the UAVs or drones are mainly electrically powered aircraft that are small in size and have a limited flight duration and range (Wang et al., 2021). UAVs have been widely applied in military operations and have more recently been adopted for civil use (DHL, 2014). Among the UAVs, fixed-wing, rotary-wing, and multi-copters with low-weight payloads are used for civil and logistics applications (DHL, 2014). In the commercial supply chain, UAVs are mainly used for first and last-mile delivery services, property surveillance, and intralogistics operations (material movement within a distribution centre) (DHL, 2014; 2020). In the healthcare and humanitarian context, fixed-wing and multi-copters have been used for medicines, blood samples, and emergency aid equipment (Scott and Scott, 2017).

As mentioned in Section 1.1, to further conceptualise SCSS, developing context-based social sustainability indicators and identifying the relevant stakeholders is essential. The social implications of AVs in supply chains are crucial to their successful deployment (Kim et al., 2022). Deploying AVs in the supply chain has shown great potential in economic (return on investment) and environmental performances (reduced energy use and carbon emissions) in the long term (Ha et al., 2018; Murray and Chu, 2015; Tang and Veelenturf, 2019). However, compared to economic and environmental sustainability, social sustainability has received much less focus. This topic is rarely explored and discussed, which creates a novel research field for academia and practitioners (Bechtsis et al., 2017). There are indeed many important social issues inherent in the adoption of AVs in supply chains for discussion. The UGVs for freight transport improve road traffic safety for traffic users by eliminating human-driver error-led accidents in long-haul freight transport (McManus and Rutchick, 2019; Gružauskas et al., 2018). Other social issues such as privacy and data security (Tatham et al., 2017); terrorism attacks (Aydin, 2019); and job creation and elimination (Heard et al., 2018) are also important and worth discussing. Understanding these social impacts, as well as the involved stakeholders must be considered so that

organisations are capable of understanding the stakeholders' enquiries and can create value for them (Hörisch et al., 2014). Therefore, it is important to discuss the social impacts and develop social sustainability concepts in the AV adoption context. However, in the existing literature which describes the social impacts of AV adoption in supply chains, stakeholders and their roles received limited focus and are not explicitly mentioned in the discussion of SCSS of AV adoption. The existing literature either focuses on a single group of stakeholders (e.g., local communities or end customers (Aydin, 2019; Kapser et al., 2021)) or points out the potential groups that are related to the impacts without detailed analysis of the salience of the stakeholders or their degrees of the influence (e.g., traffic users (Gružauskas et al., 2018); employment issues (Heard et al., 2018)). Similar to social impacts, investigating context-specific stakeholders is also important to understanding SCSS more generally, since stakeholders are essential in the SCSS concept (Hussain et al., 2018). Hence, a lack of evaluation of context-specific stakeholders in the AV adoption context is the first research gap identified in this thesis.

Identifying the social impacts, stakeholders, and relevant social sustainability indicators is not sufficient to comprehensively understand how AV adoption affects SCSS. These elements form one perspective of understanding the social implications of AV adoption in supply chains: the social impacts of AV adoption in supply chains. The stakeholders expect organisations to implement a series of actions, initiatives, or solutions to address these impacts and the relevant social sustainability indicators (Agyemang et al., 2022; Ghadge et al., 2021). Organisations are under stakeholders' pressure to act socially sustainably to satisfy their demands (Correia et al., 2024). Therefore, when assessing AVs' social impacts, it is necessary to include the actions that are proposed to address these identified social impacts (especially the negative ones) in supply chains for improved SCSS performance. This forms the other perspective of understanding how AV adoption affects SCSS. The two perspectives construct a holistic view of SCSS implications of AV adoption in the supply chain – the social impacts of AV adoption, and the actions proposed to address these impacts in the AV adoption context.

The existing literature suggests various actions for organisations to implement to facilitate wider AV adoption in supply chains, such as active stakeholder engagement (Haula and Agbozo, 2020); familiarity enhancement (Aydin, 2019), and systematic experiments and tests in real-life scenarios (Tatham et al., 2017). However, wider AV adoption requires broad social approval (Kurniawan et al., 2021), which asks for the social impacts of AV adoption to be addressed (Kim et al., 2022). The existing literature does not clarify how social impacts should be addressed by organisations to improve AV adoption. This means that the actions implemented by organisations to address social impacts and improve SCSS performance are currently missing. With these arguments, the actions employed by organisations in supply chains to address the identified social impacts should be evaluated to facilitate wider AV adoption, which serves as the second research gap of this thesis.

Action is defined as “the fact or process of doing something” by the Concise Oxford Dictionary (1999). In this research context, such processes address the social impacts of AV adoption inclusively, regardless of whether they are positive or negative, and do not emphasise whether the issue has happened or not. For instance, some processes are “feedback actions” that are raised after small-scale AV adoption or tests, such as measuring behaviours” (Tatham et al., 2017; Kurniawan et al., 2021) in the “Continuous improvement” category. Some processes, on the other hand, occur prior to the adoption, such as “Designing and integrating technologies into supply chain processes” in the “Planning” category. Therefore, the suggested action categories should be aligned with the diverse stages of the AV adoption process to tailor the organisations with diverse AV adoption statuses to pursue improved SCSS performance.

The Diffusion of Innovations theory (DOI) developed by Rogers (2003) provides a theoretical framework that illustrates the process by which an innovation (technology or idea) is communicated through certain channels over time among the members of a social system. This theory is considered the most widely deployed theory to study technological innovation solutions adoption mechanisms (Pervan et al., 2005). According to Yuen et al. (2020), AVs are recognised as technological innovations under the scope of DOI in five attributes:

AVs have Relative Advantages in safety and environmental protection compared to conventional vehicles; AVs are Compatible with existing traffic systems; AVs are perceived to be more Complex; AVs can be Trialled before adoption; and the Benefits of AVs can be Observed. Hence, AVs can be regarded as a technological innovation that fits the lens of DOI theory.

In terms of considering the innovative technology adoption in supply chains, DOI provides a solid theoretical base for understanding the organisational-level adoption process of the technology in supply chains (Wamba and Queiroz, 2020), presenting a 5-stage Innovation Process (IP): agenda-setting, matching, restructuring/redefining, clarifying, and routinising:

- Agenda-setting – an organisational problem is defined and a performance gap is identified to create a perceived need for the innovation;
- Matching – the problem is fitted with an innovation to plan and design the match;
- Redefining/restructuring – the innovation is re-invented to accommodate the organisation's needs and structure, likewise the organisation to fit the innovation;
- Clarifying – the innovation is more widely used in an organisation and is clearer to the internal members;
- Routinising – innovation has been incorporated into regular activities of the organisation.

This model (shown in Figure 1-1) provides the framework to analyse the main sequence of decisions, actions, and events in the process of deploying technologies in organisations (Rogers, 2003).

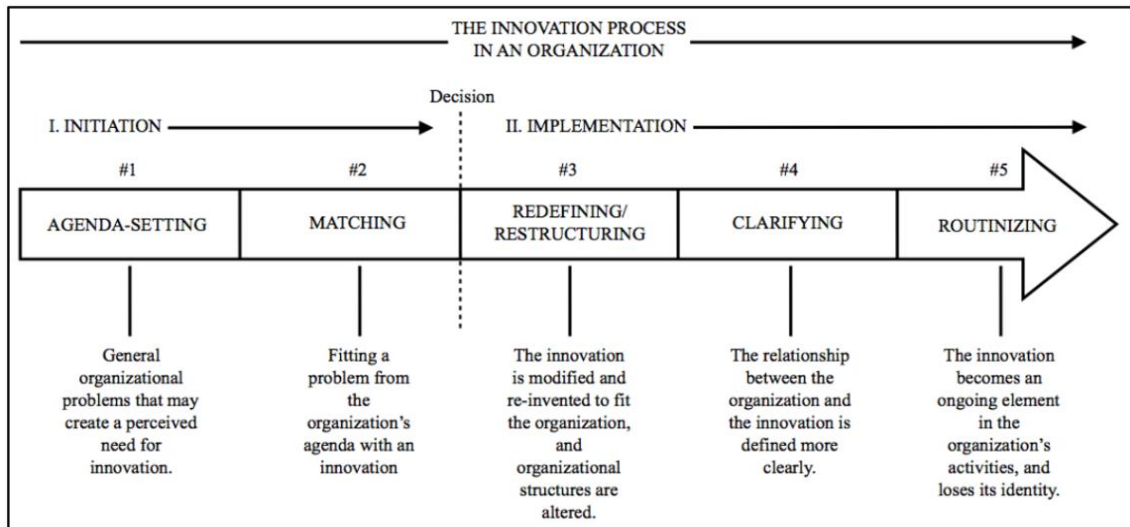


Figure 1-1 Five stages in the Innovation Process in Organisations (Rogers, 2003)

As a result, this model instructs how organisations should act at the different stages of adopting AVs. Aligning the actions with the IP allows those actions to be structured on the basis of the stages of innovation adoption, i.e., what actions to take to address the social impacts at various stages of AV adoption for improved SCSS. Therefore, this research attempts to use IP as a tool to help structure the sequence of the actions, so as to form a logical action plan for the organisations to take for an improved SCSS when adopting AVs in their operations. Based on the arguments above, this research aims to understand how SCSS is affected by AV adoption from two perspectives: first, explore the social impacts and stakeholders that relate to the AV adoption context; and second, investigate the actions to address these social impacts to improve the social sustainability performance. To the best of the author's knowledge, no existing research specifically and systematically has made such attempts to investigate SCSS in the context of AV adoption.

1.3 Personal motivations

Before I started my PhD journey at Cranfield University, I studied for a BA in International Business and Spanish at the University of Nottingham, Ningbo, China. I first came into contact with supply chain and logistics during my summer internship after finishing the second year of the BA degree in 2015. I interpreted the business cases for SYCOR, a German digital transformation solution provider

in partnership with SAP, providing tailored Enterprise Resource Planning (ERP) systems for Chinese business customers in the manufacturing industries. That experience inspired my great interest in logistics and supply chain management and directly guided me to choose the Logistics and Supply Chain Management MSc programme at Cranfield University for postgraduate study to strengthen my knowledge in this field. In addition, I was introduced to sustainability topics during my BA studies at Nottingham. At that time, I did not realise how important sustainability was, but the later occurrence of extreme weather, natural disasters, and the severe over-workload (so-called “996” – 9 am to 9 pm, 6 days a week; or even “007” – full days of working or standing by, from 0 – 24hr, 7 days a week), along with numerous young workforce sudden death incidents in China triggered my thoughts about “sustainability” issues. It is worth thinking about whether what we are doing is sacrificing the next generations’ or even this generation’s well-being for current economic benefits.

During my MSc at Cranfield, I happened to read the book “The Fourth Industrial Revolution” written by Schwab (2016). According to this book, Autonomous vehicles (AVs), the Internet of Things (IoT), Cloud Computing (CC), Additive manufacturing (AM) etc. are all innovations after the “Industry 4.0” concept which was proposed in 2011 at Hannover Messe, Germany. I had a strong feeling about the supply chain being empowered by disruptive technologies and that these innovations can have great impacts on sustainability as well. Meanwhile, a droid delivery service provider called “Starship” offers grocery delivery services in partnership with Costa Coffee and Co-op in Milton Keynes, a city located around eight miles away from Cranfield University. The delivery robots on the roads appear to be very interesting, not only to me but also to the local communities and visitors to this place. Therefore, I believe that the adoption of AVs in supply chains should be interesting to focus on. In combination with the sustainability concerns mentioned above, I was motivated to look at the sustainability-related issues of AV adoption in the supply chain.

As a result, I was motivated to understand more about the impacts of adopting AVs in supply chains. To be specific, I am most interested in the social impacts of AVs, on the multiple stakeholders in the supply chain. Economics and the

environment are such popular topics that attract people's interest, while personally, I am keen to look at the fields which have not been extensively covered yet.

1.4 Research Questions, Aim, and Objectives

Given the importance and necessity of the research, this thesis aims to answer the overall research question (RQ): how does AV adoption in the supply chain affect SCSS? This includes two main perspectives: the direct social impacts of AV adoption and the relevant SCSS indicators, and the management of these implications. These two perspectives are first investigated through a review of the literature. After that, the identified research gaps and these two perspectives were further evaluated through two empirical studies respectively. Each study covers respective sub-research questions (Sub-RQ) and each sub-RQ is addressed by research objectives (ROs).

The first paper aims to understand the social impacts and sustainability aspects as well as the actions to improve them by extracting evidence from the existing literature.

Sub-RQ 1.1: What are the social impacts of AV adoption in supply chains?

RO1: To identify the positive and negative social impacts of AV adoption in supply chains from the extant literature;

RO2: To identify relevant SCSS indicators in the AV adoption context and relate the identified social impacts to the indicators;

Sub-RQ 1.2: What are the actions organisations can take to address the social impacts of AV adoption in supply chains?

RO 3: To identify and synthesise the key suggested actions that companies can employ to address the social impacts of AV adoption to achieve a socially sustainable supply chain;

The literature review attempts to relate social impacts with SCSS indicators and identifies the actions organisations enact for wider AV adoption. However, as

argued in section 1.2, stakeholders and actions addressing social impacts suggest two research gaps for the empirical works. Therefore, the empirical studies aim to identify and evaluate the stakeholders, actions, and to further refine the results achieved from the literature review.

Sub-RQ 2.1: What are the SCSS implications of AV adoption in supply chains?

RO 4: To empirically refine and evaluate the social impacts and SCSS indicators in the AV adoption context;

Sub-RQ 2.2: What are the key stakeholders involved in the context of adopting AVs in supply chains?

RO 5: To empirically identify and evaluate the key stakeholder groups in the context of AV adoption in supply chains;

Sub-RQ 3: How should organisations act to address the social sustainability implications of AV adoption in supply chains?

RO 6: To empirically refine and evaluate the suggested actions and action categories that companies can adopt to address the social impacts of AV adoption;

RO 7: To empirically evaluate the action categories for the organisations to employ at various stages of AV adoption in supply chains.

The detailed structure of the whole thesis is described in Chapter 1.6.

1.5 Research Paradigm and Method

It is important to establish a paradigm for the PhD research, which guides the overall flow of the research logic. The paradigm includes a philosophical concept or framework that research locates within, which suggests various routes for connecting ideas and realities for social science researchers (Blaikie, 2007).

1.5.1 Philosophical perspective

Each research paradigm suggests a particular combination of ontological and epistemological assumptions for social researchers to adopt. Ontology is a

branch of philosophy that concerns the nature of social reality, while epistemology calls for the researchers to develop assumptions about the knowledge, or the method of gaining knowledge on the world around, on the basis of the ontology the researchers hold (Blaikie, 2007; Saunders et al., 2019). In social science research, it is common to understand the social actors' activities and understanding regarding a specific social phenomenon. Unlike the investigation of natural science which mainly needs sole observation, the study of social science needs researchers to explore and interpret how social actors construct their understanding of the social phenomenon (Blaikie, 2007). This implies that social science researchers holding interpretivism stances (with idealist ontology and constructionist epistemology) are parts of the research itself, rather than those who hold positivist stances (realist ontology and empiricist epistemology) that are independent entities observing the phenomenon as outsiders (Blaikie, 2007). Hence, for interpretivist researchers, human interpretation drives the development of social world knowledge (Symon and Cassell, 2012). The researchers are required to be constantly involved in interpreting and reinterpreting the social actors' opinions, to develop meanings and make sense of the social actors' opinions (Blaikie, 2007). As a result, the outcomes of the research are established on the researcher's understanding of the social actors' reactions towards the social phenomenon. These understandings are constructed and evaluated to form knowledge (Symon and Cassell, 2012). In this research, the researcher has an interpretivism stance.

With the interpretivist stance, the ontology and epistemology for this research are idealism and constructionism respectively. In the social world, individual minds are crucial elements in forming the facts (Blaikie, 2007). Different social actors differ in opinions and narratives that help to form different social realities (Saunders et al., 2019). In this regard, the social implications of AV adoption in supply chains are understood by various social actors. Some of these social actors are directly involved in the AV adoption context as stakeholders, while others who are not directly involved provide their subjective understandings and opinions about the social impacts of this context. These understandings and opinions about social impacts form social realities with various perspectives. On

the basis of the opinions about social impacts, the social actors recommend actions that are constructed to address those social impacts. All of these opinions and recommendations serve the evidence for the researcher to interpret, explain, and construct in order to form the facts of how AV adoption affects SCSS (Saunders et al., 2019).

1.5.2 Research strategy

Taking an interpretivism stance for this research, the author considers that an abductive strategy is suitable for this thesis (Blaikie, 2007; Saunders et al., 2019). The abductive strategy combines both deductive and inductive approaches in theory development. In social science, deduction is applied mainly for theory testing via a series of hypotheses with quantitative analysis, while induction is used for theory generating via qualitative data collection methods (Blaikie, 2007; Ketokivi and Choi, 2014). Abduction, according to Ketokivi and Choi (2014), is to elaborate the theory by modifying and expanding the general theory logic into a specific research context. With a combination of induction and deduction, abduction normally consists of the logic of moving back and forth between “theory to data” and “data to theory” mechanisms (Saunders et al., 2019).

In this thesis, the identification of the main themes regarding social impacts, stakeholders, and suggested actions presents an inductive mechanism (Ketokivi and Choi, 2014). However, the following processes, such as the comparison between the identified themes with the existing literature and concepts, as well as the follow-up evaluations of the refined themes, showcase a deductive mechanism (Ketokivi and Choi, 2014). By combining the mechanisms of inductive theme identification and deductive theme evaluation, the SCSS concept is expanded through the investigation of contextual social impacts, stakeholders, and actions to address the contextual SCSS indicators. The back-and-force process between induction and deduction, therefore, presents an overall abductive approach to the study.

1.5.3 Research Method Overview

In accordance with the research paradigm (sections 1.5.1 and 1.5.2) and to investigate stakeholders, social impacts, actions for organisations to enact, and relevant social sustainability indicators, this exploratory thesis adopts qualitative data collection techniques and analytical procedures (e.g., through open-ended questions) (Edmondson and McManus, 2007; Saunders et al., 2019).

The empirical research is presented in Papers two and three in Chapters three and four. This study aims to understand the social sustainability implications of AV adoption in supply chains. On the one hand, this thesis investigates the context-specific SCSS indicators that support SCSS concept development in academia. It requires academic insights to construct conceptual frameworks that illustrate the social implications of AV adoption in supply chains, as well as how organisations address the social implications to enable wider AV adoption. On the other hand, the social implications are investigated in the real-life context of adopting AVs in the supply chain that is of industrial relevance. It requires practical evidence to ground support and supplement the academic insights. Hence, it is necessary to achieve insights from academic and industrial participants for this research. In addition, this study explores what the social sustainability implications of AV adoption are, what stakeholders are involved, and how organisations manage the social implications to realise wider AV adoption in supply chains. To answer these interlinked questions that are related both to the future development and implications of new technology adoption, it is suitable to collect and synthesise professional insights to develop new knowledge and predictions (Hohn and Durach, 2021; Durach et al., 2017; Reefke and Sundaram, 2017). This research seeks to form a solid understanding of the SCSS implications of AV adoption with collective, professional, and insightful evidence to contribute to SCSS concept development. As a result, the Delphi method is selected as a viable option for knowledge collection and development to gain a consensus from a group of experts sharing a specific interest field with heterogeneous backgrounds (Seuring and Müller, 2008; Okoli and Pawlowski, 2004). The Delphi method is commonly used in exploratory studies that explore the implications of advanced technology adoption in supply chains (Durach et al.,

2017), supply chain sustainability considerations (Seuring and Müller, 2008; De Lima and Seuring, 2023), and the combination of the two topics (Hohn and Durach, 2021). By collecting insights from a group of experts, the Delphi method is considered rigorous in knowledge development (Okoli and Pawlowski, 2004; Hohn and Durach, 2021). Therefore, the Delphi method is appropriate for this research.

The Delphi study identifies the key themes in this research but is not sufficient to evaluate the relationships among the identified themes. A follow-up study is required to collect supplementary data. It is not rare to adopt follow-up individual or group interviews and surveys to verify and validate Delphi results, and to discuss the relationships and dynamics among the concepts identified in the Delphi study (Hassan et al., 2015; Moradlou et al., 2021; De Lima and Seuring, 2023). This research adopts follow-up interviews to further validate the identified actions and action categories by confirming their relationships to the pre-identified social sustainability indicators, and to arrange the action categories in a logical structure. The follow-up interviews are appropriate to supplement, deepen, and validate the Delphi results.

1.6 Thesis structure outline

This doctoral thesis is structured into five chapters shown in this section. It is organised in the 'paper format'; therefore, it is structured and presented in progressive articles as distinct chapters. Each of the three chapters in the main body of the thesis represents an independent and integrated study with a literature review (Chapters 3 and 4), methodology, findings, discussion, and conclusion. These three papers address the research objectives raised in Section 1.4 and contribute to the overall aim of the work. Figure 1-2 presents the overall structure of the thesis.

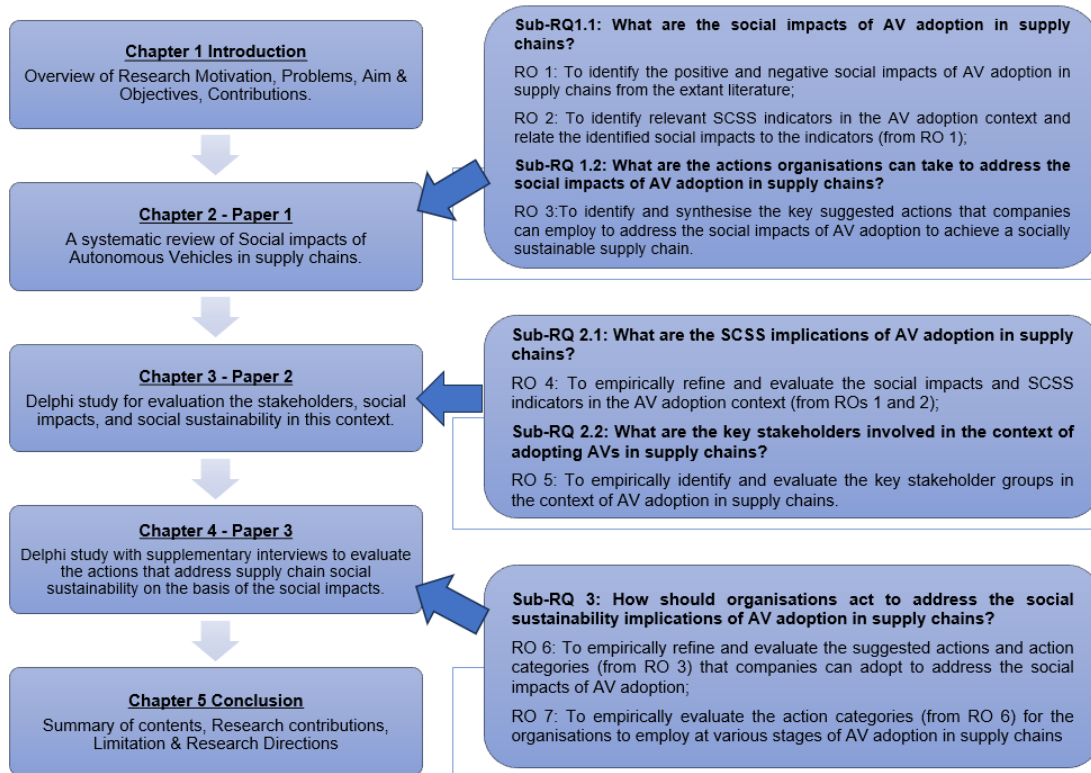


Figure 1-2 Overall Thesis Structure

1.6.1 Description of each chapter

Chapter 1 provides a holistic introduction to the whole research. With the background, context, motivations and rationale argued, the research problems are identified and the aim and objectives are developed upon them. These are followed by the structure outline of the whole research and the layout logic of the three papers. A brief summary of the dissemination of the works for this thesis is presented at the end of this chapter.

Chapter 2 addresses the first three ROs, that is to explore the social impacts of AV adoption in the supply chain from existing literature and academic publications. A systematic literature review (SLR) analyses the key domains covered in this research, including autonomous vehicles in supply chains, the social impacts of AV adoption, and the relevant social sustainability indicators. A descriptive analysis provides the research works state-of-art, while a thematic analysis synthesises the findings from multi-disciplinary papers and establishes

a foundation for the proposed models that are to be evaluated and refined in the subsequent studies.

Chapter 3 provides the Delphi study applied in this research. The Delphi study further explores the key elements that are related to SCSS of AV adoption and gains a general view of how AV adoption affects social sustainability through specific impacts. This chapter addresses objectives 4 and 5 and is linked with the first two research objectives of this thesis, which require further exploration and evaluation of the key elements identified in the previous literature review. By gathering insights from both academics and practitioners, the results are more reliable for both knowledge and industry. An attempt to relate the stakeholders to SCSS in this context is also raised to investigate what social impacts are relevant to which groups. Also, the proposed framework is refined based on the Delphi results. The outcomes of this paper partially serve as input for Chapter 4.

Chapter 4 presents a two-phase study that combines the Delphi and follow-up interviews for this research. Similar to Chapter 3, the Delphi study in the first phase identifies the individual actions as well as the categories, while the follow-up interviews in the second phase further validate the results from the Delphi study and align the actions with the social sustainability indicators and organisational innovation processes. The combined methods explore, refine and evaluate the key actions, to investigate how these actions the organisations take to further affect the SCSS performance in the context of AV adoption. In addition, a series of future research agendas are suggested as part of the outcomes of this study. This chapter addresses the final two ROs.

Chapter 5 concludes the whole research. This chapter includes a summary of the entire research and presents the contributions to both existing knowledge and industry. In addition, this chapter discusses a series of limitations and suggests a variety of research directions for future efforts in addressing the limitations mentioned in this chapter, as well as the works covered in this thesis.

1.6.2 Logic flow of the main papers and research objectives

The description of each chapter presents an overview of the thesis. In addition to the separated sections of the overall research, a logic flow exists among the three papers that connect the attempts to fulfil the ROs. On the basis of the overall thesis structure and the logical arrangement of the three papers, Figure 1-3 visualises such a logic flow.

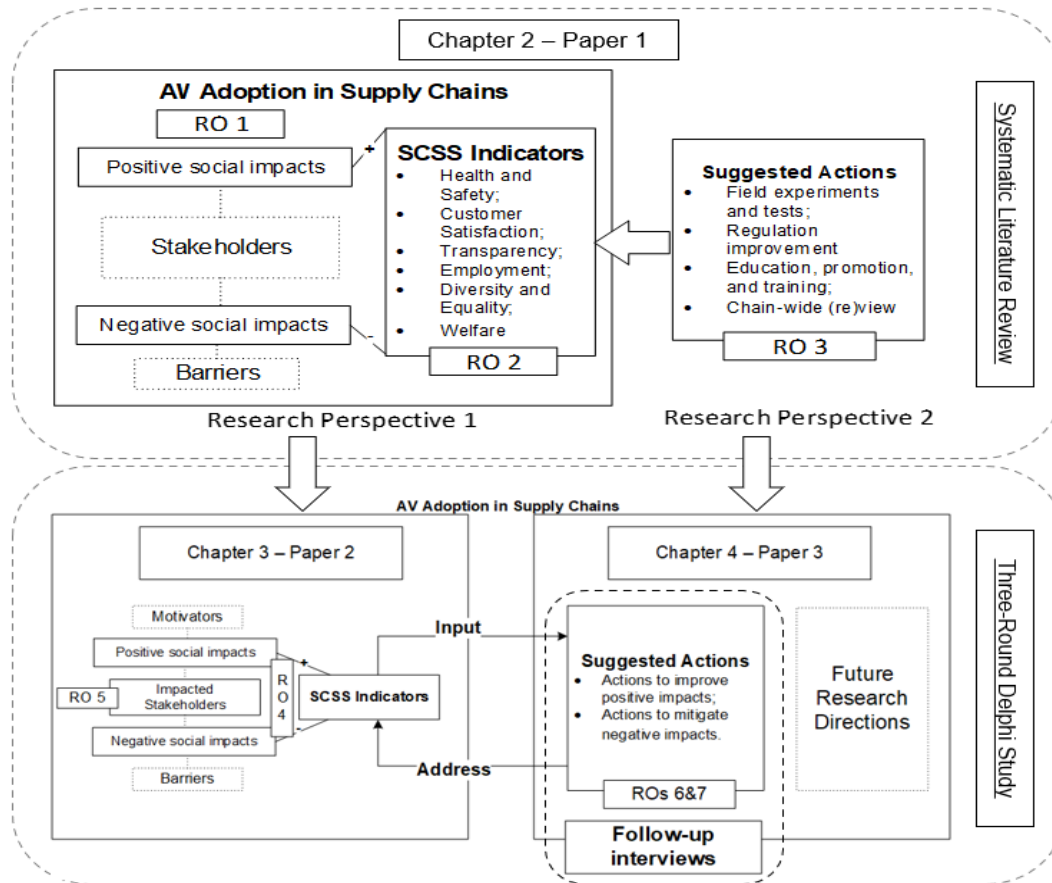


Figure 1-3 Logical flow of the three papers

As the first paper of the research, the SLR paper mainly identifies the key positive and negative social impacts of AV adoption in supply chains and relates them to the SCSS indicators (ROs 1 and 2). On the basis of the social impacts, a series of actions are suggested by the existing literature to improve the positive impacts and mitigate the negative impacts (RO 3). These two perspectives form conceptual bases for the two following empirical papers.

On the basis of ROs 1 and 2 fulfilment, the first empirical paper seeks to further refine and evaluate the social impacts and SCSS indicators with evidence from academics and practitioners (RO 4). The empirical study not only extends the social impacts and the SCSS indicators from the literature but also assesses the impacts regarding their importance in this context. Apart from the social impacts, conceptualising SCSS requires an emphasis on stakeholders, which is ignored by the extant literature. Therefore, this empirical study also identifies and classifies the stakeholders into internal and external groups, and evaluates them regarding their degrees of “affecting” and “being affected” (RO 5). The fulfilment of ROs 4 and 5 develops contextual SCSS indicators and stakeholders, which contributes to SCSS conceptualisation; they are fulfilled through a Three-Round Delphi study.

Similar to the fulfilment of RO 3 which uses the identification of SCSS indicators as inputs in the SLR, the second empirical paper also uses the outcomes of the first empirical paper (fulfilment of RO 4) as inputs for the identified actions to address. These actions are refined in the Delphi study, and further evaluated in the follow-up interviews to analyse what social impacts are addressed by each action category (RO 6). In addition, the five-stage IP provides a structured framework to streamline the process of the adoption of innovations in organisations. Since the actions seek to address the social impacts, it is sensible to use such a framework to align the actions with the various stages of AV adoption to form a structured action plan for the organisations to improve SCSS performance in this context (RO 7). The fulfilment of ROs 6 and 7 defines and proposes an action plan to realise improved SCSS performance in the context of AV adoption in supply chains.

1.6.3 Overall positioning of the thesis and each chapter

This thesis is dedicated to discussing the social sustainability implications of AV adoption at the supply chain level. The first research perspective explores social impacts, relevant stakeholders, and SCSS indicators in the AV adoption context at the supply chain level. In order to realise social sustainability improvement within supply chains, the second perspective of the thesis focuses on the actions

for various organisations to implement. Investigating the organisational level actions is key to addressing social impacts that are related to various stakeholders and nodes within supply chains, to achieve improved social sustainability performance at the supply chain level.

Paper 1 in Chapter 2 systematically reviews the social impacts of AV adoption in supply chains from the literature. This suggests a focus on the whole supply chain, instead of specific nodes. It also synthesises key actions to be implemented by various relevant groups to improve AV adoption. This suggests that a focus on the actions that are enacted at the organisational level is required, to realise wider AV adoption at the supply chain level.

Paper 2 in Chapter 3 identifies stakeholders and refines the social impacts and social sustainability of AV adoption in supply chains, which suggests a supply chain-level position as well. It does not emphasise any of the nodes in the supply chain as a “focal company”.

Paper 3 in Chapter 4 identifies and refines the actions implemented by organisations to address the social impacts of AV adoption, to realise wider social approval for AV adoption in supply chains. This is based on the social sustainability implications of AV adoption that are relevant to the various organisations and stakeholders in supply chains. Focusing on the actions implemented by the organisations at various AV adoption stages is necessary to understand how social sustainability is addressed. Therefore, this paper focuses on the organisational-level actions that target at social impacts of AV adoption to improve overall social sustainability performance in the supply chain.

1.7 Research Dissemination

Table 1-1 presents the dissemination of the papers for this doctoral research.

Table 1-1 Dissemination of the papers

Papers	Journal/Book Chapter	Conference Presentations
Paper 1 (Chapter 2)	Accepted: Gu C, Reefke H, Yates N, Ekren B, & Abushaikha, I (2023). "Exploring the Social Impacts of Autonomous Vehicle Adoption in Supply Chains", <i>In: The Palgrave Handbook of Supply Chain and Disruptive Technologies</i> Palgrave Macmillan.	Gu C, Reefke H, & Yates N (2022). Exploring the social impacts of adopting autonomous vehicles in the supply chain. <i>In: Logistics Research Network Conference</i> . Birmingham, 7-9 September 2022.
Paper 2 (Chapter 3)	Prepared for submission: Gu C, Reefke H, & Yates N (2023). "Investigating social sustainability of adopting autonomous vehicles in the supply chain: A Delphi Study". <i>Journal of Cleaner Production</i>	Gu C, Reefke H, & Yates N (2023). Exploring social impacts and social sustainability of adopting autonomous vehicles in the supply chain. <i>In: 30th EurOMA International Annual Conference</i> . Leuven, 3-5 July 2023.
Paper 3 (Chapter 4)	1st round revision: Gu C, Reefke H, & Yates N (2024). "Improving supply chain social sustainability in the Autonomous Vehicle adoption context: A Delphi study and expert interviews". <i>International Journal of Physical Distribution and Logistics Management</i>	Gu C, Reefke H, & Yates N (2023). How Does Autonomous Vehicle Adoption Improve Supply Chain Social Sustainability? A Delphi Study. <i>In: Logistics Research Network Conference</i> . Edinburgh. 6-8 September 2023. [Abstract]

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2 Paper 1: Exploring the Social Impacts of Autonomous Vehicle adoption in Supply Chains: a systematic literature review

2.1 Introduction

Autonomous vehicles (AVs) have served the logistics sector in the form of automated guided vehicles (AGVs) for decades. With the advent of Industry 4.0 in 2011, significant advances have been witnessed (Schwab, 2016). The rapid development of innovation, such as droids and drones, indicates wider adoption across the industry (Tang and Veelenturf, 2019). Logistics giants such as Alibaba and JD.com in China, and DHL and Amazon in Europe and the USA are applying or testing autonomous vehicles for use in distribution and storage processes (Merlino and Sproge, 2017; Mangiaracina et al., 2019; Mohamed et al., 2020). Further, Zipline is a successful drone delivery service providing medical supplies in African countries (Scott and Scott, 2017). However, compared with the rapid progress of technology, academic research into technology usage and the impacts of the applications on society is lagging (Van Meldert and De Boeck, 2016; Monios and Bergqvist, 2020). Previous studies have discussed, simulated, and compared AVs with conventional vehicles with regard to carbon emission levels, energy consumption, as well as various operational costs (Tsolakis et al., 2018; Murray and Chu, 2015; Ha et al., 2018; Heard et al., 2018). The variables that measure economic and environmental sustainability in supply chains are developed and can be used to demonstrate the positive performance of AV adoption in these two dimensions (Tang and Veelenturf, 2019), while the social implications of sustainability in supply chains have received much less focus.

There are many important social issues inherent in the adoption of AVs. Adoption of AVs potentially improves traffic safety, as over 90% of fatal road crashes are due to human errors, e.g., fatigued driving in long-haul freight transport (McManus and Rutchick, 2019; Wang and Li, 2019). They can also reduce traffic congestion on highways by increasing road capacity and traffic flow (Zhao and Lee, 2023). However, the impacts of the adoption of AVs on employment remain controversial – new job and skill creation, inefficient job reduction and labour

shortage mitigation in logistics (Fawcett and Waller, 2014; Ferreira et al., 2023), versus unemployment and job replacement (Heard et al., 2018). Risks such as privacy and data security (Tatham et al., 2017), and vehicle crashes (Wang and Li, 2019) also undermine public acceptance. These social concerns lead to strict regulations that restrict the further deployment of AVs: both uncrewed ground vehicles (UGVs) and uncrewed aerial vehicles (UAVs) are currently not allowed to operate logistics tasks without human monitoring or intervention in public areas (Van Meldert and De Boeck, 2016). Hence, when considering the adoption of AVs in supply chain processes, these social issues should not be ignored. The social demands raised by stakeholders and the potential social impacts on them must be considered, to allow organisations to create value for them (Hörisch et al., 2014) and improve their quality of life (Serrano-Hernandez et al., 2022). Stakeholders are defined as the entities that are involved in the organisation's activities (i.e., being affected or affecting) (Freeman, 1984). Gaining social approval among stakeholders is essential for wider AV adoption in logistics (Kim et al., 2022; Kurniawan et al., 2021). Hence, it is important to discuss the social impacts and social sustainability of AV adoption in supply chains.

In this research context, AVs include both UGVs and UAVs (Rai et al., 2022; Tubis and Poturaj, 2021). UGVs include automated guided vehicles (AGVs) or self-driving vehicles that can operate without direct human-driver intervention (Flämig, 2016). Self-driving vehicles follow a widely accepted standard of automated driving level published by the Society of Automotive Engineers (SAE) (Klumpp and Zijm, 2019; SAE, 2021) that categorises autonomous vehicles into level 3 (conditional automation), level 4 (high automation) and level 5 (full automation) (shown in Appendix A). These three levels represent the automated driving vehicle types with limited or no human driver intervention. AGVs, AMRs (Autonomous mobile robots – advanced AGVs with smart sensors and self-navigation systems), and self-driving trucks all fit into this definition (Rai et al., 2022). UAVs on the other hand, have been widely applied in military operations and have more recently been adopted for civil use (DHL, 2014). There are three main categories of UAVs in logistics and supply chain operations: first and last-mile delivery in urban and rural areas (outdoor), property surveillance and

inspection (indoor), and intralogistics operations (indoor) (DHL, 2014, 2020). UAVs supplement and augment conventional logistics operations with their advantages of speed, safety, and cost-efficiency (DHL, 2020).

The conceptual foundation of this research, supply chain social sustainability (SCSS) is rooted in the concept of corporate social responsibility (CSR), which calls for a corporation to be ethically and socially accountable to a series of stakeholders on the environmental and social outcomes of operations, rather than solely economic performance (Maloni and Brown, 2006). When the requirements extend from a focal company to the supply chain, Spence and Bourlakis (2009) emphasised a chain-wide consideration. Ethical and social benefits are to be gained within the whole supply chain, by collaborating with supply chain partners. Hence, the whole supply chain behaves ethically and responsibly to accomplish social benefits as a goal. Unlike economic and environmental sustainability, which can be assessed by general quantitative measures, social sustainability is difficult to quantify and can only be presented by qualitative indicators for performance (Ahi and Searcy, 2015a). Indicators such as health and safety, philanthropy, employment, transparency, equality, labour, human rights, and welfare are recognised to define and qualitatively measure SCSS from a general perspective (Carter and Rogers, 2008; Ahi and Searcy, 2015a, 2015b; Yawar and Seuring, 2017). For further conceptualising SCSS, it is necessary to investigate contextual indicators and not all of the items mentioned above apply to a specific context (Ahi and Searcy, 2015a; Denu et al., 2023). Therefore, this paper seeks to identify the relevant social sustainability indicators in the AV adoption context to conceptualise SCSS.

In addition to the social impacts and the respective SCSS indicators, it is important to understand how to address the social impacts, especially the negative ones, for improved SCSS performance. The stakeholders expect a series of actions and initiatives to address the social impacts to improve social sustainability (Agyemang et al., 2022; Ghadge et al., 2021). Therefore, it is necessary to identify the suggested actions that are relevant to the SCSS performance improvement in this context, to fully understand how AV adoption affects SCSS.

Currently, there is a lack of research that comprehensively discusses the social impacts of AV adoption in supply chains. The existing relevant studies either focus only on a specific stakeholder (e.g., end-customers), or a single type of technology. Hence, this paper seeks to explore the social impacts of both UGVs and UAVs in both the healthcare humanitarian and commercial supply chains, to understand the SCSS implications of AV adoption. By systematically reviewing the existing literature, the researcher can understand the social sustainability implications in this context from a holistic viewpoint. Therefore, a systematic review of existing literature is sensible for systematically and transparently collecting and synthesising information to minimise biases (Tranfield et al., 2003; Durach et al., 2017). Based on these arguments, this paper aims to answer the research questions (RQ):

RQ1: What are the social impacts of AV adoption in supply chains?

RQ2: What are the actions organisations can take to address the social impacts of AV adoption in supply chains?

The following research objectives (ROs) are designed to address the RQ:

RO 1: To identify the social impacts of AV adoption in supply chains.

RO 2: To identify the SCSS indicators that are relevant to the recognised social impacts in the AV adoption context.

RO 3: To identify and synthesise the key suggested actions that companies can employ to address the social impacts of AV adoption to achieve a socially sustainable supply chain

The paper is organised as follows. Section 2.2 introduces the methodology, followed by Sections 2.3 and 2.4, which analyse descriptive characteristics and thematic findings of the identified literature. The proposed model and a series of action categories are presented in Section 2.5 accompanied by a discussion of the literature and the findings. The final section concludes the paper with an overview of research contributions and limitations, as well as future research suggestions.

2.2 Methodology

To help gain a comprehensive understanding of the social dimension of the sustainability of AV adoption on supply chain processes, a systematic review of literature from both academic and practical sources was applied. A systematic literature review (SLR) aims to systematically and transparently synthesise and consolidate the research from different contexts and disciplines, using various methods and data types, to minimise biases through both published and unpublished studies, and to identify future research directions (Tranfield et al., 2003; Durach et al., 2017). Through a series of steps: i.e., planning, searching, criteria forming, screening, extracting and synthesising, an SLR provides a rigorous and transparent review process for document research (Denyer and Tranfield, 2009).

As a crucial review method for operations and supply chain management research, the SLR allows researchers to summarise the state-of-the-art development of relevant areas, and establish context-specific conceptual frameworks, based on the existing theories and concepts (Durach et al., 2017). This research aims to understand the social sustainability of AV adoption in the supply chain, which targets the development of the SCSS concept in this particular context. Therefore, the SLR provides a critical path for the researcher to understand the concurrent research outcomes and form a framework for concept development in this research.

Prior to the searching stage, a scoping study was carried out to ascertain the key domains of this research: Supply Chain Management, Social Sustainability, and Autonomous Vehicles. A series of seminal papers were reviewed in advance to help understand the definitions of the domains. After the planning, keywords used for searching were classified into three search strings that presented the intersection of the domains of this study. The search strings (presented in Table 2-1) should identify all the papers suitable and relevant for fulfilling research aims (Tachizawa and Wong, 2014). With the requirement of understanding the social sustainability of AV adoption in the supply chain, the three strings under the three categories of keywords are encompassed together through an “AND” operator (Tachizawa and Wong, 2014; Kühl et al., 2020). The combined search strings

were then used in three reputable databases for academic publications – EBSCO, ProQuest, and Scopus; the first two focus on the managerial discipline while Scopus covers a wider spectrum of fields. Since this research is relevant to the social and managerial impacts of technology adoption, the combination of these three databases is appropriate for the data source.

Table 2-1 Search strings

SS1: Supply chain management	SS2: Social sustainability	SS3: Autonomous Vehicles
("Supply chain*" OR "supply network*" OR "supply management" OR logistic* OR "demand chain*" OR "demand management" OR "value chain*" OR deliver* OR distribut* OR transport* OR freight OR storage OR warehous* OR manufactur* OR produc*)	(sustainab* OR ethic* OR social* OR societ* OR CSR OR responsib*)	(drone* OR droid* OR robot*) OR (unmanned OR "automated guided" OR autonomous OR self?driving OR driverless OR "remotely pilot*" OR "remotely operat*" OR "remotely control*") w/3 (vehicle* OR truck* OR lorr* OR wagon* OR van* OR system*)

It is essential to select high-quality, relevant studies to ensure accurate and meaningful analysis. A series of inclusion and exclusion criteria were applied to filter the initial research results and gain the most appropriate studies for analysis (Vu et al., 2021). In line with the research context, a tailored series of inclusion and exclusion criteria are developed (shown in Table 2-2).

Full-text screening applied both inclusion and exclusion criteria and quality assessment of the papers evaluating theory robustness, methodology, findings, and contribution (shown in Appendix A) (Pittaway et al., 2004). The papers are assessed on a scale from zero to three for each of these four items and those with aggregate scores of six or higher (at least half of the total score) were included since the papers with this score are considered to have solid quality or high relevance (Kühl et al., 2020).

Table 2-2 Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion	Rationale
Language	Papers are written in English	Papers not written in English.	The official language, avoids errors in translation.
Geography	All	None	To ensure the literature is selected without bias against regions.
Source	Papers come from peer-reviewed academic journals and conference proceedings.	Papers come from non-academic sources such as news, web pages, etc.	To ensure rigorous methodology and robust argument.

Sector/industry	All	None	To include adoption in all supply chains without bias.
Research method	All	None	To avoid bias.
Searching Timeframe	Up till June 2022	None	AV developed significantly since the 2010s, but some seminal papers predate this.
Phenomena	Papers in the context of autonomous vehicles in supply chain social sustainability	Papers focusing on topics such as IT, GIS, remote sensing, biological distribution, mining and passenger transportation.	To ensure the papers are relevant to answer the review questions.
Topic	Papers that discuss the social implications of autonomous vehicles in supply chain processes	Papers that solely discuss the environmental and economic impacts.	To ensure the papers are relevant to answer the review questions.

The literature selection process is presented in Figure 2-1. A total number of 4141 papers were identified from the three databases and after duplication removal, 3469 papers remained for screening. During the title and abstract screening, 3314 papers were rejected and the remaining 155 papers were selected for full-text screening. After the full-text screening, 49 papers were retained, while nine more papers were added using a snowballing process as they were not extracted from the search string selection. Quality was assessed during the full-text screening and excluded two papers. Ultimately 58 papers were identified and included.

As categorised as one type of grey literature, papers from published conference proceedings are significant in credibility and can supplement information for academic literature reviews (Adams et al., 2017). Due to the novelty of this research topic, conference proceedings can provide up-to-date evidence with a much shorter time period between being written and being published (Mangiaracina et al., 2019). Hence, this thesis considers including conference papers to enrich arguments with the most recent ideas. Concerning other non-academic grey literature sources, although contents involved in newsletters, industrial reports, and policy documents provide fruitful insights (Vu et al., 2021), most non-academic grey literature lacks a rigorous peer-reviewed process for publishing, which suggests risks in its low-quality and biased content (Durach et al., 2017). This study focuses on the management perspective of technology

usage in supply chains and forms a conceptual framework within academic discourse. Hence, non-academic sources are referred to enrich introduction and discussion sections but are excluded from the literature pool for thematic analysis.

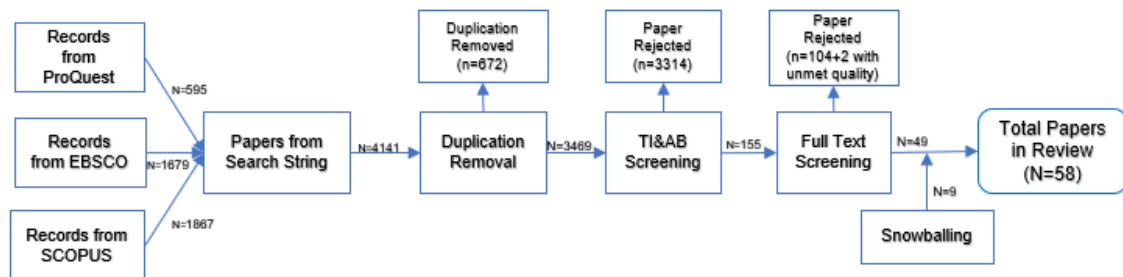


Figure 2-1 Paper searching and screening process

Following the content analysis approach, the collected data went through descriptive and thematic analysis (Seuring and Muller, 2008). After searching and screening, descriptive and thematic data were analysed following the instructions proposed by Tranfield et al. (2003). The analysis stage extracted information including title, author, publication, study nature, method, findings, limitations, etc. and recorded them on a spreadsheet. The descriptive information helped form the understanding of the current state of the field, and the specific themes that fulfil the research aim (Vu et al., 2021). With the exploratory nature of this study, there is no formative “theory” that this study can closely follow or tailor to. Rather, this study referred to the seminal literature on general SCSS concepts and used them as a guide to construct the identified social impacts. Therefore, the analysis of the key elements involved in the research objectives was conducted inductively by combining and synthesising the included studies. The themes were inductively developed from the reviewed literature (Seuring and Muller, 2008). The bottom-up mechanism suggests that social impacts were initially categorised according to specific perspectives (e.g., safety, security, job issues, equal treatment, etc.), or to target relevant entities (e.g., employees, customers, communities, etc.). These impacts are recognised as first-order concepts, following Gioia’s guidance for thematic analysis (Gioia, 2013). The impacts on similar entities regarding the identical perspectives were later gathered together to form a subtheme, or the second-order themes (e.g., AVs’ fast response and saving lives for the victims

suffering from emergency issues such as heart strikes or venomous snake bites are grouped as the “fast response and life-saving in emergency scenarios” impact). The subthemes covering similar perspectives that target distinct entities were ultimately categorised under an aggregate theme (e.g., Health and Safety, Labour issue, Transparency, etc.).

2.3 Descriptive analysis

This section presents the descriptive analysis of this literature review. Figure 2-2 presents the distribution of the publication year of the papers. The emergence and development of Industry 4.0 technologies have led to a rapid increase in the number of papers since 2015 and the trend has reached its peak in recent years with a slight decrease in the quantity of papers in 2021. The incremental discussions on social implications have emerged throughout the years.

Apart from the publication year, the rest of the descriptive elements are listed in Table 2-3. In terms of the geographic distribution of the research, most papers selected are in the context of Europe, followed by North America. Only seven papers are in the context of Asia-Pacific (Asia and Oceania) and one for Africa. Ten papers do not explicitly mention the geographic context. The papers under the global context are either literature review papers or papers that collect data from several continents. The geographic context here means the locations of the research targeted, rather than the locations of the authors or institutions that conducted the research.

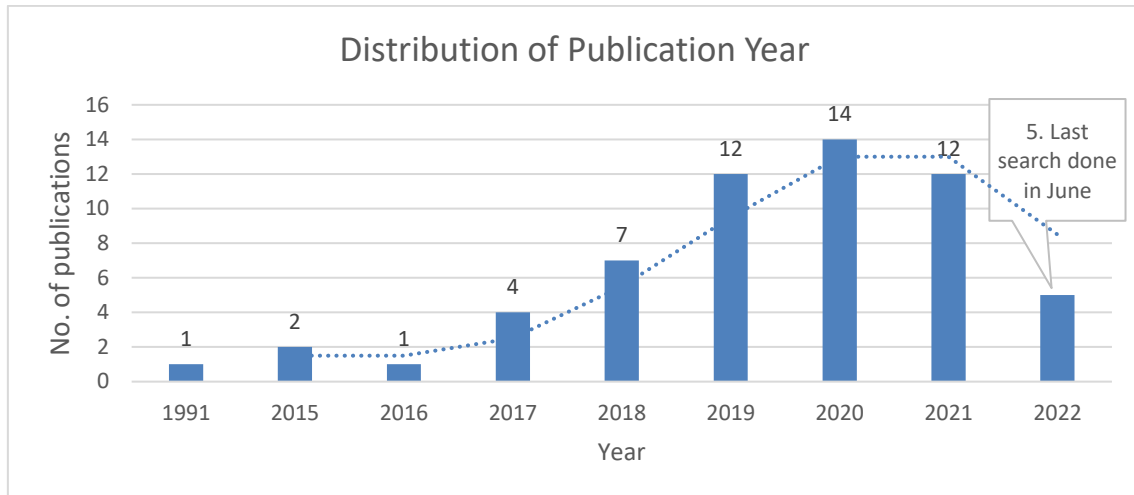


Figure 2-2 Distribution of publications by year

Regarding the source of the papers, 52 are journal papers and six are from conferences. Due to its interdisciplinary nature, this paper includes papers from journals targeting subjects such as sustainability, logistics and transportation, technology application in society, and bio-medical domains in the humanitarian context.

Various research methods are adapted for the papers selected for this SLR. The selected papers are divided into conceptual (15), survey (14), literature review (LR, 11), mathematical modelling (6), case study (7), experiment (1), simulation (3), and interview (1). From the results, empirical studies, especially qualitative research are lacking in this field, which suggests that further research directions can focus on qualitative empirical research. Most of the quantitative research focuses on a single stakeholder group (i.e., end-customers) and discusses the impacts on them. Much fewer explorations target wider stakeholder groups and hence, the social sustainability relating to them lacks conceptualising.

There is a balance in the technology type of distribution for papers focusing on UAV and UGV. Apart from the exclusive focus, five studies include both types of AVs, and these provide an insightful guide for this study to inclusively analyse the social impacts of both UAVs and UGVs. In addition, most of the studies fall into the transportation and warehousing processes of the supply chain, indicating the usage of AVs is mainly in these processes. Only three papers specifically mention

AV adoption in the manufacturing process, while the rest either include AVs in multiple processes, or do not explicitly mention the supply chain process.

Table 2-3 Descriptive analysis of the literature review

Descriptive category	Sub-Category	Paper quantity
Research Methodology	Conceptual	15
	Survey	14
	Literature review	11
	Mathematical Modelling	6
	Case study	7
	Simulation	3
	Experiment	1
	Interview	1
Geographic Context	Asia-Pacific	7
	Africa	1
	Europe	16
	North America	11
	Global	13
	N/A	10
AV type	UAV	25
	UGV	25
	Both	5
	General/Not explicit	3
Journal*	Journal of Cleaner Production	4
	Technological Forecasting and Social Change	3
	Transportation Research Part A	3
	Technology in Society	3
	Sustainable Cities and Society	3
	Transportation Research Interdisciplinary Perspectives	2
	Transportation Research Part C	2
	International Journal of Logistics: Research and Applications	2
	Commercial/Healthcare**	46
Supply Chain Processes	Humanitarian/Healthcare	15
	Transportation	44
	Warehousing	2
	Both Transportation and Warehousing	3
	Production & Manufacturing	3
	General/Not explicit	6

*Includes the journals with more than one included.

**Papers including humanitarian/healthcare context are listed in the humanitarian/healthcare part.

Table 2-4 Theoretical frameworks identified from the literature

AV category	Theory	Unit of Analysis	Source
UAV	Socio-technical theory	Supply Chain	Haula and Agbozo, 2020
	Technology Acceptance Model (TAM)	Individual (Customer)	Eiðfeldt et al., 2020
	Multi-level perspective	Supply Chain	Comtet and Johannessen, 2022
	Circular Economy ReSOLVE framework	Supply Chain	Mahroof et al., 2021
	(Motivated) Consumer Innovativeness	Individual (Customer)	Hwang et al., 2021a, 2021b

	Knowledge, Attitude and Practice Model (KAP)	Individual (Customer)	Aydin, 2019
UGV	Unified Theory of Acceptance and Use of Technology (UTAUT2)	Individual (Customer)	Kapser and Abdelrahman, 2020
	Unified Theory of Acceptance and Use of Technology (UTAUT2)	Individual (Customer)	Kapser et al., 2021
	Socio-technical System theory	Organisation	Vlachos et al., 2023
	Hierarchical decision-making	Supply Chain	Bechtsis et al., 2017
	Business Model Innovation (BMI)	Supply Chain	Monios and Bergqvist, 2020
	Fuzzy-set	Supply Chain	Llopis-Albert et al., 2019
General	Critical Success Factor (CSF)	Supply Chain	Azmat and Kummer, 2020

Table 2-4 summarises the theories and theoretical frameworks adopted by the literature. The theories adopted in the literature mainly structure variables for analysing the individual acceptance, or describe the decision-making or change process of the technology adoption to a social system or a supply chain.

2.4 Thematic Analysis

This section presents the thematic findings of this review. The SCSS concepts and indicators are introduced in advance as the foundation for the main thematic findings. The positive and negative social impacts in both commercial and humanitarian logistics contexts are identified. Apart from these elements that mainly answer the review question, this paper identified a series of social barriers to wider AV adoption in supply chains.

2.4.1 Positive social impacts

After synthesising the findings, this review identified 13 main positive social impacts and classified them into six distinct groups based on the relevance of the identified items. A holistic view of the positive impacts of AV adoption in both commercial and healthcare humanitarian contexts is shown in Table 2-4.

2.4.1.1 Faster and more customised delivery services

The development of e-commerce and urbanisation has led to the increasing importance of urban logistics – especially B2C last-mile logistics (Marsden et al., 2018), and calls for customer-oriented service for last-mile delivery (Kapser and Abdelrahman, 2020). Reduced delivery time and more customised services are

demanded by consumers, and these are challenging for existing conventional delivery modes (Bechtsis et al., 2017), while AVs are feasible solutions to these challenges to satisfy customers' needs (Merlino and Sproģe, 2017; Amarfi-Railean, 2018). Among the positive impacts, fast delivery is the most mentioned and significant advantage for AVs, especially drones – pointed out by around 75% of the papers. For UAVs, this is enabled by their capabilities of ignoring ground traffic and geographical blocks, so that they can operate in direct and uninterrupted routes to conduct delivery tasks (Kellermann et al., 2020). Such advantages in delivery speed reduce consumer waiting time, or customer lead-time, which can satisfy the customers' demands for shorter delivery time (Hwang et al., 2019; Perussi et al., 2019; Tang and Veelenturf, 2019; Kellermann et al., 2020; Mohamed et al., 2020). On the other hand, UAVs are considered more flexible, so they can provide more customised services – time slot, and location of reception (Mangiaracina et al., 2019), and therefore avoid inefficiency in delivery failure and repetitive delivery (Slabinac, 2015). UGVs show similar features in providing rapid and customised delivery services (Pani et al., 2020; Gružas et al., 2018; Kapser and Abdelrahman, 2020). Although still using the road infrastructure, there are no driving time restrictions for UGVs – 24/7 operations enable UGVs to conduct transport services with higher flexibility, which is a competitive advantage compared with conventional ground vehicles (Azmat and Kummer, 2020; Merlino and Sproģe, 2017).

Specifications in fast and customised delivery services are crucial in providing medical supplies in humanitarian and healthcare supply chain contexts (Ding, 2018; Dhote and Limbourg, 2020). Various medical supplies can be delivered rapidly and directly to recipients with specific needs (i.e., automated external defibrillators (AEDs) for heart attacks, antivenom serum for snake attacks) in urban areas or remote places (Tatham et al., 2017; Poljak and Šterbenc, 2020; Rosser et al., 2018). In emergency scenarios, where time is precious, rapid response and delivery are essential for life-saving, which is highly relevant to the following section: health and safety of the related entities.

2.4.1.2 Health and safety of the related entities

Safety is one of the major issues regarding social impacts. In the context of AV adoption, the discussion of health and safety goes beyond the consumers and recipients to include multiple related entities such as employees, traffic users, etc. As mentioned above, using AVs to deliver emergency medical supplies showcases their advantages in fast response and rapid delivery speed (Haula and Agbozo, 2020; Azmat and Kummer, 2020). Such advantages are crucial in life-saving in emergencies, and reducing morbidity significantly (Kellermann et al., 2020). In commercial contexts, AVs provide touchless customer delivery services, which significantly prevent the spread of contagious viruses, especially after the COVID-19 pandemic (Pani et al., 2020), and therefore, improve end-customers' health and safety. In workplaces, deploying AVs helps enhance workforce health and safety by replacing their tasks in hazardous working environments (Bechtsis et al., 2017, 2018) and reducing workplace accidents (Llopis-Albert, 2019). In the food supply chain, the use of drones in pesticide application reduces workers' exposure in hazardous farming fields (Mahroof et al., 2021). In addition, the introduction of AVs, especially long-haul UGVs for road transport, potentially lead to enhanced safety for traffic users, and the load carried, by taking the place of human drivers (Sohrabi et al., 2020; Perussi et al., 2019; Sen et al., 2020). Road freight transport represents an essential role in logistics; hence, road traffic safety is crucial. More than 90% of traffic accidents are caused by human error – mainly due to fatigue and alcohol or drug abuse (Gružauskas et al., 2018). These human-made fatal accidents can be diminished by the adoption of AVs due to the implementation of smart sensors, big data analytics, and the Internet of Things (IoT) that automatically control the trucks in the transport process without human interference (Gružauskas et al., 2018). Therefore, the related entities, including employees or workers, other traffic users, and the end customers, can benefit from improved health and safety performance in the supply chain by deploying AVs.

2.4.1.3 New job creation and filling labour shortage

The labour shortage in logistics, especially in the transportation process is increasingly challenging. On the one hand, ageing and retiring labour forces will

result in a decrease in available truck drivers by 25% in the next decade (Klumpp and Zijm, 2019). On the other hand, a low birth rate in Generations Y and Z has led to an insufficient supplement of the young labour force in the supply chain (Hwang et al., 2019). Under such circumstances, deploying AVs in the supply chain, especially in the transportation process, will reduce the labour shortage issue and ensure stable productivity in the supply chain. The adoption of AVs requires reduced operational employees for manual and repetitive tasks such as driving fork-lift trucks in warehouses and heavy-load trucks on the highways (Bechtsis et al., 2017, Klumpp, 2018). The logistics tasks are expected to be improved with higher speed and greater accuracy (Tang and Veelenturf, 2019). Meanwhile, AVs are believed to create new job opportunities such as AGV operators, monitors, and programmers (Gružauskas et al., 2018; Sohrabi et al., 2020). AV and infrastructure maintenance jobs are also to be created (Sen et al., 2020). In addition, the deployment of AVs leads to job transformation in the supply chain – truck drivers no longer take the steering wheel, but monitor the trucks from screens in control centres or conduct administration tasks in the driving seat (Klumpp, 2018). The workforce that is capable of new technology-related tasks will be increasingly competitive and in demand in the labour market (Sohrabi et al., 2020).

2.4.1.4 Reduced traffic impacts

Not using ground space provides the advantage for drones to ignore geographical restrictions on the ground. Drones use low-altitude air space instead of ground area and ignore geographic limitations (Mangiaracina et al., 2019), they can utilise the fastest and most direct routes for delivery (Mohamed et al., 2020). The drones do not use ground infrastructure, so their use for parcel delivery instead of conventional ground vehicles decreases the number of deployed delivery vehicles, further reducing road traffic congestion (Perussi et al., 2019). On the other hand, smart technologies such as sensors and cloud computing equipment on the UGVs, instead of human operators, help optimise the distances from other vehicles, which smoothes road traffic flows (Fagnant and Kockelman, 2015; Sohrabi et al., 2020). Therefore, deploying AVs in supply chains potentially reduces road traffic congestion.

2.4.1.5 Product and asset security

AVs help to realise the real-time visibility of the assets and product flows in supply chains efficiently, which remains challenging in remote and infrastructure-poor places (Sellevold et al., 2020). Equipped with smart sensors, drones are capable of assets and inventory surveillance to guarantee the real-time safety of products in warehouses and pipelines (Perussi et al., 2019; Tang and Veelenturf, 2019), which benefit logistics managers and decision-makers to monitor the product flows and intervene to adjust operations in a timely way (Mahroof et al., 2021; Roy et al., 2023). With the built-in sensors, AVs automatically provide real-time status visibility and traceability of the products during freight transport without human interference (Gružauskas et al., 2018; D'Amico et al., 2021; Roy et al., 2023). Conventional vehicles require extra installations of such sensors to achieve similar effects.

2.4.1.6 Improved gender equality

There is a serious imbalance of gender distribution in the logistics sector. In freight transport, for instance, less than 6% of truck drivers are female in the main developed economies, which presents the stereotype that males dominate the truck driving role (Kim et al., 2022). However, the adoption of AVs diminishes this imbalance by creating more gender-neutral job opportunities that both males and females are equally qualified for, with no existing labelling such as “male dominant jobs”. For example, autonomous trucks take long-haul driving tasks, while human pilots conduct monitoring tasks (Klumpp, 2018). An increased percentage of females are expected to take the role on the trucks so that mitigated stereotypes can benefit gender diversity (Kim et al., 2022). Hence, the adoption of AVs in supply chains is beneficial in gender-stereotype mitigation – either gender is eligible to conduct logistics-related tasks in the future.

2.4.2 Negative social impacts

Similar to the positive impacts, this study identified seven main negative impacts in five groups. Table 2-5 summarises the identified negative impacts of this study.

2.4.2.1 Safety

Despite the positive impacts on the health and safety of AV adoption, the negative impacts cannot be ignored. Incidents due to the immaturity of the UAV technology such as collision, loss of signal, and inability to cope with extreme weather, will cause threats to the safety of the public, as well as the security of the payload to be delivered (Perussi et al., 2019; Wang, 2019; Mohamed et al., 2020). In addition, incidents such as the use of delivery drones to conduct terrorist attacks mentioned by Aydin (2019), and the operation of drones in commercial airline space pointed out by Rao et al. (2016) also threaten public safety. Similar concerns exist for UGVs. The reliability is still not guaranteed so these vehicles will still potentially cause fatal accidents, which again threaten public safety (Fagnant and Kockelman, 2015; Marsden et al., 2018).

2.4.2.2 Privacy and Cybersecurity

Tightly related to safety problems, weak privacy and cyber security are other negative impacts. The vulnerability to hackers targeting the AVs cannot be ignored (Nikitas et al., 2021). Cyberattacks on AV software systems can lead to the delivery of parcels to the wrong address, as well as leaking customers' personal information and threatening privacy (Nelson et al., 2019; Mohamed et al., 2020; Aydin, 2019). On the other hand, individuals do not trust organisations and governments to use UAVs responsibly – there is a possibility that their data will be abused by these institutions (Nelson et al., 2019). Hence, privacy and cyber security issues remain tough in this context.

2.4.2.3 Unemployment

Unemployment is a broadly identified negative impact in the literature. AVs will take the places of numerous positions in the logistics sector and result in job loss. Truck drivers who conduct long-haul freight transport, as well as vehicle-related service providers, could potentially lose their jobs due to autonomous driving (Sohrabi et al., 2020). Similar concerns of potential unemployment are raised in the last-mile delivery process, in that the AVs will take the place of delivery persons (Marsden et al., 2018; Io and Lee, 2019). Employees in industries that support conventional vehicles where the requirements differ from the AVs, will

face short-term employment disruption (i.e., conventional vehicle maintenance, finance, petrol stations, etc.) (Nikitas et al., 2021). Although job transformation will exist (Klumpp, 2018), those who are ageing and less educated employees with limited transferable skills are more likely to be laid off (Nikitas et al., 2021). Examples of previous industrial revolutions suggest that, although new jobs will be generated after disruptive technology deployment, it is inevitable for a large number of low-skilled workforces to suffer from unemployment, at least in the short term (Dadzie and Johnston, 1991; Ding, 2018).

2.4.2.4 Social inequality

Although not highlighted by most of the literature, deploying AVs potentially aggravates social inequality by enlarging the gap between the rich and poor classes (Tang and Veelenturf, 2019). Those who cannot afford smartphone devices are digitally excluded, leading to a worsening inequality to them (Garus et al., 2022). In addition, as familiarity with the technology plays an important role in public acceptance (Kapsner et al., 2021), those who receive less education regarding AV technology and AV usage in parcel deliveries are less familiar with them, and therefore, less willing to accept them. This potentially further restricts these social classes from accessing the benefits of AV delivery services.

2.4.2.5 Human interaction

AVs in the supply chain reduce human interactions both in workplaces such as warehouses or manufacturing plants and in last-mile delivery. In workplaces, more transportation tasks are handed to AVs in the supply chain, and workers become isolated as they do not need to transport the products themselves (Soni and Soni, 2019). Organisations in the supply chain need employee participation in decision-making, to which they cannot contribute if they are isolated. The employees need meaningful interactions when they are working to fulfil their human needs (Soni and Soni, 2019; D' Amico et al., 2021). In the delivery process, Tatham et al. (2017) emphasised the importance of building a relationship between healthcare providers and receivers. The AV delivery service potentially reduces human care and weakens the treatments for patients who face cold machines, rather than warm human beings they can interact with.

Table 2-5 Positive social impacts of AV adoption in SC

Source	Supply Chain Process	Technology	Positive Social Impacts												
			1	2	3	4	5	6	7	8	9	10	11	12	13
Wang, 2019	Transportation	UAV					X								
Sellevoid et al., 2020	Transportation & Warehousing	UAV							X	X					
Kellermann et al., 2020	Transportation	UAV					X	X							
Hwang et al, 2021a	Transportation	UAV					X							X	
Hwang et al, 2019	Transportation	UAV			X		X				X			X	
Rao et al., 2016	Transportation	UAV					X								
Mohamed et al., 2020	Transportation	UAV	X				X							X	
Rejeb et al., 2021	General	UAV	X		X		X	X						X	
Serrano-Hernandez et al., 2021	Transportation	UAV		X				X							
Hwang et al., 2021b	Transportation	UAV					X	X							
Mahroof et al. 2021	Production & Manufacturing	UAV			X				X						
Scott and Scott, 2017*	Transportation	UAV	X				X							X	
Tatsidou et al., 2019*	Transportation	UAV	X				X								
Haula and Agbozo, 2020*	Transportation	UAV	X				X								
Dhote and Limbourg, 2020*	Transportation	UAV					X	X						X	
Tatham et al., 2017*	Transportation	UAV	X					X							
Poljak. and Sterbenc, 2020*	Transportation	UAV	X				X	X						X	
Rosser et al., 2018*	Transportation	UAV	X				X	X							
Ding, 2018*	Transportation	UAV					X	X							
Comtet and Johannessen, 2022*	General	UAV	X				X	X							
Azmat and Kummer, 2020*	Transportation	UAV & UGV	X											X	X
Tang and Veelenturf, 2019	Transportation & Warehousing	UAV & UGV	X				X		X						
Mangiaracina et al., 2019	Transportation	UAV & UGV						X						X	X
Perussi, J. et al., 2019	Transportation & Warehousing	UAV & UGV		X			X	X	X	X				X	X
Slabinac, 2015	Transportation	UAV & UGV					X	X							
Amarfii-Railean, 2018	General	UAV & UGV						X							

Rai et al., 2022
D'Amico et al., 2021
Kapser. and Abdelrahman, 2020
Klumpp, 2018
Pani et al., 2020
Llopis-Albert et al., 2019
Sohrabi et al., 2020
Dadzie and Johnston, 1991
Bechtsis et al., 2018
Sen et al., 2020
Monios and Bergqvist, 2020
Gružasuskas et al., 2018
Fagnant and Kockelman, 2015
Marsden et al., 2018
Bechtsis et al., 2017
Engholm et al., 2021
Kim et al, 2022
Kurniawan et al., 2021
Kapser et al., 2021
Nikitas et al., 2021
Tubis and Poturaj. 2021

Transportation	UAV & UGV				X					X				
General	UAV & UGV			X				X	X		X			X
Transportation	UGV						X							
Transportation	UGV					X				X	X			
Transportation	UGV				X	X	X							
Warehousing	UGV			X										
Transportation	UGV		X	X							X			X
Warehousing	UGV										X			
General	UGV			X			X				X			
Transportation	UGV		X		X						X			
Transportation	UGV		X		X									
Transportation	UGV		X			X	X	X	X		X			
Transportation	UGV		X											X
Transportation	UGV					X	X							
General	UGV			X							X			
Transportation	UGV										X			
Transportation	UGV				X						X		X	
Transportation	UGV		X								X			
Transportation	UGV				X									
Transportation	UGV		X								X			
Production & Manufacturing	UGV			X										

- | | | |
|--|---|---|
| 1. Fast response and life-saving for emergency scenarios (recipients/patients) | 6. Customised services (consumers, recipients, patients) | 11. Reduce gender inequality (employees) |
| 2. Road traffic safety (road traffic users) | 7. Security for assets & products (consumers, logistics managers) | 12. Reduced usage of ground space (consumers, road traffic users) |
| 3. Workforce health and safety (employees) | 8. Real-time information transparency and visibility (logistics managers and decision makers) | 13. Smoother road traffic flows (consumers, road traffic users) |
| 4. Customers/recipients health and safety (customers, recipients) | 9. Fill labour shortage (decision makers) | |
| 5. Fast delivery (consumers, recipients) | 10. New job creation (employees) | |

Table 2-6 Negative social impacts of AV adoption in SC

Source	Supply Chain Process	Technology	Negative Social Impacts						
			1	2	3	4	5	6	7
<i>Wang, 2019</i>	Transportation	UAV	X						
<i>Kellermann et al., 2020</i>	Transportation	UAV	X	X		X			
<i>Aydin, 2019</i>	Transportation	UAV	X	X		X			
<i>Rao et al., 2016</i>	Transportation	UAV	X	X					
<i>Nelson et al., 2019</i>	Transportation	UAV		X					
<i>Mohamed et al., 2020</i>	Transportation	UAV	X	X					
<i>Cheema et al., 2022</i>	Transportation	UAV		X					
<i>Rejeb et al., 2021</i>	General	UAV	X	X					
<i>Tatham et al., 2017*</i>	Transportation	UAV							X
<i>Ding, 2018*</i>	Transportation	UAV		X					
<i>Tatsidou et al., 2019*</i>	Transportation	UAV	X	X					
<i>Wang et al., 2021*</i>	Transportation	UAV		X					
<i>Haula and Agbozo, 2020*</i>	Transportation	UAV	X	X					
<i>Dhote and Limbourg, 2020*</i>	Transportation	UAV	X	X					
<i>Poljak and Sterbenc, 2020*</i>	Transportation	UAV	X	X					
<i>Azmat and Kummer, 2020*</i>	Transportation	UAV & UGV		X		X			
<i>Tang and Veelenturf, 2019</i>	Transportation & Warehousing	UAV & UGV		X		X	X		
<i>Mangiaracina et al., 2019</i>	Transportation	UAV & UGV				X			
<i>Perussi et al., 2019</i>	Transportation & Warehousing	UAV & UGV	X						
<i>Slabinac, 2015</i>	Transportation	UAV & UGV	X						
<i>Rai et al., 2022</i>	Transportation	UAV & UGV		X		X			
<i>D'Amico et al., 2021</i>	General	UAV & UGV	X	X				X	
<i>Klumpp, 2018</i>	Transportation	UGV				X			
<i>Soni and Soni, 2019</i>	General	UGV				X		X	
<i>Sohrab et al., 2020</i>	Transportation	UGV				X			
<i>Dadzie and Johnston, 1991</i>	Warehousing	UGV				X			
<i>Sen et al., 2020</i>	Transportation	UGV				X			
<i>Gružasuskas et al., 2018</i>	Transportation	UGV				X			
<i>Fagnant and Kockelman, 2015</i>	Transportation	UGV	X	X		X			

Merlino and Sproge, 2017

Marsden et al., 2018

Io and Lee, 2019

Engholm et al., 2021

Kim et al., 2022

Kurniawan et al., 2021

Nikitas et al., 2021

Garus et al., 2022

Vlachos et al., 2021

Transportation	UGV				X			
Transportation	UGV	X			X			
Transportation	UGV	X	X		X			
Transportation	UGV				X			
Transportation	UGV		X		X			
Transportation	UGV				X			
Transportation	UGV		X	X	X			
Transportation	UGV	X				X		
Production & Manufacturing	UGV				X			

1. Safety incidents due to crashes, failures, and attacks (consumers, civilians)
2. Privacy and cybersecurity (consumers, patients, local communities)
3. Unemployment in supportive industries (employees)
4. Unemployment in logistics sectors (employees)
5. Social inequality, not accessible (potential consumers)
6. Reduced interactions among employees (employees)
7. Reduced interactions between patients and service providers (patients, victims)

2.4.3 Current social barriers to a wider AV Adoption

In addition to the clearly identified social impacts, a series of social barriers are recognised as hindering AVs from wider adoption. They can be considered as the potential outcomes of the identified social impacts, rather than the direct impacts of AV adoption in supply chains. In this context, social acceptance and legal restrictions are the main barriers identified in the literature.

2.4.3.1 Social acceptance

According to Nelson et al. (2019), it is crucial not to hinder the advantages of AVs, by understanding individuals' perceptions and acceptance of the emerging technologies. Public acceptance is relevant to the social impacts mentioned above, especially the negative ones. Aydin's survey (2019) shows that safety and security concerns (for people and products) result in low acceptance, similar to the findings regarding privacy concerns (Nelson et al., 2019), unemployment, and working environment safety (Dadzie and Johnston, 1991). People who see UAVs flying overhead could make unpleasant assumptions instantly (Tatsidou et al., 2019). On the other hand, consumers who show curiosity about AVs are more willing to attempt to be served by AVs (Marsden et al., 2018; Io and Lee, 2019; Hwang et al., 2021a). These diverse attitudes, according to the existing studies, are rooted in personal experience, or familiarity with the technologies (Eiðfeldt et al., 2020). Several surveys have found that a respondent who is more familiar with the technology will express a higher willingness to pay – hence a higher acceptance of the technology (Aydin, 2019; Pani et al., 2020; Nelson et al., 2019; Eiðfeldt et al., 2020). In addition, when UAVs are conducting humanitarian or healthcare supplies, the public shows a higher acceptance than in other commercial contexts (Eiðfeldt et al., 2020).

2.4.3.2 Regulation restrictions

Apart from technology issues (i.e., battery life), a lack of proper regulations is the major limitation for wider adoption (Rao et al., 2016). As discussed in the previous sections, there are considerable social concerns regarding the negative impacts

such as illegal use of AVs for terrorism, cyberattacks and leakage of personal data, and resistance from those who are potentially unemployed. Those concerns drive legislative authorities to formulate restrictions that delay the practical implementation of AVs (Fagnant and Kockelman, 2015). Given the perceived negative impacts and technology immaturity, regulations are still limiting the operations of AVs at outdoor sites. For example, Beyond-line-of-sight (BLOS) flying permits for UAVs are currently not available, which restricts the wider deployment of UAVs in small parcel delivery services (DHL, 2020). However, the literature calls for improved regulations and official guidance on AV adoption to be applied, especially for humanitarian and healthcare purposes. When a disaster occurs in a region where drones are not permitted, it hinders relief organisations from planning to deploy UAVs for efficient humanitarian medical supplies (Tatsidou et al., 2019). Therefore, clear licensing and regulations are necessary for AV applications in the supply chain (Mohamed et al., 2020).

2.4.4 Key stakeholders identified

From reviewing the literature, social impacts are identified. However, the targets of the social impacts are not emphasised, i.e., those who are affected by AV adoption and regarding which social impacts. The targets (or the “who”) that are affected in this context, are defined as “stakeholders”, i.e., “any group or individual who is affected by or can affect the achievement of an organisation’s objectives” (Freeman, 1984). Since SCSS discusses the “human” side of sustainability, it is necessary to understand who the stakeholders are in the research that focuses on SCSS (Huq et al., 2014; Hussain et al., 2018). As argued, compared to explicit mentioning of social impacts, the existing literature implicitly lists the potential stakeholders that are potentially related to the impacts. This lack of mentioning stakeholders hinders the further discussion of the SCSS concept in this context.

As shown in the notes of Tables 2-4 and 2-5, relevant stakeholders are inferred from the literature and relate to the corresponding social impacts. In terms of the impacts regarding parcel/medical supply delivery, stakeholders are consumers, recipients, and local communities (Aydin, 2019; Merlino and Sproge, 2017), while

long-haul freight transport potentially affects road traffic users and truck drivers (Gružas et al., 2018). Table 2-7 shows the identified stakeholders.

Table 2-7 Stakeholders identified in the AV adoption context concerning SCSS

Impact Category	Stakeholders
Positive	<ul style="list-style-type: none"> ● Consumers, recipients, patients; ● Logistics managers and decision makers; ● Employees, truck drivers; ● Road traffic users.
Negative	<ul style="list-style-type: none"> ● Consumers, patients, recipients; ● Local communities; ● Employees
Not direct impacts	<ul style="list-style-type: none"> ● Government/Policy makers (Kurniawan et al., 2021) ● Shareholders (Llopis-Albert et al., 2019) ● Labour unions (Llopis-Albert et al., 2019)

To the best knowledge of the author, there is a lack of comprehensive presentation of stakeholders, as well as their roles (i.e., How are they affected?) in the literature that discusses the social impacts of AVs in supply chains. This implies a gap in the existing research and a potential research avenue to follow to discuss stakeholders, which is an essential element to conceptualise SCSS (Huq et al., 2014; Hussain et al., 2018) in the AV adoption context. Hence, a lack of evaluation of context-specific stakeholders in the AV adoption context is the first research gap this literature review identifies.

2.4.5 Suggested actions and categorisation

Given the identified social impacts (especially the negative ones) and the relevant social sustainability indicators, a series of actions are proposed. From the literature, the proposed actions are for wider AV adoption in supply chains, rather than directly addressing the social impacts of AV adoption. Since social issues are crucial for wider AV adoption (Kurniawan et al., 2021), The actions should target the social impacts of AV adoption. Among the surveys conducted in the existing literature, familiarity with the technologies from the survey participants plays a key role in determining whether they choose to use the technologies or not (Pani et al., 2020; Aydin, 2019; Nelson et al., 2019). Meanwhile, regulatory limitations are raised repeatedly in the literature, and easing the regulations and improving the guidance in this regard may prove beneficial for the wider adoption

of AVs (Fagnant and Kockelman, 2015; Mohamed et al., 2020; Tatsidou et al., 2019). However, the regulation improvement and promotions require proof of concepts, which call for real-world experiments and tests to ensure the safe usage and advantages of AVs in practice (Tatham et al., 2017; Marsden et al., 2018). Furthermore, connecting back to chain-wide sustainability, integration is also mentioned in some of the papers (Ding, 2018; Sen et al., 2020; Perussi et al., 2019). Regarding these appeals, this paper synthesises the actions into four categories that are related to the managerial aspects in order to address the listed social impacts (particularly, the negative impacts) for a socially sustainable supply chain: 1. Field experiments; 2. Regulation improvement; 3. Education, promotion, and training; and 4. Chain-wide view and review.

2.4.5.1 Field experiments

Conducting sufficient field tests and experiments is mentioned as an important action to improve technical reliability and safety incident prevention. In some studies, this action is listed as the first step for the wider deployment of AVs (Tatham et al., 2017; Monios and Bergqvist, 2020). Indeed, new technology systems should be thoroughly tested to prevent the occurrence of safety incidents of UAVs in operations (Poljak and Šterbenc, 2020; Sohrabi et al., 2020). In addition to the safety of AV technologies to be verified in the tests, the integration of the use of airspace should also be designed. Rosser et al. (2018) pointed out that, in emergency scenarios, the integrated use of the airspace of the UAVs and other commercial aircraft should be carefully designed, since the unforeseen nature of the incidents leads to the emergency use of UAVs for first-aid relief. With holistic tests and experiments, more preventative measures can be integrated into AV designs (Kellermann et al., 2020), for improved health and safety purposes.

2.4.5.2 Regulation improvement

Although regulations are protecting the public from the potential safety risks brought by AVs, they are restricting the broader adoption of AVs in supply chains (Rao et al., 2016). Within the literature, appeals for improved regulations for appropriate guidance and standards for AV adoption in the supply chain are

mentioned frequently. It is essential to enact regulatory restrictions for safety, security, and privacy issues such as the no-fly zones (Haula and Agbozo, 2020; Kellermann et al., 2020) and collected data elimination protocols (Sohrabi et al., 2020). However, appropriate frameworks that guide the implementation of AVs are lacking (Rejeb, 2021; Wang et al., 2022). In addition to the regulations targeting health and safety and privacy issues, the mitigation of outcomes of unemployment and subsidising the AV adopters that relate to employment are also suggested (Sen et al., 2020; Kapser et al., 2021).

2.4.5.3 Education, promotion, and training

In the studies that discuss the customer acceptance variables of AV delivery services, familiarity is identified as one of the determinant elements (Aydin, 2019; Eißfeldt et al., 2020). Thus, it is crucial to improve the stakeholders' familiarity and knowledge regarding AVs. On the one hand, actions such as enacting intra-organisational education and training programmes for employees are raised to enhance employee skills to properly operate (reduce fear and keep safe in operations) the AVs in the supply chain (Klumpp, 2018; Dadzie and Johnston, 1991). Professionally trained employees are in high demand for AV operations (Poljak and Šterbenc, 2020). The appropriate introduction and re-skilling strategies will significantly benefit the employees and the social classes who are lower-skilled and less educated to avoid inequality (Nikitas et al., 2021). Various types of education and training are needed to match different levels of employees. On the other hand, actions such as promoting and introducing the knowledge, benefits, and risk mitigations of AVs to local communities by media and government will eliminate people's concerns regarding privacy and safety (Aydin, 2019; Sohrabi et al., 2020). These actions seek to strengthen the communities' awareness and knowledge of the technologies.

2.4.5.4 Chain-wide (re)view

Supply chains consist of various nodes and processes. Socially sustainable supply chains, therefore, call for ethical operations of each process or node of the supply chain (Sen et al., 2020). From this perspective, stakeholder engagement is essential. Engaging the stakeholders along the supply chains

collectively is effective for resistance and miscommunication mitigation (Ding, 2018; Haula and Agbozo, 2020; Vlachos et al., 2021), which therefore guarantees stakeholder participation in decision-making. Involving stakeholders such as senior-level employees and board members is especially important for the wider adoption of AVs in supply chains, for the effective designing and integration of AV technologies in the operations (Llopis-Albert et al., 2019; Mohamed et al., 2020). Collaboration between nodes can enhance communication in the supply chain, which will benefit logistics managers and decision-makers in the supply chain as a whole. In addition, establishing a relationship between stakeholders is also proposed to gain feedback after the technologies are fully implemented in the communities for better services and continuous improvement (Tatham et al., 2017; Kurniawan et al., 2021).

Based on the literature and the arguments above, a synthesised table is presented in Table 2-8. This table contains the proposed actions to mitigate the negative consequences of AV adoption and their categories. These action categories are proposed to link and target the relevant SCSS indicators. Currently, there is no extant study that comprehensively lists all these four categories.

Table 2-8 Actions and Action categories

Category	Actions suggested in the literature	References
Field experiments and tests	<ul style="list-style-type: none"> ● Preventative measures for drone designs; ● Thorough living lab experiments and tests in a small-scale place preliminary; ● Tests the integration of airspaces. 	Tatham et al., 2017; Sohrabi et al., 2020; Monios and Bergqvist, 2020; Tatsidou et al., 2019; Marsden et al., 2018; Kellermann et al., 2020; Poljak and Šterbenc, 2020; Rosser et al., 2018.
Regulation Improvement	<ul style="list-style-type: none"> ● Regulatory Measures for safety, accountability, and privacy; ● No fly zones; ● Data collection and operations protocol; ● Transnational legislative approvment; ● Regulations and legal guides, frameworks; ● Subsidising the delivery solutions; ● Regulations to mitigate the outcomes of unemployment; ● Federal guidance for adoption and certifications. 	Rao et al., 2016; Haula and Agbozo, 2020; Kellermann et al., 2020; Sohrabi et al., 2020; Rejeb, 2021; Wang et al., 2022; Sen et al., 2020; Kapser et al., 2021; Kurniawan et al., 2021; D'Amico et al., 2021; Rao et al., 2016; Nelson et al., 2019; Aydin, 2019 Rosser et al., 2018; Fagnant and Kockelman, 2015; Mohamed et al., 2020; Tatsidou et al., 2019; Hwang et al., 2021; Comtet and Johannessen, 2022.

Education, promotion, and training	<ul style="list-style-type: none"> ● Promote public benefits and risk mitigation methods; ● Introduce AVs to the communities regarding their benefits to health and safety; ● Education and training to the employees via organisational education programmes; ● Re-skill strategies for less-educated and lower-skilled employees; ● Highly trained and experienced workforce is needed. 	Aydin, 2019; Eißfeldt et al., 2020; Klumpp, 2018; Dadzie and Johnston, 1991; Poljak and Šterbenc, 2020; Nikitas et al., 2021; Sohrabi et al., 2020; Klumpp, 2018; Llopis-Albert et al., 2019; Nelson et al., 2019; Haula and Agbozo, 2020.
Chain-wide (re)view	<ul style="list-style-type: none"> ● Collective stakeholder engagement and participation for resistance mitigation; ● Build relationship between community and clinic; ● Integrate AVs into smart cities and collaborate with other technologies; ● Gain feedback and measure behaviours after the technologies are available and fully implemented in the communities. 	Amarfi-Railean, 2018; Vlachos et al., 2021; Ding, 2018; Mohamed et al., 2020; Perussi et al., 2019; Sen et al., 2020; Kurniawan et al., 2021; Llopis-Albert et al., 2019; Haula and Agbozo, 2020.

These identified actions are mainly proposed for the organisations to enact for wider AV adoption in supply chains. However, wider AV adoption requires broad approval among the society (Kurniawan et al., 2021), which asks for the social impacts of AV adoption to be addressed (Kim et al., 2022). With these arguments, the actions employed by organisations in supply chains to address the identified social impacts should be evaluated for wider AV adoption. Therefore, “the actions organisations employ to address social impacts for wider AV adoption in supply chains” serves as the second research gap that is recognised by this paper.

2.5 Discussion

The previous section extracts the positive and negative social impacts of AV adoption from the literature. On the basis of the definitions of SCSS indicators in the general context, this section relates the social impacts to the relevant indicators to investigate the SCSS aspects in the AV adoption context. After that, a range of 12 research directions are presented. This introduces the two research perspectives in the empirical research. Social impacts, stakeholders, actions, action categories, and research directions suggest avenues for the next stage of research.

2.5.1 Contextual SCSS indicators

Following the requirement to develop contextual SCSS indicators for SCSS concept development (Denu et al., 2023), this study aims to understand the relevant social sustainability indicators in the context of AV adoption in supply chains. After reviewing the SCSS indicators in the seminal literature, this study categorises the identified social impacts of AV adoption under the relevant indicators, to determine the context-specific SCSS indicators that are especially relevant in the AV adoption scenario. The categorisations are presented in a conceptual framework (Figure 2-3) that illustrates the social sustainability of AV adoption in supply chains. Such attempts to investigate contextual SCSS implications support the development of SCSS concepts.

2.5.1.1 SCSS indicators from the existing seminal literature

According to Ahi and Searcy (2015a), an indicator is considered to be a sign of showing the condition or existence of something. As mentioned in the first section, the SCSS indicators are those measures that qualitatively present the SCSS performance in various aspects, including human safety, labour conditions, welfare, community development, etc. (Ahi and Searcy, 2015b). With the aim of understanding the social sustainability of adopting AVs in supply chains, the researcher of this study is dedicated to gathering the social dimension of indicators from the seminal publications on supply chain sustainability. After reviewing the supply chain sustainability seminal papers and as well as the literature included in this review that includes SCSS as a conceptual base, a summary of SCSS indicators accompanied by the definitions is presented in Table 2-9.

Table 2-9 Definitions of SCSS indicators in the conceptual literature

Social indicators	Source*	Description
Community	Community (3)	The interactions between supply chain organisations and local communities, such as supporting community projects, community complaints, community connection and networks.
Culture	Culture (4)	A shared, organisation-wide vision and core value, which also generate internal drive and passion.
Customer satisfaction	Customer Satisfaction (3)	Customer perception in terms of the products or services provided by the supply chain organisations.
Diversity and Equality	Gender (2)	Equal treatment of different genders, catering to their needs, and assigning equal rights at the workplace. Include the disabled/marginalised people in the workplace, and also treat people equally regardless of their religion, race, and ethnicity.
	Disabled/Marginalised People Inclusion (2)	
	Minority Development (2)	
	Diversity (4)	
Education	Education (1)	Education includes elements such as the percentage of employees trained, and supporting educational institutions.
Employment	Employment (1) (3)	Labour inputs and outputs, such as the unemployment issue, labour productivity, and employee satisfaction.
Health and Safety	Health (1)	Physical and mental health that are directly related to safety and hygiene at work. It also describes hazardous working conditions which could leave long-term effects on the personal health of the worker. Work by children under the age of 18 is hazardous to the physical or mental health of the child.
	Public Safety (1)	
	Safety (4)	
	Health and Safety (2) (3)	
Housing	Housing (1)	Housing indicator includes the public's living conditions, quality of living and the neighbourhood.
Human rights	Human Rights (2)	The rights are inherent for all human beings, irrespective of demographic status. Without discrimination is the core of human rights.
	Human Rights (4)	
Labour conditions	Labour conditions (2)	Working conditions of the employees include low wages, extended hours of working, right to form unions, contract labour and exploitation of the employees.
	Income (1)	
	Child Labour (2)	
Philanthropy	Philanthropy (4)	The voluntary or discretionary decision of donating money or other corporate resources to social causes.
Quality	Quality (3)	The quality and quality improvement of the product or services provided by the supply chain.
Regulation	Regulation (3) (4)	Binding government policies and documents that are influenced by environmental and social concerns.
Reputation	Reputation (4)	The image of an organisation which represents public sentiment in terms of the actions of the organisation.
Risk Management	Risk Management (4)	The ability to understand and manage the risks, for more resilient and agile supply chains.
Transparency	Transparency (4)	Collaborate with stakeholders for sharing of monitoring information and enhancing remediation to improve supply chains.
Welfare	Welfare (3)	Well-being, happiness and quality of life

Source*: 1. To and Lee, 2017; 2. Yawar and Seuring, 2017; 3. Ahi and Searcy, 2015a, 2015b; 4. Carter and Rogers, 2008.

2.5.1.2 Social impacts and SCSS indicators

The collection of positive and negative impacts of AV adoption in supply chains serves to fulfil the first research objective. Meanwhile, the identified impacts provide the base for the second research objective, which relates to social sustainability indicators. On the basis of the listed SCSS indicators and their definitions, the 20 identified social impacts are allocated under the relevant indicators. It is possible that one impact relates to multiple SCSS indicators, while in this study, one impact is linked with only one most directly and primarily relevant SCSS indicator. For example, the impact of “workforce health and safety” is relevant to both health and safety and employment. As it concerns the health and safety impacts on the employees, this impact is placed under the “health and safety” indicator. In this context, there are six indicators found relevant to be related to the identified social impacts. Figure 2-3 presents the proposed links between the social impacts and SCSS indicators in this context.

2.5.1.2.1 Health and Safety

This indicator covers broadly the physical and mental health of the relevant entities in a context (Carter and Rogers, 2008; To and Lee, 2017). According to the definition, the entities’ health and safety issues are all under the scope of this indicator. Hence, positive impacts including life-saving, road traffic safety, workforce safety, and customers’ health and safety are included. The safety incidents from the negative impacts are also categorised under this SCSS aspect.

2.5.1.2.2 Customer satisfaction

Customer satisfaction represents the customers’ thoughts, preferences, and expectations in terms of the products or services offered by supply chain organisations (Ahi and Searcy, 2015a, 2015b). Following the definition, the impacts regarding faster and more customised delivery services are categorised beneath this SCSS indicator. These two impacts represent the consumers’ (end-customers’) expectations of the improved delivery services provided, which match the customer satisfaction concept.

2.5.1.2.3 Transparency

Transparency calls for collaboration with stakeholders for information sharing and monitoring to improve supply chain visibility (Carter and Rogers, 2008). This means that impacts that relate to information visibility and security are appropriate to be classified under this aspect. With this consideration, assets and products security, information integration and visibility, as well as privacy and cybersecurity concerns are categorised under the transparency indicator.

2.5.1.2.4 Employment

This category addresses issues including labour inputs and outputs, unemployment, productivity, etc. (Ahi and Searcy, 2015a). This means that the social impacts on employees in the workplace should be included. Since this study exclusively discusses social implications, elements such as salaries, productivity, and efficiency that are shared within the economic dimension are excluded from the scope. Therefore, impacts including labour shortage filling, new job creation, and unemployment in logistics sectors and supporting industries are relevant to employment.

2.5.1.2.5 Diversity and Equality

This indicator covers issues including gender equality, diversity, disabled people inclusion, minority development, etc (Carter and Rogers, 2008; Yawar and Seuring, 2017). The findings from this SLR did not indicate very much about this SCSS aspect. In this study, only the gender equality and stereotype mitigating from the positive list and the social class inequality from the negative list of the social impacts are included.

2.5.1.2.6 Welfare

The description of welfare, “well-being, happiness, and life quality” (Ahi and Searcy, 2015a) is covered broadly. Based on this description, two main aspects are included in this indicator: human interaction, and traffic congestion. The positive impacts regarding the reduced usage of ground traffic space as well as the smoother road traffic flows are classified under the traffic congestion, while

reduced communications and human interactions among various entities are involved in the negative perspective of welfare.

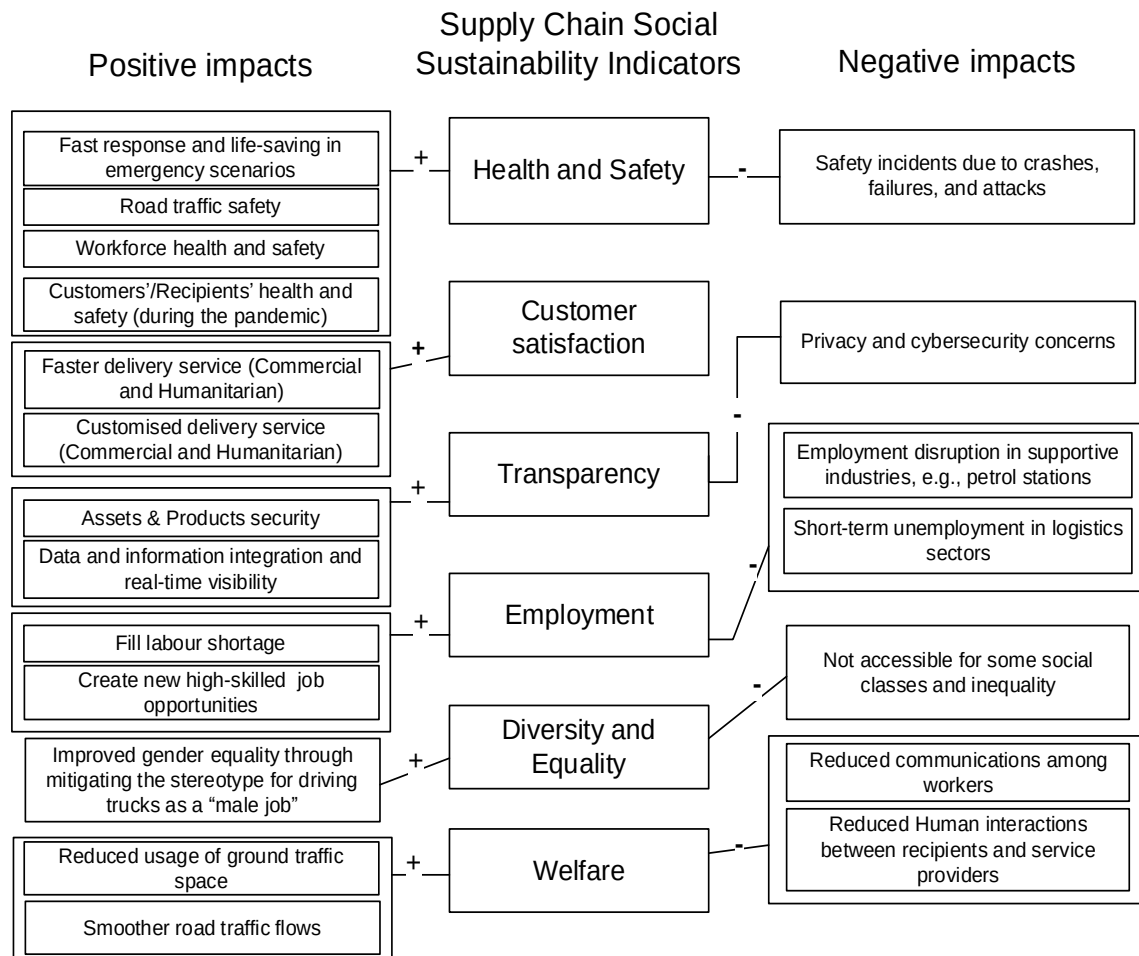


Figure 2-3 Links between social impacts and SCSS indicators in the AV adoption context

2.5.2 Potential research directions suggested

After discussing the social implications of AVs from the existing literature, a summary of the future research suggestions is captured to map the key directions for future research regarding the SCSS of AV adoption. All of these research suggestions are gathered from the literature pool. After synthesising the key aspects of these research suggestions, there are 12 key research directions suggested by the literature (shown in Table 2-10). These directions include four main dimensions: conducting longitudinal research with appropriate methods, in-depth research in social sustainability with more stakeholders, managing AV

adoption in supply chains and in a wider variety of contexts, and interactions with humans and other technologies.

2.5.2.1 Conducting research in various contexts with appropriate methods

The research into social sustainability implications of AV adoption is emerging and under-developed yet. According to Saunders et al. (2019), it is necessary to use qualitative methods to conduct exploratory studies to establish a foundation for AV adoption context-specific SCSS concepts. This requires brainstorming the social impacts among research participants through open-ended questions with typical qualitative methods such as interviews (Edmondson and McManus, 2007; Symon and Cassell, 2012). After the social sustainability concepts are matured, quantitative methods can be applied for concept evaluation and testing (Edmondson and McManus, 2007). By quantifying SCSS indicators with context-specific indices, future research can achieve detailed measures of SCSS performance of AV adoption across diverse scenarios. Conducting surveys is a feasible option recommended in the literature (Serrano-Hernandez et al., 2021; Mangiaracina et al., 2019). With more studies conducted in wider contexts, more detailed quantifiable variables can be identified and tested (Hwang et al., 2021b) to provide insights that construct the SCSS performance of AV adoption.

Practising future research can be facilitated by following a long-term track of the changes in the social impacts (Kapser et al., 2021). AVs are not yet matured technologies that are widely available in the supply chain. This on the one hand leads to a low familiarity of the technology among the stakeholders. On the other hand, this leads to more negative perceived social impacts than benefits. Future research can capture the changes in social impacts as AVs are continuously adopted in supply chains – social implications potentially differ at various stages of AV maturity and adoption. In addition, future research should begin by identifying key social impacts at different stages during the period, followed by longitudinal examining to track the changes in SCSS metrics. Therefore, studying the social impacts of AV adoption with appropriate methods over a wider period is a necessary route for future research.

2.5.2.2 In-depth research in social sustainability with more stakeholders

The social impact of AV adoption on end customers has been extensively studied. Analysing social impacts on a single stakeholder group offers a limited perspective on the overall social sustainability of AV adoption in the supply chain. In order to rigorously discuss social sustainability in-depth, other stakeholders should be studied (Serrano-Hernandez et al., 2021; Kapser et al., 2021). In addition to end customers, other stakeholders, such as various levels of employees (Llopis-Albert et al., 2019), technology providers, and policymakers (Kurniawan et al., 2021) are involved in AV adoption. Currently, a comprehensive exploration of stakeholders and how they are involved in AV adoption (e.g., to what degree are they affected by AV adoption, or are they affecting AV adoption) is lacking. Future research is needed to widely explore the stakeholders and deeply investigate the social impacts that are in accordance with these stakeholders. Such efforts support the further development of SCSS concepts in the AV adoption context.

2.5.2.3 Managing AV adoption in supply chains and in a wider variety of contexts

Organisations potentially operate differently when adopting AVs compared to conventional vehicles. Therefore, research into new business models for AV adoption is raised extensively (Monios and Bergqvist, 2020; Gružasuskas et al., 2018; Mangiaracina et al., 2019). New business models are suggested to highlight network and fleet optimisation, risk management, and stakeholder feedback management (Monios and Bergqvist, 2020; Aydin, 2019; Sohrabi et al., 2020). The adoption of new technologies in operations requires organisations to work out new working modes for managing AVs to improve efficiency (Bechtsis et al., 2017). This derives future discussions of using appropriate types of AVs on the basis of the application context, for example, selecting the most efficient innovative solution after comparing a wide range of technologies in a specific last-mile delivery context (Mangiaracina et al., 2019). Therefore, it is important to distinguish the impacts of different AV types in specific contexts, and also the impacts of a type of AV in different contexts. Regarding the geographical context, Table 2-3 shows that the studies in this field are mainly conducted in Western

European countries, the US, and Asia-Pacific countries. Different geographical contexts differ in infrastructure, AV adoption scenarios, and local technology development status. Whether the social implications in these contexts apply to other geographical contexts with limited research focus is unknown. Hence, investigating and comparing the social impacts of AV adoption across a greater number of geographical contexts will benefit the development of SCSS and related concepts. As a result, given the variation in application contexts across distinct AV types, a detailed investigation of their social implications within various scenarios is necessary (Eiðfeldt et al., 2020; Kaper et al., 2021).

2.5.2.4 Interactions with humans and other technologies

This research investigates the social dimension of sustainability, which by definition means the “human” side (Huq et al., 2014) of AV adoption in the supply chain, further research into the interactions between AVs and human beings is applicable. Under the topic of Industry 5.0, human-robot interaction calls for better device design to enable humans to safely and efficiently interact with robotic systems (Klumpp, 2018; Nahavandi, 2019). Future research is needed to understand how human-robot interactions in supply chains affect the social sustainability of various stakeholders. In addition, future research can evaluate whether the social impact findings on AV adoption can inform research on the social sustainability of other smart technology adoption scenarios (Vlachos et al., 2021). Findings from research on the social implications of other technology adoptions also potentially complement and strengthen the existing results in this context, which can be carried out in future studies. When conducting logistics tasks, AVs are not independent, rather, they rely on a synergistic integration with other technologies like IoT, cloud computing, and AI for operations. This calls for future research in standards and impacts of the interoperability of AVs with other technologies (Comtet and Johannessen, 2022; Frederico et al., 2019; Rejeb et al., 2021).

The summary of the research directions is presented in Table 2-10.

Table 2-10 Research directions suggested in the literature

Author	Paraphrased research suggestions	Research Directions											
		1	2	3	4	5	6	7	8	9	10	11	12
<i>Haula and Agbozo, 2020</i>	1. More databases to be involved, 2. more geographical regions involved, 3. security and privacy aspects.	X	X				X						
<i>Kapser and Abdelrahman, 2020</i>	More than half of the participants are not familiar with the ADV delivery service. Future research should focus on the participants more familiar with this kind of delivery.		X	X									
<i>Sellevdal et al., 2020</i>	UAS-logistics system determines the societal, health, safety, labour and social acceptance impacts.			X			X						
<i>Klumpp, 2018</i>	Human-artificial interaction and acceptance			X	X		X						
<i>Dhote and Limbourg, 2020</i>	Case of other regions, other attributes of transport - service, accessibility, reliability, safety, security, flexibility	X	X				X						
<i>Kellermann et al., 2020</i>	Calls for social sciences engaging with emerging transportation technologies in general as well as for disciplines of transport and urban planning or civil society, the public acts as a central stakeholder in this innovation process - and avoids potential societal conflicts in the future.		X	X		X	X						
<i>Tatham et al., 2017</i>	Field trials are needed		X										
<i>Sohrabi et al., 2020</i>	1. More to focus on rural and SAE level 3 & 4 vehicles, 2. Research the uncertainties shown in the framework. 3. More quantitative research as well.		X			X		X			X		
<i>Bechtsis et al., 2018</i>	The adoption of IAV in last-mile delivery and pharmaceutical supply chain								X		X		
<i>Hwang et al., 2021a</i>	1. Other delivery services. 2. meaningful to assess potential barriers in better predicting the formation of consumers' acceptance behaviour towards drone food delivery services.			X						X	X		
<i>Hwang et al., 2019; 2021b</i>	MCI in other contexts - different types of data collection methods.	X				X				X			
<i>Sen et al., 2020</i>	Any aspect that improves the public's standards of living, starting from human health should be prioritised.			X			X			X			
<i>Monios and Bergqvist, 2020</i>	1. A new modified model of the freight transportation system is needed. 2. New business model.							X					
<i>Gružasuskas et al., 2018</i>	The proposed framework is to be adopted in other industries, and more sustainable supply chain strategies are to be raised.							X					
<i>Aydin, 2019</i>	Developing effective risk mitigation and response strategies after public acceptance to be achieved shortly.			X				X					
<i>Eißfeldt et al., 2020</i>	1. Further research should also consider different drone types and their functions, as this might have an impact on public acceptance. 2. more investigations focus on the improvement of social acceptance for drone applications that are currently not very high.			X			X			X	X		

<i>Ding, 2018</i>	More empirical data in the future; How smart logistics based on Industry 4.0 can provide a sustainable and agile delivery service can be investigated.		X				X						
<i>Bechtsis et al., 2017</i>	Currently only in warehouse management and distribution and in the manufacturing division, a lack of exploitation across the entire spectrum of SC operations; Management of a fully automated fleet in the supply chain.		X					X	X				
<i>Io and Lee, 2019</i>	Future studies may focus on analysing comments about the use of drones for delivery.		X	X		X							
<i>Mangiaracina et al., 2019</i>	1. More innovative solutions to investigate, and their business models and cost-benefit factors; 2. Wider geographical contexts of these solutions.						X				X	X	
<i>Cheema et al., 2022</i>	A drone trajectory optimisation and path planning are to be added to enhance the efficiency of the delivery process to be more autonomous. Also, time optimisation for drones is to be pursued. A privacy-preserving mechanism is required to avoid revealing information.			X		X	X						
<i>Rejeb et al., 2021</i>	Interoperability of drones with other technologies.											X	
<i>Engholm et al., 2021</i>	1. More environmental and economic impacts of DL-trucks on future transport systems and society; 2. Network modelling, 3. Social impacts resulting from the DL-trucks					X	X	X					
<i>Serrano-Hernandez et al., 2021</i>	1. More information to be obtained from the population to better understand the significant approval for the aerial distribution - survey; 2. more groups other than resident evaluations - other stakeholders; 3. future work for regulators; 4. more geographic contexts.	X	X	X		X							
<i>Kapser et al., 2021</i>	1. Further research should explicitly target actual users to identify the differences in users' behavioural intentions but also to investigate actual use behaviour; 2. Further studies should take a longitudinal approach and should collect data to compare findings before and after the virus outbreak; 3. More geographical regions to be included; 4. Other AVs to be investigated.	X	X	X								X	
<i>Vlachos et al., 2021</i>	1. Future research may rely on multi-case studies that can test and validate the action plan in wider contexts, 2. researchers can use other research methods to collect and test key data; 3. an action plan is needed. 4. future studies can test how the key concepts from socio-technical theory can be applied in other smart scenarios.		X			X		X					X
<i>Comtet and Johannessen, 2022</i>	Proof of concepts: The usage of drones in the organisation processes – to what extent in-depth; Whether drones in combination with other technologies have the power to transform the healthcare system?								X			X	X

1. More geographical contexts;
2. More datasets and databases;
3. Focus on more stakeholders
4. Human-robot interactions;

5. More data collection methods;
6. More social aspects to be covered;
7. New business models for AV adoption;
8. Wider SC processes to cover;

9. More variables in quantitative studies;
10. More and detailed AV types and adoption contexts
11. Interoperability with other techs
12. Transferrable concepts into other smart scenarios.

2.5.3 Two perspectives of the empirical studies.

The four categories of directions provide considerable paths for future research. Relating to the aim of this thesis, the empirical research seeks to verify and refine the social implications and the actions that are identified from the literature with real-world insights. In addition, a lack of stakeholder analysis is the first research gap. The empirical research seeks to fill the gap by using the qualitative method (Saunders et al., 2019) to explore the stakeholders in the AV adoption context and to analyse their roles. This links to the first and second categories of the research direction: more research methods to explore more stakeholders and investigate social impacts deeper. Stakeholders are essential in SCSS research and are closely related to the social impacts. Therefore, exploring the stakeholders and refining the social implications of AV adoption in the supply chain serves as the first research perspective to understand the overall research question: how does AV adoption affect SCSS?

From the arguments presented in the previous sections, the second research gap is a lack of analysis into the actions that organisations implement to improve SCSS performance to facilitate wider AV adoption in the supply chain. When adopting AVs, organisations at various AV adoption stages act differently, which is not reflected in the literature. Hence, aligning the actions with the organisational AV adoption stages is necessary to analyse how organisations act to address the social implications and improve SCSS performance. Therefore, a deeper analysis of the actions serves as the second research perspective.

As mentioned in Chapter 1.6.2, the two perspectives are closely related to each other in that, the outcomes of the first perspective provide input for the second perspective to address. Therefore, follow-up studies seek to investigate these two perspectives more deeply to form a comprehensive understanding of “how AV adoption affects SCSS”. Figure 2-4 presents the perspectives of the two empirical papers for the next stage.

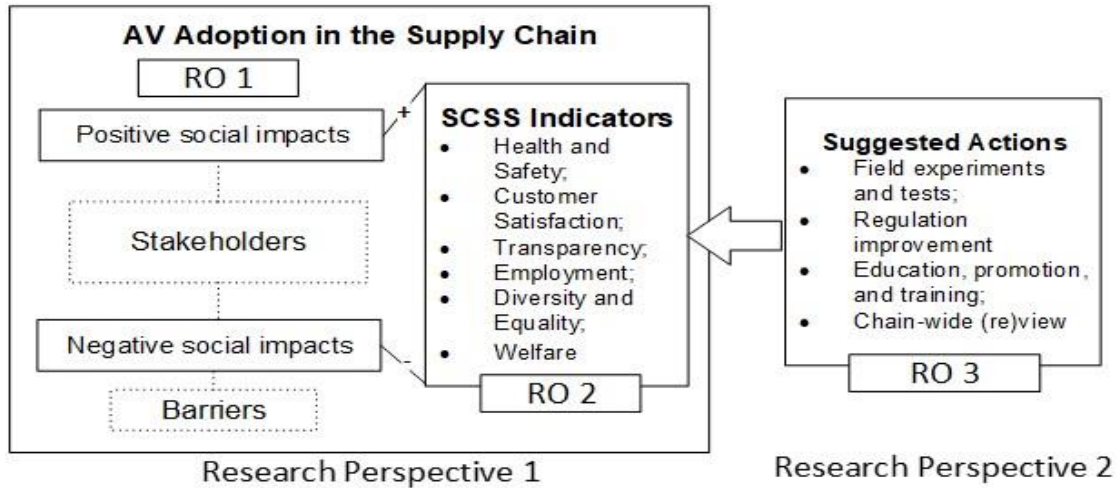


Figure 2-4 Two perspectives of understanding the SCSS of AV adoption

2.6 Conclusion

This SLR gathers the social impacts of AV adoption in the supply chain. Both positive and negative impacts brought by UAVs and UGVs adopted in the commercial and humanitarian supply chain are synthesised from the existing literature. In addition to these impacts, this paper also gathers a series of actions that are suggested by the literature to address the negative impacts of wider adoption of AVs in the supply chain and a socially sustainable supply chain.

2.6.1 Contributions

This review defines the types of autonomous vehicles adopted in the supply chain. This SLR is, to the authors' knowledge, the first piece of work on the social impacts of both UGVs and UAVs in commercial and humanitarian logistics contexts.

This study first explores the positive and negative social impacts on commercial and humanitarian and healthcare supply chains; 13 positive and seven negative social impacts are identified. All these impacts are connected with six relevant social sustainability indicators according to the definitions of these indicators: Health and Safety, Customer Satisfaction, Employment, Transparency, Diversity and Equality, and Welfare. A model that connects the impacts and sustainability indicators is built upon the outcomes. This finding attempts to explain that SCSS

is affected by these positive and negative social impacts in the context of AV adoption. Hence, this paper contributes to the SCSS concept by exploring the specific context-based social sustainability indicators (Ahi and Searcy, 2015a; Denu et al., 2023) with a conceptual model. This conceptual framework illustrates the social sustainability of AV adoption in supply chains. In addition to the impacts, four categories of actions are also identified for wider adoption of AVs as well as improved SCSS, namely: field experiments; regulation improvement; education, promotion, and training; and chain-wide integration. Therefore, this paper proposes two research perspectives: refining the matching of social impacts and SCSS indicators and investigating the matching of suggested actions and SCSS aspects. This literature review provides a solid conceptual foundation for future empirical research.

For practical implications, this review first presents a holistic overview of the key social impacts and SCSS aspects to focus on. These outcomes serve as a foundation for organisations to establish a tailored overview of key performance indices regarding social issues. This review also provides a guide for organisations in the supply chain to enhance the adoption of AVs in operations when considering social demands from stakeholders. In addition, this review enlightens organisations at diverse stages of AV adoption to understand what actions potentially work for SCSS improvement. Finally, this research raises recommendations to legislative authorities to reflect the existing regulations and enact more suitable laws for the broader adoption of AVs in the supply chain.

2.6.2 Research limitations and future research suggestions

This study has a few limitations. First, it focuses on AV adoption in the supply chain and the social dimension of sustainability, an area that is still in its infancy and hence an emerging field of research. AVs have not been broadly adopted in the supply chain yet so the impacts and relevant social sustainability indicators should be verified as the AVs are incrementally adopted. This study mentioned some of the stakeholders that are potentially related to the social impacts and social sustainability, while the existing literature did not explicitly emphasise them. In addition, the empirical data the existing literature pool collects are mainly

from Germany, America, and mainland China, so the findings are not generalised enough for wide geographical applicability. Finally, the review is limited to papers written in English, and contributions published in other languages are, therefore, not captured.

In addition to the 12 classified research directions from the literature, this paper provides several research paths based on the outcomes and limitations. First, the two perspectives proposed in the previous section are to be further verified in future research. On the basis of these two perspectives, the specific stakeholder groups should also be identified in future empirical studies to strengthen SCSS conceptualisation, since “social sustainability” discusses the “human side of sustainability issues” (Huq et al., 2014), so that the analysing stakeholders is very important. Currently, the existing literature investigates in-depth the consumer and local community side of the social impacts of AV adoption but only presents partial stakeholder groups. More exploratory studies should be conducted to identify other stakeholders using a qualitative research method. Since research into social sustainability is still lagging, compared to the other two sustainability dimensions, more qualitative studies should focus on identifying contextual SCSS indicators, to develop SCSS concepts further. Explicit stakeholders, social impacts, and relevant sustainability indicators should be clarified to strengthen the research on SCSS. Such research should also be conducted in wider geographical contexts to benefit the generalisation of SCSS concepts.

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3 Paper 2: Investigating the Social Sustainability of Autonomous Vehicle Adoption in Supply Chains: A Delphi Study

3.1 Introduction

Autonomous vehicles (AVs) include uncrewed ground vehicles (UGVs) and uncrewed aerial vehicles (UAVs) which are increasingly matured technologies (Rai et al., 2022). With constant tests and small-scale deployment in logistics providers such as Alibaba, JD.com, and Zipline, their potential for long-term economic and environmental benefits is proven (Tang and Veelenturf, 2019). However, academic research and knowledge development regarding the social impacts of AV deployment in the supply chain are lagging (Monios and Bergqvist, 2020; Van Meldert and De Boeck, 2016).

Social impacts are defined as the social outcomes of a series of activities that are relevant to people's welfare and life quality improvement issues (Rawhouser et al., 2019; Esteves et al., 2012). When related to the AV adoption context, social impacts represent the social outcomes that affect the relevant groups in the supply chain when organisations deploy AVs in their operations. These relevant groups of people are stakeholders (Freeman, 1984). From Chapter 2, the social impacts and relevant stakeholders are closely related to the investigation of supply chain social sustainability (SCSS) performance in this context. However, the validity of these impacts collected from the literature still needs to be evaluated in an empirical study. As the first research gap, the stakeholders were not emphasised in the existing literature, which undermines the contextual SCSS conceptualising. The questions regarding what the social impacts are and how important they are; who the stakeholders are and how relevant they are in this context remain to be explored, refined, and assessed.

The questions relate to the arguments by Mani et al. (2016), that researchers need to understand to whom the focal firm is socially responsible and what issues need to be addressed, to explore SCSS further. According to Freeman (1984), stakeholders are internal and external groups or individuals who can either influence or be influenced by the achievement of the organisation's objectives.

This is accompanied by Spence and Bourlakis's argument (2009) that SCSS focuses on the ethical and social benefits to be gained within the whole supply chain, in collaborating with supply chain partners (Maloni and Brown, 2006), under a chain-wide consideration. This requires the social sustainability of the supply chain to be managed among all the stakeholders regarding their social sustainability performance (Hussain et al., 2018), which calls for comprehensive stakeholder identification as the first step to realise this consideration.

In general, SCSS is assessed through measures such as equity, philanthropy, health and safety, human rights, welfare, and employment (Mani et al., 2018; 2016). In some specific scenarios, not all these measures apply to assessing social sustainability. Hence, to drive social sustainability conceptualisation in-depth, there is a need to identify context-specific sustainability indicators and stakeholder groups (Ahi and Searcy, 2015).

The positive and negative social impacts of AVs have been discussed in the literature. Some typical issues include the use of long-haul freight UGVs to prevent fatal human-error accidents; and employment issues such as new job creation, labour shortage mitigation, and unemployment. It is important to consider the issues that concern the stakeholders, as gaining social approval is essential to the wider AV adoption in logistics and the supply chain (Kim et al., 2022; Kurniawan et al., 2021).

Based on the arguments above, this research aims to deepen the knowledge of the AVs' social sustainability in the supply chain. This is realised through the exploration of the social impacts and stakeholders, as well as the evaluation of the importance of these elements. In order to gain wide social approval regarding AV adoption, it is sensible to gain group approval regarding the key SCSS implications and the stakeholders of AV adoption as the first step. With these requirements, the Delphi method is a viable data collection approach that gathers opinions from experts with diverse backgrounds to explore and form a consensus regarding a topic (Seuring and Müller, 2008; Okoli and Pawlowski, 2004). The exploratory and iterative nature of the Delphi method provides a viable data

collection and knowledge development protocol for this study. Therefore, this paper aims to answer the following research questions (RQs):

RQ1: What are the SCSS implications of AV adoption in supply chains?"

RQ2: What are the key stakeholders involved in the context of adopting AVs in supply chains?

The RQs are further addressed by the following research objectives (ROs) respectively:

RO 1: To empirically refine and evaluate the social impacts and relevant SCSS indicators in the AV adoption context.

RO 2: To empirically identify and evaluate the key stakeholders in the context of AV adoption in supply chains.

This paper is structured as follows. Relevant literature is reviewed for this research in Section 3.2, followed by the detailed arguments of the research method. The results regarding the specific social implications and key stakeholders of AV adoption in supply chains and the detailed analysis of these results are presented in Sections 3.4 and 3.5 respectively. This is followed by the theoretical and managerial contributions accompanied by limitations and suggested research paths as concluding remarks.

3.2 Review of the literature

This section provides a comprehensive review of the literature which relates to the domains of this research. The review starts with the introduction of social impacts under general circumstances. This is followed by an explanation of social sustainability and the indicators. Stakeholder identification and classification play an important role for organisations to manage stakeholders. Such attempts help understand who the relevant groups are. Since SCSS considers the human side of sustainability, stakeholder identification and classification help structure a strengthened argument regarding SCSS. The description of the AVs adopted in the supply chain is the context of this study and is positioned in the final part of this section.

3.2.1 Social impacts and supply chain social sustainability

This study investigates SCSS through the distinct social impacts of AV adoption in the supply chain. Hence, it is necessary to first review the social impacts under general circumstances, and then tailor the concepts to this specific context. The same logic applies to the social sustainability indicators as well. In addition, this section discusses the stakeholder approach and its application in this context by relating to social sustainability concepts.

3.2.1.1 Social Impacts

Under general circumstances, the term “social impact” is defined as “the outcomes resulting from prosocial behaviour, that address social problems and be responsible for environment, community, workers, customers, and governance, for an improved quality of life and social welfare” (Esteves et al., 2012; Rawhouser et al., 2019). According to Becker (2001), the measuring process of these consequences, namely, “social impact assessment” consists of three levels: micro-level (individuals), meso-level (organisations), and macro-level (general social systems). These three levels are considered the three benchmarks of target groups to assess the social consequences of an organisation's activity. Apart from this, Therival and Wood (2017) developed a framework to assess and manage the social impacts of a project through a structured procedure and feedback loops. As mentioned by Rawhouser et al. (2019), specific types of social problems require a tailored assessment to be created. This argument is aligned with the appeal raised by Ahi and Searcy (2015) that the measures assessing social sustainability should be context-specific, relating to various stakeholder groups.

In the supply chain, social impact assessment encourages the implementation of unified social performance standards and provides awards for good social performance among the supply chain stakeholders (Esteves et al., 2012). Numerous standards that establish social responsibility and performance norms are mentioned in the existing literature (Agyemang et al., 2022), including ISO26000 (ISO, 2010) (standards on fundamental organisational duties and general knowledge for social responsibility); United Nations Global Compact

(UNGC, fundamental principles for companies to focus on employment and organisational management issues) (UN, 2020); and SA8000 (SAI, 2014) (specifically on employment treatment in organisations). As Rawhouser et al. (2019) argue, the social impacts are important performance-based dependent variables that present the consequences of corporate actions. These aforementioned aspects together with the standards form assessments for social impacts and social sustainability performance.

3.2.1.2 Supply chain social sustainability (SCSS) and indicators

As one of the three pillars of sustainability, SCSS concerns the human side of sustainability which focuses on the health and well-being of the groups involved in the supply chain processes (Huq et al., 2014). One of the well-accepted arguments is that corporate social responsibility (CSR) provides theoretical roots for the development of SCSS concepts (Mani et al., 2016; Klassen and Vereecke, 2012). CSR calls for a corporation to be ethically and socially accountable to a series of entities including customers, employees, unions, government, NGOs, communities, regulators, supply chain members, and media (Maloni and Brown, 2006). These groups that can affect or be affected by the operations of the organisation are called “stakeholders” (Freeman and McVea, 2001). The focal organisation is required to be ethical and responsible to stakeholders for the social outcomes of its operations.

In supply chain management, although supplier responsibility assessment and sustainable buyer-supplier relationship were emphasised (Mani et al., 2018; Yawar and Seuring, 2017), all the other internal and external stakeholders should be focused on to gain ethical and social benefits within the whole supply chain (Spense and Bourlakis, 2009; Yu et al., 2023). Hence, supply chain managers are under pressure to behave socially responsibly throughout the whole chain and for all of the stakeholders (Hussain et al., 2018; Donaldson and Preston, 1995).

Concerning the assessment of SCSS performance, one of the key reasons is the difficulty in quantifying the measures (Ahi and Searcy, 2015). There is no singular definition of social sustainability, so it is reflected in a variety of key aspects

regarding social issues relevant to sustainability, such as human rights, safety, dignity, equality, etc. (Hussain et al., 2018). In supply chains, the social impacts relating to the social sustainability aspects that organisations' activities generate, consist of SCSS (Hussain et al., 2018; Klassen and Vereecke, 2012). The aspects that can qualitatively present SCSS performance are called SCSS indicators (Ahi and Searcy, 2015). In the general conditions, SCSS indicators include but are not limited to equity, reputation, customer satisfaction, philanthropy, safety and health, human rights, welfare, labour, and product responsibility (Mani et al., 2018; 2016a; Carter and Rogers, 2008; Yawar and Seuring, 2017). Since not all these indicators suit every supply chain context, it is necessary to explore particular indicators concerning the relevant stakeholder groups to meet their demands and enquiries in specific contexts (Ahi and Searcy, 2015; Carter and Rogers, 2008; Denu et al., 2023).

3.2.1.3 Focusing on stakeholders and SCSS

A broadly recognised definition for a stakeholder is “any group or individual who is affected by or can affect the achievement of an organisation’s objectives” (Freeman, 1984; Freeman and McVea, 2001; Hussain et al., 2018). Different stakeholders vary in roles and importance levels for the organisations (Freeman, 1984; Huge-Brodin et al., 2020), which means that stakeholder identification and classification are important steps for managing stakeholders (Sarkis et al., 2011). For instance, the three-attribute criterion is one of the tools for stakeholder identification and classification: power, legitimacy, and urgency (Freeman and McVea, 2001; Mitchell et al., 1997; Co and Barro, 2009). These attributes represent the dynamics of interactions among the stakeholders and the focal organisation. Entities who are positioned in at least one attribute of this framework can be considered as stakeholder groups of the organisation. In addition, Sarkis et al. (2011) and Olander (2007) classify stakeholders into two essential categories: internal stakeholders – who are actively involved in the organisation's execution, and external stakeholders – who are not directly involved but are affected by the execution.

In the supply chain, managers need to understand the roles and concerns of all the stakeholder groups to develop short-term objectives and long-term business

strategies with their support, to improve supply chain performance (Freeman and McVea, 2001; Hussain et al., 2018). By managing the stakeholders, Co and Barro (2009) conclude that improved performance can be achieved if the supply chain managers build collaborative relationships with the strategic partners and other stakeholders. Similarly, Freeman and McVea (2001) argue that there is a positive correlation between stakeholder management and the social and financial performance of an organisation. Various stakeholder groups are involved in multiple stages in the supply chain and place incremental requirements on the organisation managers to address environmental and social issues to affect the performance (Carter and Easton, 2011; Hussain et al., 2018). Different stakeholders have heterogeneous impacts on the organisations' operations, and either positively or negatively influence the organisations' performances (Prataviera et al., 2023). Therefore, stakeholders play crucial roles in supply chain performance improvement.

Social sustainability represents the human side of sustainability (Huq et al., 2014), and the stakeholders remain essential in the SCSS concept (Hussain et al., 2018). Hence, when analysing social sustainability indicators in a specific context, it is necessary to understand who those indicators are related to. This means that identifying the contextual stakeholders is crucial to investigate SCSS. Chapter 2.5.2 captured a list of stakeholders that are implicitly mentioned in the literature (Table 2-7). However, a comprehensive listing of stakeholders is not yet presented and fully identified. For instance, there are distinct levels of employees in supply chains – various levels of managerial personnel, operational level employees, etc. (Hohn and Durach, 2021). The sole existence of “employee” in Table 2-7 is far too inclusive. The distinct levels of employees in supply chains have received limited focus. In addition, the illustration in “how important are these stakeholders” (Stieb, 2009) – to what degree are these stakeholders affected, is also vague. The degrees of being affected by or affecting an organisation's execution among managerial employees potentially differ from those of operational employees (Llopis-Albert et al., 2019). Therefore, it is necessary to identify contextual stakeholders to support the conceptualisation of SCSS.

3.2.2 Autonomous vehicles in the supply chain

After discussing SCSS in general circumstances, this part specifically focuses on SCSS in the AV adoption context. The types of AVs in the supply chain are introduced first, followed by the illustration of context-specific SCSS indicators.

3.2.2.1 AV types and their applications in the supply chain

In this research context, AVs include both UAVs and UGVs (Rai et al., 2022). For UGVs, a well-accepted standard of automated driving level published by the Society of Automotive Engineers (SAE) categorised AVs into three levels: Level 3 (conditional automation), Level 4 (high automation) and Level 5 (full automation) (Klumpp and Zijm, 2019; Wang and Li, 2019). Any ground vehicles categorised at or higher than level 3, are recognised as AVs (Rai et al., 2022). Typical UGVs in the logistics sectors include automated guided vehicles (AGVs), autonomous mobile robots (AMRs), and heavy-load uncrewed trucks (Flämig, 2016; DHL, 2020).

AGVs have served the logistics sectors for more than 50 years as an initial form of AVs in defined territories such as harbours, warehouses, and manufacturing plants (Flämig, 2016; Van Meldert and De Boeck, 2016). As the advanced version of AGVs, the AMRs are equipped with smart sensors and telecommunication technologies that guide them to conduct home delivery tasks in outdoor spaces and avoid obstacles (e.g., via pavements or special lanes) (DHL, 2020). Further, heavy-load UGVs are suitable for long-haul road freight transport, and they are expected to be operating on the highway soon since highway traffic scenarios are simpler than city situations (Gružauskas et al., 2018).

UAVs or drones have been widely adopted in military operations and have more recently been applied for civil use. Most of these civil-use UAVs are electrically powered aircraft with small sizes and limited flight duration and range (Wang et al., 2021). There are various main types of UAVs for civil applications: fixed-wing, multi-copters, and rotary-wing that can carry low-weight payloads (Wang et al., 2021). Their advantages in travelling speed and the use of low-altitude airspaces make them an applicable choice for parcels and emergency medical goods delivery (Perussi et al., 2019; Tang and Veelenturf, 2019; Scott and Scott, 2017).

In the food supply chain, drones are capable of monitoring the farms to manage irrigation and pesticide usage (Mahroof et al., 2021). Currently, most UAVs applied in logistics sectors are remotely piloted by human operators and under the operators' sight. Beyond-line-of-sight (BLOS) flying permits are likely to be implemented soon (DHL, 2020).

3.2.2.2 Social impacts and SCSS of AV adoption in the supply chain

The literature identifies 13 individual positive impacts and seven individual negative impacts that are relevant to six categories of SCSS implications. These categories match the social sustainability indicators: Health and Safety, Customer Satisfaction, Transparency, Employment, Diversity and Equality, and Welfare. Table 3-1 illustrates these indicators and Table 3-2 describes the key social impacts of AV adoption in the supply chain from the literature.

Based on Table 3-2, Figure 3-1 was developed and presents the links between social impacts and SCSS indicators. The table and the figure served as a conceptual background for the Delphi study – the items are to be evaluated by the participants.

Table 3-1 SCSS indicators in the general context

SCSS Indicators	Brief definition	Source
Health and Safety	Stakeholders' physical, mental health and safety	Yawar and Seuring, 2017; Carter and Rogers, 2008
Customer Satisfaction	Customers and recipients' preferences and expectations towards the services or products	Ahi and Searcy, 2015
Transparency	Information sharing, monitoring, supply chain visibility	Carter and Rogers, 2008
Employment	Labour input, output, unemployment, employee satisfaction	Ahi and Searcy, 2015; Yawar and Seuring, 2017
Diversity and Equality	Equal treatment and equal rights of different genders, disabled/marginalised groups, regardless of religion, race, ethnicity	Carter and Rogers, 2008; Yawar and Seuring, 2017
Welfare	Well-being, happiness, life quality	Ahi and Searcy, 2015

Table 3-2 Key social implications in this context

SCSS Indicator	Positive impacts	Negative impacts
Health and Safety	<ul style="list-style-type: none"> ● Fast response and life-saving in emergency scenarios; ● Road traffic safety; ● Workforce health and safety; 	<ul style="list-style-type: none"> ● Safety incidents due to crashes, failures, and attacks (Kellermann et al., 2020; Aydin, 2019)

	<ul style="list-style-type: none"> ● Customers or recipients' health and safety (in the pandemic) (Gružauskas et al., 2018; Pani et al., 2020) 	
Customer Satisfaction	<ul style="list-style-type: none"> ● Faster delivery service (commercial and humanitarian); ● Customised delivery service (commercial and humanitarian) (Gružauskas et al., 2018) 	
Transparency	<ul style="list-style-type: none"> ● Assets and Product security; ● Data and information integration and real-time visibility. (Sellevold et al., 2020) 	<ul style="list-style-type: none"> ● Privacy and cybersecurity concerns (Aydin, 2019)
Employment	<ul style="list-style-type: none"> ● Fill labour shortage; ● Create new high-skilled job opportunities. (Klumpp, 2018) 	<ul style="list-style-type: none"> ● Employment disruption in supportive industries, e.g., petrol stations; ● Short-term unemployment in logistics sectors (Sohrabi et al., 2020)
Diversity and Equality	<ul style="list-style-type: none"> ● Improved gender equality for mitigating the stereotype of drivers as "male job" (Kim et al., 2022) 	<ul style="list-style-type: none"> ● Not accessible for some social classes and inequality (Tang and Veelenturf, 2019)
Welfare	<ul style="list-style-type: none"> ● Reduced usage of ground traffic space; ● Smoother road traffic flows. (Sohrabi et al., 2020) 	<ul style="list-style-type: none"> ● Reduced communications among workers; ● Reduced human interactions between recipients and service providers. (Tatham et al., 2017)

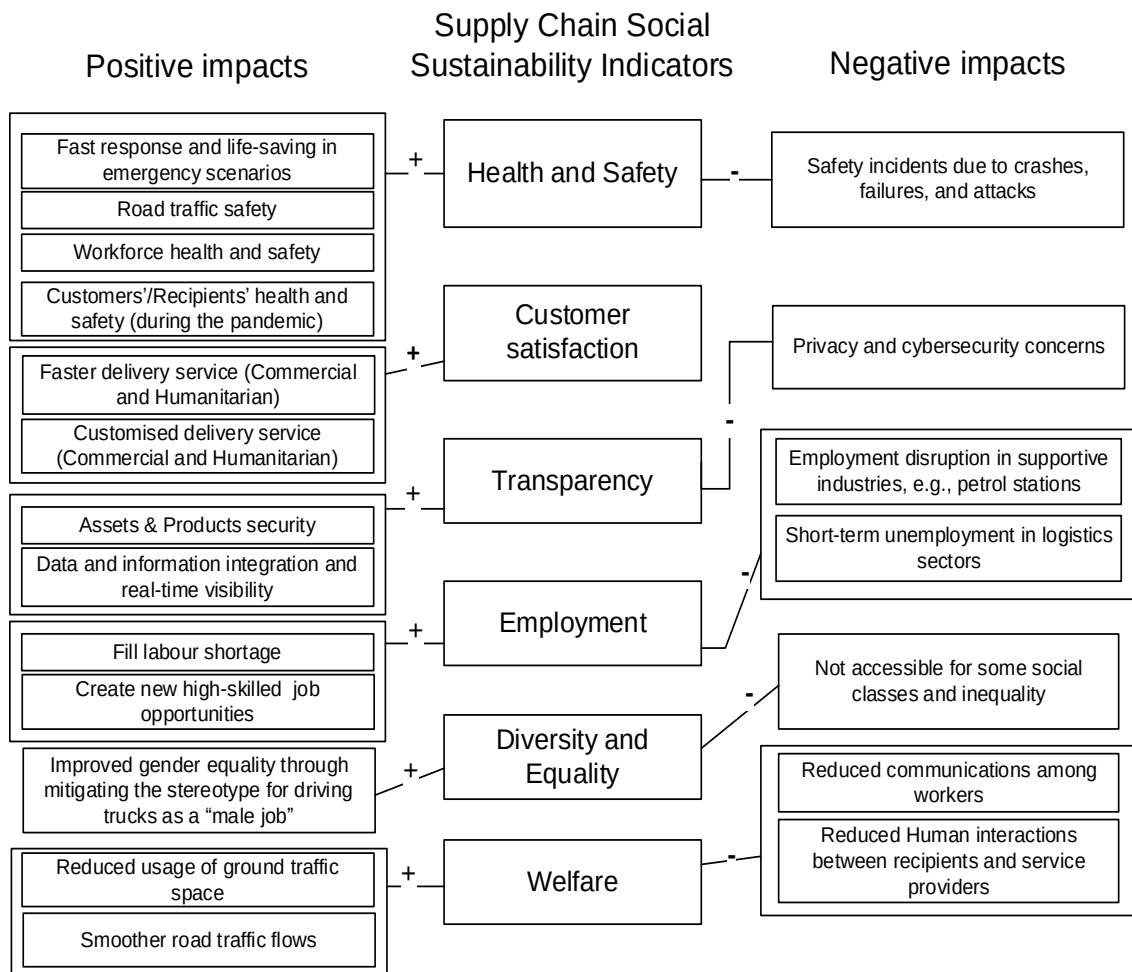


Figure 3-1 Links between social impacts and SCSS indicators

3.3 Methodology

The overall interpretivism research paradigm and abductive research strategy suggest a qualitative research method for the empirical study. The proposed research objectives call for identifying and refining stakeholders and social impacts, meaning that an exploratory study with the primary data to be collected through open-ended questions is appropriate (Edmondson and McManus, 2007). Although the literature identified several groups of social impacts and stakeholders in this context, they need to be identified, verified and refined. In addition, this research seeks to evaluate the achieved stakeholders and social impacts, regarding the extent of involvement of the stakeholders, as well as the importance of the impacts. The mechanism of identifying and then evaluating the

identified themes for concept development is an abductive strategy for research (Saunders et al., 2019).

In the meantime, this study seeks to investigate the social implications of AV adoption in supply chains, which relate to real-world practice. It is therefore necessary to gain insights from both academia and industry. To involve the insights from as many perspectives as possible in an efficient manner, the Delphi method is selected as the data collection method. The Delphi method has been proposed as a viable option for knowledge collecting and development to gain a consensus from a group of experts sharing a specific interest field with diverse backgrounds (Hohn and Durach, 2021; Seuring and Müller, 2008; Okoli and Pawlowski, 2004). The strong professional grounding of the experts in the relevant fields expresses robust data sources for this study (Reefke and Sundaram, 2017). This method is widely applied for exploratory social science research under the abductive research strategy to elaborate the existing concepts and theories (Moradlou et al., 2021; Ketokivi and Choi, 2014; Akkermans et al., 2003). Therefore, this research applies the Delphi method for data collection and knowledge development.

3.3.1 Delphi method

The Delphi method is a well-established data-collecting method developed by Dalkey and Helmer (1963) at the Rand Corporation. It is a questionnaire-based method with questions that cover multiple perspectives and disciplines. Linstone and Turoff (1975) also pointed out that, Delphi can be characterised as a structured communication process to effectively solve a complex problem by gathering insights from a group of individuals. The iterative revision of the answers and feedback provided by the previous rounds supports the richness and depth of the final research outcomes so that no further insights are achieved (Seuring and Müller, 2008). Thus, the Delphi method is tailored to those studies that aim to reach a group consensus and develop conceptual frameworks (Reefke and Sundaram, 2017). Within the two to four rounds of study, the first round starts with basic and open-ended questions of an exploratory nature. This allows experts to freely present their opinions and to introduce unanticipated and

valuable information beyond the questions being asked (Reefke and Sundaram, 2017). Within each round, the researchers analyse and assess the responses to design the next Delphi round. Meanwhile, the participants have the opportunity to revise and amend their responses on the basis of the provided group feedback (Reefke and Sundaram, 2017). Hence, Delphi provides an opportunity for receiving feedback as well as further elaboration against the feedback (Akkernans et al., 2003). The iterative processes will end until no further and deeper information is achieved, and a consensus is reached.

The exploratory research in the supply chain management field commonly adopts the Delphi method to investigate the implications of technological innovation adoption in supply chains (Durach et al., 2017); the factors in decision-making in technology adoption context in supply chains (Hassan et al., 2015); the management of supply chain sustainability and resilience (Seuring and Müller, 2008; De Lima and Seuring, 2023), and sustainability implications of adopting advanced technologies in supply chains (Hohn and Durach, 2021). The included experts in these studies provide solid insights into item identification and importance evaluation. Relating to the RQ and ROs of this study, it is sensible to apply the Delphi method and invite a group of experts to identify key stakeholders, social impacts, and social motivators and barriers. Then, these elements are evaluated through the degree of affecting/being affected; and their importance.

3.3.1.1 Expert Selection

Since the data are sourced from experts, it is crucial to select an appropriate number of experts with suitable expertise and background, to develop a successful Delphi study (Hohn and Durach, 2021; Mitchell, 1991). Several key issues needed to be illustrated to clarify the rationale of the panel selection process: panel size, inclusion criteria, and invitation and reminder processes.

3.3.1.1.1 Expert Inclusion Criteria

According to Scheele (2002), the participants should include but not be limited to stakeholders (who are directly affected), experts (who have special experience) and facilitators (who have special skills and analysis techniques) and combine them into an integrated panel. An expert is defined as 'one who has acquired

special skills in, or knowledge of, a particular subject' (Mitchell, 1991). Therefore, the included experts should 1). Be professional in knowledge and experience in the fields they are located in, 2). Come from multiple fields and backgrounds, 3). Provide opinions that can be integrated as a group, 4). Potentially act as a stakeholder or be integrated into a supply chain or a supply network, and 5). Be equipped with knowledge of the other disciplines covered in the Delphi (trans-disciplinary), not only their own specific field. Among these characteristics, the fourth one particularly suits the Delphi studies on supply chains.

In terms of this context, the potential participants had to be knowledgeable in at least one area of AVs, supply chain sustainability, and healthcare/humanitarian logistics. Hence, the participants to be involved should be those academics whose research field and interest lie within these areas or the practitioners who are the stakeholders or the consultants with much knowledge about these areas. Following the existing guidance and procedures of expert selection (Reefke and Sundaram, 2017; Moradlou et al., 2021; Okoli and Pawlowski, 2004), this study formed the following inclusion criteria:

1. The academics have a track record in their professional practice (e.g., academic peer-reviewed journal publication);
2. The practitioners have experience in AVs, supply chain management and/or sustainability, or healthcare/humanitarian logistics. The participants belonging to this group shall:
 - a. Be employed as an SCM practitioner for at least three years, or
 - b. Be employed as SC stakeholders (as identified in section 2.4.4), such as up- and downstream partners, logistics managers, government, employees, or
 - c. Be employed as consultants who specifically analyse the supply chain trends and technology deployment in the SC, and have published industrial reports, or
 - d. Be employed in sustainability-related function departments.
3. Other experts show their consistent professional interest in AVs, supply chain

management and/or sustainability, or healthcare/humanitarian logistics.

To be selected for this study, the academic panel included participants with relevant publications in the field or the related contexts, or associated research interests. Hence, professors, associate professors, lecturers, and institutional researchers with doctoral titles were involved as participants in the academic panel (Reefke and Sundaram, 2017). The practitioner panel included industrial consultants who have an overview of business and industrial knowledge (Durach et al., 2021), supply chain managers, technology providers, sustainability experts and government officers. Appendix G lists the detailed categories of fields of expertise, years of experience, and affiliations (for the practitioners). Each single participant was categorised under the fields of expertise and years of experience to show that the participant fit the criteria and was qualified for this study.

3.3.1.1.2 Panel size

The appropriate number of participants to be included in a Delphi study is highly varied, depending on the aim and field. A larger group of experts potentially increases the accuracy over the rounds, but also faces risks in low response rates and large workload for data analysis (Rowe et al., 1991; Hsu and Sandford, 2007), while a smaller group may not contribute sufficient results and undermine the theoretical contribution of the study (Hsu and Sandford, 2007). Several existing studies that discuss the appropriate number of experts to be included in a Delphi study suggest the size of the panel should range between 15 and 50, with a balanced number between academics and practitioners (Hsu and Sandford, 2007; Mitchell, 1991; Okoli and Pawlowski, 2004).

Regarding the existing Delphi studies focusing on supply chain sustainability (especially social sustainability), as well as digital supply chain management, the panel size ranged between 20 and 46 participants in the first round (Reefke and Sundaram, 2017, 2018; Kache and Seuring, 2017; Seuring and Müller, 2008). An initial size of about 40 participants included in the first round was therefore reasonable, with redundancy to cover the potential attrition effects.

3.3.1.1.3 Invitations and reminders

Apart from the identification of the experts, it is also crucial to reach out to them through sensible means. All the participants were contacted via email and social networking platforms such as LinkedIn. For academics, Google Scholar is important in providing scholar profiles that indicate the contact information. Most of the academics were the authors of the identified papers cited in the literature review (Sauer and Seuring, 2019). An additional seven academics not cited in the literature review were involved through a snowballing method (e.g., were nominated by the existing academics) (Sauer and Seuring, 2019), with their eligibility checked against the criteria. LinkedIn and email were the chosen approaches to contact them (Hohn and Durach, 2021). Meanwhile, the practitioners were partially identified from the cases and examples that the literature review listed, such as the main organisations that are testing and operating AVs in the supply chain. Some typical technology and service providers among the researcher's supervisor and review panels' networks were also invited. Others were experts the researcher met at the LRN 2022 conference and the 2022 Hannover Industrial Messe. These practitioners were reached by email and LinkedIn. The invitation email is shown in Appendix C.

All the identified experts were invited in the first two rounds while those who responded in the second round were invited in the following rounds. Concerning the unavoidable attrition effects in the multi-round studies, this Delphi study attempted to minimise them by adequately informing the participants of the existence of the following rounds (Moradlou et al., 2021; Reefke and Sundaram, 2017). Multiple reminders with various styles were designed: the thankyou notes at the end of the questionnaire, the thankyou email that indicated the potential invitation to the next round after the data analysis, and the email regularly reminding those who had not responded yet. These reminders attempted to guarantee that most of the participants stayed with the study, although it was still inevitable that some participants would quit the study, especially the practitioners, from round 1 to round 2. Some of the experts retired between the first two rounds and were not accessible any longer. Hence, the researchers had to identify and

contact new industrial experts for the second round. Table 3-3 presents the Delphi panellists for each round.

Table 3-3 Delphi Panellists

Panel	Round 1	Round 2	Round 3
Academic	22	22	18
Industrial Experts	14	17	12
Government	1	0	0
Total	37	39	30

3.3.2 Pilot study

Prior to the formal study, a pilot study should be conducted to ensure the rigour of the study as well as the reliability of the results. The first round of the Delphi is considered the foundation for the subsequent rounds. Hence, the validity of this round is important and needs to be tested in a wide spectrum of perspectives: the overall flow and question sequence, the applicability of the questions, the clarity of the instructions offered to the participants, and the language preciseness. The second and third rounds were to be evaluated by the pilot testers regarding the overall validity and logic flow, as well as whether the questions fully covered the questions presented in the previous round. Based on these requirements, the pilot testers were provided with the invitation letter attached with a consent form. The first round was tested by five academics who specialised in sustainable supply chains, disruptive technology in supply chains and questionnaire design. The second round was also tested by four academics in the fields of sustainable supply chain and disruptive technology in the supply chain. The following aspects are the specific items the testers were asked to comment on, while the full instructions with the letter are shown in Appendix B.

- **Purpose:** Do you think the survey will elicit what we hope it will? Are the questions framed/phrased in an appropriate fashion?
- **Understanding:** Do you see any issues with the way it is designed or the explanations?
- **Ease of use:** Any problems in using the website or the questionnaire?
- **Time:** How long did it take you?
- Any important details that you think are missing and should be included?
- Any additional comments?

The full details of the pilot studies are shown in Appendix B.

3.3.3 Consensus

The main objective for applying the Delphi method for data collection is to use the iterative nature to guide a group of experts' opinions to a common agreement or "consensus" on the answers to the specified questions (Linstone and Turoff, 1975; Seuring and Müller, 2008). The consensus is the collective opinion reached or agreed upon by a number of individuals or the process of reaching collective results (Von Der Gracht, 2012). Due to the subjective characteristics of the Delphi method, the consensus is therefore subjective to interpret, making it controversial to justify whether the Delphi study reaches a consensus (Hsu and Sandford, 2007; Von Der Gracht, 2012). Also, not all the existing Delphi studies define the exact meaning of "consensus" in their context, as Diamond et al. (2014) concluded in their review work of the Delphi studies. Several types of consensus and measurements were presented – agreement, the proportion within a range, central tendency (within a specific range), stability and decrease in variance etc (Diamond et al., 2014). Common measurements include agreement percentage within categories (Reefke and Sundaram, 2017), Kendall's W coefficient of concordance for ranking (De Lima and Seuring, 2023); standard deviation convergence for opinion stability (Hohn and Durach, 2021). However, there is a lack of justification in the existing Delphi studies regarding which consensus measures are valid for which type of evaluation method (rating, ranking etc.). There is a lack of such inclusive guidelines yet, only a summary of the existing studies (Diamond et al., 2014).

Currently, the Delphi studies that evaluate importance via five-point Likert Rating scales commonly apply the agreement percentage for consensus measurement (Moradlou et al., 2021; Reefke and Sundaram, 2017; 2018). According to Von Der Gracht (2012), various criteria are included – 51% agreement among respondents, also recommended by Loughlin and Moore (1979); more than 80% on two measures within a 5-point scale, also used by Reefke and Sundaram (2017; 2018); no less than 70% participants rate an item with at least a "3" within a 5-point scale (Hsu and Sandford, 2007). Since this study seeks to evaluate the

importance of the individual items among the experts, it is not sensible to limit the rating to a specific range. Although the Interquartile range (IQR) is also used for consensus measurement in the rating scales, this study found this method not precise enough to present agreement among the experts – the items with low IQR values still received low agreement percentage values.

Based on the arguments above, if the individual item received at least 51% agreement in one category of the five-point scale, or at least 80% agreement in two adjacent categories (i.e., 80% of respondents gave either a 4 or a 5 in the rating scale), the item is considered to reach consensus. This standard is presented as the “51-80 rule”. Meanwhile, the items that have not yet reached a consensus but showed convergence in opinions (i.e., a decrease in standard deviation values between two rounds) are considered to move towards a consensus (Moradlou et al., 2021).

3.3.4 Termination of the Delphi study

Since its iterative nature requires the Delphi study to continue evaluating the outcomes until no further insights are captured (Seuring and Müller, 2008), it is subjective for the researcher to decide whether the insights are sufficient at the end of the current round. A reached consensus with statistical evidence among the participants is applied as a generally used criterion (Mitchell, 1991). This means that limited extra insights will be gained even if the study continues. Although many existing Delphi studies implicitly suggest the study terminates when the consensus is achieved (Diamond et al., 2014), it is still necessary to clarify when the study terminates and why.

In addition to the consensus, there are also disputes around the number of rounds – “how many rounds are feasible and sufficient? Too few rounds might not capture sufficient content, making the results meaningless, while too many rounds exhaust the researcher’s and the participant’s time and resources (Schmidt, 1997). Mitchell (1991) concludes that the number of rounds should be reduced due to the increased panel attrition effect that lowers the validity of the study. A study produced by Giannarou and Zervas (2014) that includes 32 Delphi studies shows that almost all of them fall into the range between two and four

rounds (only one study experienced five rounds). Also, Seuring and Müller (2008) argued that Delphi studies in practice are likely to finish within three rounds. Although one recent Delphi conducted by Moradlou et al. (2021) regarding Brexit experienced four rounds, there were a considerable number of additional items after the second round. Hence, if there are no significant additions in items to be evaluated between the second and third rounds, a three-round Delphi study is a suitable balance to reach a sufficient convergence of opinion (Reefke and Sundaram, 2018).

Based on the consensus achieved, the Delphi study was terminated after three rounds. Figure 3-2 shows the overall Delphi process, with detailed illustrations presented in the following section.

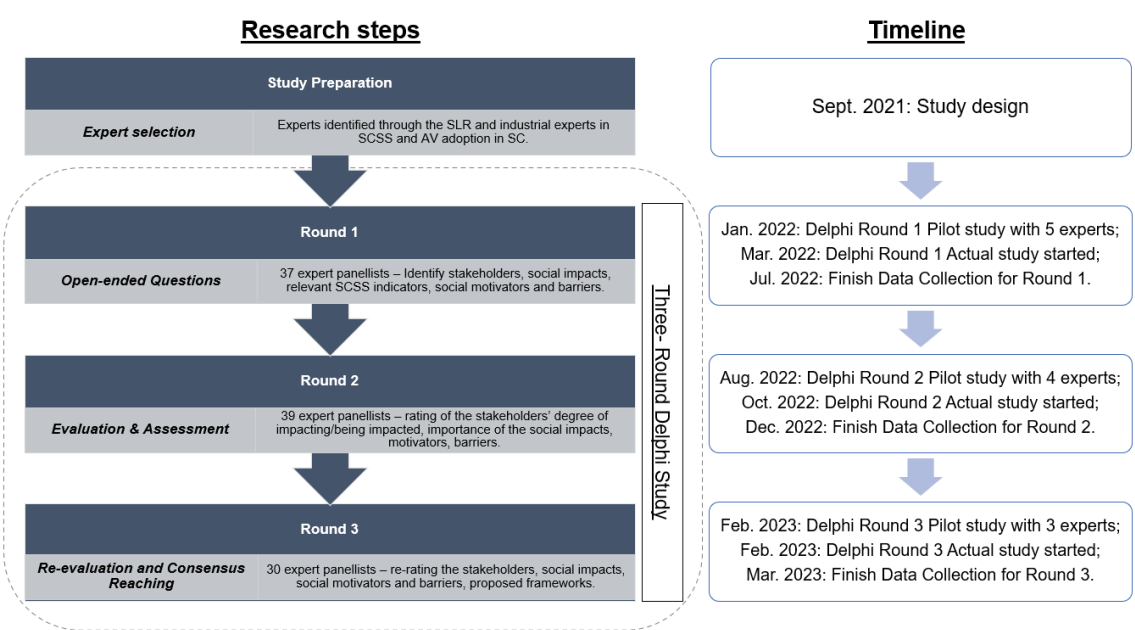


Figure 3-2 Delphi study process and timeline

3.3.5 Delphi Process

3.3.5.1 Round One

A series of open-ended questions are designed for the first round, requiring the participants to brainstorm the social motivators, barriers, internal and external stakeholder groups, and social impacts. The participants were expected to provide as wide and deep opinions as possible to enrich the outcomes. The questions posed to the panel are listed below:

- 1) AV adoption and stakeholder groups
 - What motivates organisations to implement AVs in the supply chain?
 - What prevents organisations from implementing AVs in the supply chain?
 - Who are the internal/external stakeholder groups affected by AV deployment in the supply chain?
- 2) Social impacts
 - What are the positive impacts of AV deployment in the supply chain?
 - What are the negative impacts of AV deployment in the supply chain?
- 3) Open comments
 - Please feel free to add any additional comments on your understanding or experience of this research context.

Since this round collected qualitative data from participants' opinions, content analysis was adopted after all the results were captured from this round. The process followed the typical analysis process suggested by existing Delphi studies (Moradlou et al., 2021; Reefke and Sundaram, 2017).

The first step of the analysis process is to retrieve data from the online questionnaires. All the data were loaded into NVIVO, a computer-assisted qualitative data analysis software (CAQDAS) to facilitate the following analysis stages (i.e., coding, theme establishment, etc.) (Saunders et al., 2019).

The next step is the coding procedure. By definition, coding is a process of using tags or labels to assign meaningful units attached to the chunks of original data that potentially contain useful information (Miles and Huberman, 1994; Saunders et al., 2019). In this context, each code represented an aspect of social impact, social motivator/barrier, or a specific group of stakeholders. All the original information that presented similar meanings was gathered under one code. Meanwhile, the information to be coded is labelled with the sources (the participants) to maintain traceability and anonymity (Beitzen-Heineke et al., 2017; Reefke and Sundaram, 2017). During the coding procedure, the contents which included environmental and economic perspectives were regarded as noise to be reduced, since this study mainly focuses on the social perspective.

After the coding procedure, themes were established to incorporate codes with similar aspects, levels, and groups (Saunders et al., 2019). In this study, the

codes representing internal stakeholders and social impacts were grouped firstly into sub-themes. Then the sub-themes were grouped under themes that categorised the main internal stakeholder levels and social sustainability aspects. Taking internal stakeholders as an example, each sub-theme stands for one gathered aspect within the same level (i.e., sub-theme operational-level employees stand for delivery truck drivers, material handling workers, etc; sub-theme technology maintenance stands for IT engineers, maintenance crew, etc. Both these two sub-themes are included in the “Operational-level and shop-floor employees” theme). In comparison, codes representing external stakeholders and social motivators and barriers were directly categorised into themes. There were no sub-themes applicable to these elements. The coding and theme-establishing processes presented a bottom-up logic (Moradlou et al., 2021).

Finally, the codes and themes were refined by checking the overlaps and referring to the categories from the literature. The refined codes and themes presented the evidence for designing the following rounds of the Delphi study.

3.3.5.2 Round two

The second round of the Delphi study was formed based on the analysis of the previous round. This round recognised two main objectives: a). to quantitatively rate the key elements – the identified stakeholders regarding their degree of being affected/affecting, the importance of the social impacts, and social motivators and barriers; b). to qualitatively evaluate the applicability of the proposed model. This round is a key stage that transforms the diverse opinions from the experts to a series of consensus. With these objectives, the development of a suitable rating scale is required.

Various types of rating scales are frequently applied in survey research, allowing participants to choose one category from several options, regarding the targeted subjects. These options are normally arranged in a hierarchical sequence with each option labelled between the two endpoints (Friedman and Amoo, 1999). The independent individual items under the standardised rating scale measures allow the participants to provide reasonable judgements, and the researchers are capable of making comparisons among these responses (Linstone and Turoff,

1975). Therefore, a rating scale with a suitable number of points is necessary to transmit sufficient information from the participants with errors eliminated (Friedman and Amoo, 1999; Cox, 1980). Scales with more than nine options are considered not to result in more accurate results compared to seven or nine points, while the scales with no more than three options are inferior in gaining accurate and precise feelings from the participants (Preston and Colman, 2000; Friedman and Amoo, 1999). However, applying a how-many-point scale depends on the specific research target and there is no uniform rating scale that is appropriate for all situations (Friedman and Amoo, 1999). Hence, to balance the validity, reliability and ease of use, a five-point Likert scale rating for the individual issues assessment was applied in this Delphi research.

Based on the rationale above, the rating scale was therefore applied to rate two dimensions: the degree of affecting/being affected of the stakeholders; the importance of the impacts, and social motivators and barriers. Numerical measures ranged from 1 to 5. The scales also include an option “Not applicable” for the items where the participants are unsure about the questions or express “it depends” (Kache and Seuring, 2017; Melnyk et al., 2009). Altogether 94 items were evaluated through this round. Table 3-4 presents the rating options for this round.

Table 3-4 5-point Likert Rating Scale

Numerical value	1	2	3	4	5	N/A
Affecting/Affected Scale	Not at all	Slightly	Moderately	Considerably	Strongly	No idea/Not Known
Importance Scale	Not at all	Slightly	Moderately	Considerably	Extremely	No idea/Not Known

3.3.5.3 Round three

The third round seeks to further evaluate the individual items that had not reached consensus in the previous round. The results of the previous round (Mean values – M and standard deviation values – SD) and the items to be assessed, were presented to the participants so that they had the opportunity to reconsider their opinions or to adjust their choices. M values represent the average degree of affecting/being affected in terms of each stakeholder group, as well as the

average importance ratings of the impacts. SD values present the spread of the results of the assessed items (Reefke and Sundaram, 2017). Among the 94 items, 12 items reached the consensus requirements in round 2 and the rest 82 items remained to be re-evaluated. Round 3 included eight additional items captured from the comments of the participants from round 2. These suggestions resulted in an extra three groups in external stakeholders, and one in the positive and negative social impact columns respectively. This round also added one question for evaluating the model as a concluded result after Round 2. In addition, based on the comments, one item was discarded for “not being a social impact but a competition impact”. In the final design of this round, 90 items remained to be evaluated.

The data processing for this round followed the 51-80 rule as in the previous round, and 55 items reached a consensus (61%). All of the items that did not meet the consensus criteria also showed a decrease in SD values, i.e., a convergence of opinions among the experts. It is valid to justify that these items are moving towards the consensus. After all, it is not sensible to require all the items to reach strict agreement standards among experts with diverse backgrounds in a single study.

The invitations to this round only were sent to the 39 participants who contributed in the second round. No extra experts were invited. Ultimately, 30 valid responses were received from the participants, consisting of 18 academics and 12 practitioners. Despite the inevitable attrition effects – five participants did not reply or complete the questionnaire in each group, this round still received more than a 75% response rate that captured considerable completions from both academia and industry. Hence, this round of study is valid and reflects both academic and practitioner aspects.

Based on the results and the rationales for consensus and terminations, it is not necessary to conduct another round – there is no significant number of additional items by the end of the second round. Also, there is no added item commented on by the participants by the end of this round.

3.3.6 Participant average deviation

In addition to the 51-80 role and the convergence in SD values, existing Delphi studies also suggest an analysis of the respondents' average deviations (Reefke and Sundaram, 2017; 2018; Moradlou et al., 2021). Figure 3-3 plots the participants' average deviations from the panel's mean responses in the second round against the respondents' average deviations between the results of the second and third-round ratings. This figure explains how the individual members adjusted their answers in the third round on the basis of the given results of the previous round. Only the 30 participants who responded to the second and third-round questionnaires were involved for comparison. The differences between academics and practitioners are minor and most experts showed a convergence in opinions. Therefore, a significant consensus was achieved by the end of the third round, which supports the termination of the study.

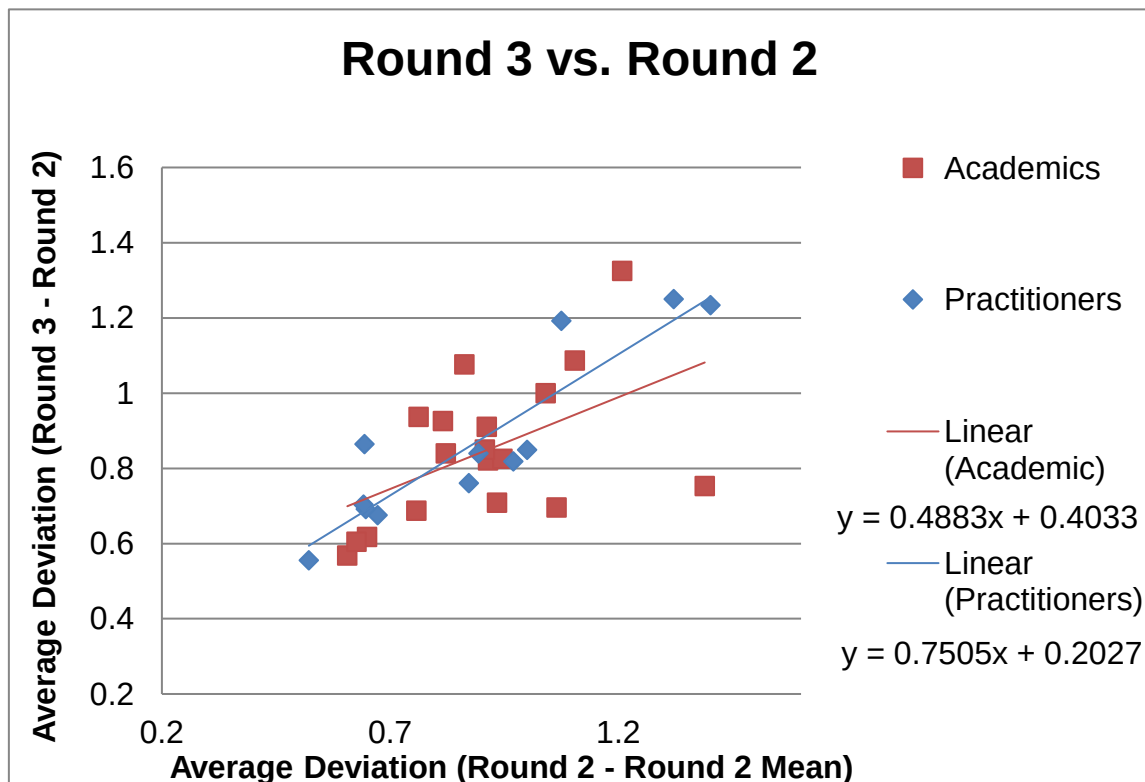


Figure 3-3 Participant Average Deviation

3.4 Findings

This section describes the final results from the 3-round Delphi study. A detailed description of the analysis process is presented in Appendices D and E. In this section, only stakeholders and social impacts are involved. Social motivators and barriers are not included in the ROs, the discussions regarding their relations to the social impacts are presented in Appendix D.

3.4.1 Stakeholders

This Delphi study identified nine main internal and 17 external stakeholder groups. This division of the stakeholders seeks to identify and classify the stakeholders in this context (Hussain et al., 2018). These stakeholders were evaluated regarding the degree of affecting the AV adoption or being affected by the AV adoption in the supply chain.

From the participants' feedback, AVs are mainly adopted in the freight transport and warehousing processes, rather than in the holistic supply chain. The major internal operational-level stakeholders mentioned are "logistics employees, truck drivers, forklift drivers, material handling personnel, warehouse workers". Meanwhile, the "logistics service providers, technology providers" that are involved in the logistics activities are the main external stakeholders in the AV adoption context.

"I assume that AV will mostly be employed by logistics service providers (LSPs) and not companies/manufacturers, given the costs and lacking expertise."
(DR1-7-A)

Although AVs are applied in the production, warehousing, and transportation processes of supply chains, participants may link AV adoption directly with the LSPs. From the SLR (Chapter 2), the literature that discusses the social implications of AV adoption in supply chains mainly is focused on the freight transport and warehousing processes. Therefore, the internal stakeholders can be concluded as being the employees mainly involved in the companies that operate logistics functions and services as their main outputs, or in the organisations outsourcing their logistics activities to the LSPs.

3.4.1.1 Internal stakeholders

Internal stakeholders mainly involve three groups: managerial stakeholders, the operational workforce, and the employees positioned in support functions. The internal stakeholders are directly related to the AV adoption decisions. As one participant commented, “are highly influenced or influencing the adoption at the corporate level”. Tables 3-5 and 3-6 list the internal stakeholder results.

3.4.1.1.1 Managerial

In this context, four groups were identified as managerial stakeholders – senior managers (C-level); change managers (Human Resources or HR, project managers); mid-level managers (supervisory, floor, logistics and supply chain managers); and shareholders/owners. It is not surprising to see that, on average, these groups were rated the highest in the affecting degree ($M=3.97$) among the three internal stakeholder categories. The managers at various levels are the decision-makers in the supply chain who influence AV adoption to different degrees. C-level managers ranked No.1 in affecting while No. 3 in being affected. Their roles are mainly the decision-making at the organisational level that influences the overall adoption of AVs.

“C-suite is the decision maker so their main driving parameter is always high-level vision towards technology advancement and unlocking business opportunities”. (DR2-22-P)

Table 3-5 Internal stakeholders' degrees of being affected

Category	Internal Stakeholders	No.	R2 M	R2 SD	R3 M	R3 SD	R3-R2 ΔM	R3-R2 ΔSD	Consensus
Managerial	C-level managers	1	3.26	1.31	3.27	1.08	0.004	-0.23	
	Change managers (HR, Project managers)	2	3.89	1.23	3.77	0.97	-0.128	-0.25	
	Mid-level	3	4.37	0.82					Y
	Shareholder	4	3.18	1.25	3.13	1.14	-0.051	-0.11	
Operational	Tech Maintenance	5	4.36	0.81					Y
	Operational Employees	6	4.62	0.63					Y
Support Function	Procurement department	7	3.44	0.99	3.40	0.86	-0.036	-0.14	Y
	Finance and Accounting	8	2.64	1.09	2.30	0.79	-0.341	-0.29	Y
	Health & Safety colleagues	9	3.74	1.14	3.70	0.84	-0.044	-0.30	

Table 3-6 Internal stakeholders' degree of affecting

Category	Internal Stakeholders	No.	R2 M	R2 SD	R3 M	R3 SD	R3-R2 ΔM	R3-R2 ΔSD	Consensus
Managerial	C-level managers	1	4.66	0.67					Y
	Change managers (HR, Project managers)	2	3.47	1.01	3.70	0.84	0.23	-0.17	
	Mid-level	3	3.68	0.93	3.93	0.64	0.25	-0.29	Y
	Shareholder	4	3.69	1.39	3.60	0.93	-0.09	-0.46	Y
Operational	Tech Maintenance	5	3.31	1.20	3.37	0.81	0.06	-0.39	Y
	Operational Employees	6	3.15	1.33	3.17	0.99	0.01	-0.34	
Support Function	Procurement department	7	3.03	1.11	3.10	0.99	0.07	-0.12	
	Finance and Accounting	8	2.97	1.14	2.77	0.82	-0.21	-0.32	
	Health & Safety colleagues	9	3.54	1.23	3.40	1.00	-0.14	-0.23	Y

While their decisions can be influenced by the development of technology and legislative frameworks, change managers received medium ranks and similar rating values in both dimensions (No. 3, 3.70 and No. 2, 3.77 respectively). HR managers are affected by dealing with the changes in the human labour force for robots, or the job transformation for the existing employees. This is similar for project managers in that they are influenced by changing the resource profiling – AVs vary in the availability profiles from the human workforce when dealing with new projects. Mid-level managers are directly relevant to the AVs in the operations compared to other managerial stakeholders. They are the executors of the senior level decisions; and the decision-makers to the operational employees, so they are rated highly in both degrees (No. 2 in affecting and No. 1 in being affected). As one participant commented:

“We observe their (AVs’) influence on decision-making and the introduction of AV from both strategic and operational perspectives.” (DR2-34-A)

The shareholders and owners are rated the lowest in both dimensions, while the rating in the degree of affecting is still higher than any internal stakeholders in operational levels and support function groups. It is also a consensus among the stakeholders that the shareholders have a considerably high degree of influencing AV adoption in supply chains.

3.4.1.1.2 Operational

The operational employees include the internal technology maintenance crew and the shop-floor operational staff and drivers who are directly confronted with the AVs in supply chains. Hence, they are mostly affected by the AV adoption ($M=4.49$), in terms of the changes in assets to maintain, and in the job opportunities (or even job loss). While the technology maintenance team has a slightly stronger degree of affecting and reached a consensus at a moderate level, the operational staff received a diverse degree of affecting. This can be illustrated by one participant’s comment that result in the long-term, operational employees potentially are more powerful in technology adoption decision-making, but not now:

“Operations teams are the ones ultimately facilitating the adoption of the technology. They hold a lot of power in the long-term with scaling up any technology adoption project”. (DR2-22-P)

3.4.1.1.3 Support function

The support functions cover a wide range of supportive departments including facility procurement, finance and accounting, and health and safety colleagues. The degree ratings for both dimensions are the lowest among the three internal groups. This implies that these departments are comparatively less influential than those who are directly confronted with the technologies and the decisions. Employees in the finance and accounting departments are believed to be affected by the decisions from the senior levels to adopt AVs – they need to calculate the budget and decide the feasible number of facilities to procure. The procurement team follows the instructions and executes the procurement plan. In comparison, the health and safety teams that deal with employee physical and mental health and safety issues received the highest degree ratings for both dimensions.

3.4.1.2 External stakeholders

External stakeholders include many more groups than internal ones. Competitors, customers/recipients, government authorities, logistics service providers, technology providers, and other external groups such as training centres, media, traffic users, lobby groups etc. are included as external stakeholders. Compared to the internal stakeholders, the participants tended to rate the degree of two dimensions for external stakeholders with similar numbers – each item received similar ratings in being affected and affecting. The exact influential effects regarding external stakeholders are not clear to most participants. As one participant commented:

“AV has not been widely adopted in many regions/countries. It is not widely realised how the external stakeholders will be affected.” (DR2-34-A)

Tables 3-7 and 3-8 list the external stakeholder results.

3.4.1.2.1 Competitors

Competitors highly affect AV adoption decisions and they act as the source of external pressure to adopt AVs. They are ranked as the fourth highest affecting stakeholders among the 17 groups. In comparison, they are slightly less affected by the organisation's decision on AV adoption (3.9, No. 5).

3.4.1.2.2 Customers/Recipients

Customers, consignees, and recipients are involved in this category and this group is the most frequently mentioned external stakeholder. However, the ratings for both dimensions were not as high as expected. The participants believed that customers are more affected by AV adoption in supply chains, rather than affecting (3.8 and 3.33 respectively).

Table 3-7 External stakeholders' degrees of being affected

Category	External Stakeholders	No.	R3 M	R3 SD	R3 M	R3 SD	R3-R2 ΔM	R3-R2 ΔSD	Consensus
Competitor	Competitors	1	3.97	0.95	3.90	0.55	-0.07	-0.41	Y
Customer	Customers	2	3.54	1.17	3.80	0.66	0.26	-0.50	Y
Logistics service providers	Service providers	3	4.19	0.91					Y
	VMI	4	3.69	1.06	3.90	0.66	0.21	-0.40	Y
Government and legislative authorities	Government	5	3.42	1.13	3.37	0.85	-0.05	-0.28	Y
	Traffic control	6	3.80	1.18	3.79	0.82	-0.01	-0.36	Y
Technology suppliers	Software supplier	7	4.21	1.09					Y
	AV manufacturer	8	4.55	0.83					Y
	External Maintenance	9	4.05	1.01	4.13	0.90	0.08	-0.11	Y
Other entities	Other traffic users	10	3.58	1.03	3.69	0.60	0.11	-0.43	Y
	Insurance provider	11	3.51	1.10	3.53	0.73	0.02	-0.37	Y
	Health & Safety experts	12	3.28	1.11	3.37	0.89	0.08	-0.22	
	Local community	13	3.24	1.11	3.13	0.82	-0.10	-0.29	
	Research Centres	14	3.37	1.11	3.20	0.96	-0.17	-0.15	
	Media	15			2.62	1.01	2.62	1.01	
	Lobby groups	16			3.21	0.83	3.21	0.83	
	Unions	17			3.79	0.74	3.79	0.74	Y

Table 3-8 External stakeholders' degrees of affecting

Category	External Stakeholders	No.	R2 M	R2 SD	R3 M	R3 SD	R3-R2 Δ M	R3-R2 Δ SD	Consensus
Competitor	Competitors	1	4.09	0.92					Y
Customer	Customers	2	3.36	1.20	3.33	0.76	-0.03	-0.44	Y
Logistics service providers	Service providers	3	3.87	1.19	3.86	0.79	-0.01	-0.40	Y
	VMI	4	3.54	1.14	3.62	0.94	0.08	-0.20	
Government and legislative authorities	Government	5	3.84	1.15	4.23	0.77	0.39	-0.38	Y
	Traffic control	6	3.74	1.27	3.79	1.05	0.05	-0.22	
Technology suppliers	Software supplier	7	4.03	1.22	4.30	0.65	0.27	-0.57	Y
	AV manufacturer	8	4.49	1.00					Y
	External Maintenance	9	3.46	1.33	3.67	0.96	0.21	-0.38	
Other entities	Other traffic users	10	3.24	1.15	3.10	0.71	-0.14	-0.44	Y
	Insurance provider	11	2.92	1.12	2.90	0.84	-0.02	-0.27	
	Health & Safety experts	12	3.08	0.89	3.07	0.91	-0.01	0.02	
	Local community	13	2.92	1.14	2.87	0.90	-0.06	-0.24	Y
	Research Centre	14	3.32	1.22	3.13	0.78	-0.18	-0.44	Y
	Media	15			3.00	0.96	3.00	0.96	
	Lobby groups	16			3.46	0.92	3.46	0.92	
	Unions	17			3.50	0.92	3.50	0.92	

3.4.1.2.3 Logistics service groups

In this category, two groups are involved: logistics service, retail, transport provision, aid providers (abbreviation as LSPs to be inclusive); and vendor-managed inventory (VMI) suppliers. This category is rated the second highest in the “being affected” dimension, while is rated comparatively lower in the other, which shows that the LSPs are considerably affected by the AV adoption decisions of organisations, rather than affecting them. According to the experts, the LSPs remain more affected than affecting.

3.4.1.2.4 Government and legislative authorities

This category received a comparatively high rating in the affecting degree ($M > 4$), which is not surprising. The government, as an individual stakeholder category was ranked third in the affecting degree, compared to No. 12 in the other dimension. This is supported by one of the participants:

“Local and national authorities significantly impact the adoption of drones for organisations.” (DR2-4-A)

The degree ratings for traffic controls in both dimensions are the same (3.79), which represents roughly a similar degree of the two influence dimensions of traffic controls in this context among the participants. This category monitors and manages the traffic flows (mainly the aerial space for drones) for AVs to smoothly operate their tasks, however, the increasing number of organisations adopting AVs in the supply chain brings more challenges to the traffic controls to effectively manage the flows.

3.4.1.2.5 Technology providers

The average values of technology providers in both dimensions were rated the highest among the external stakeholder groups by the participants, and the hardware and software suppliers are the two top-ranked external stakeholders for both affecting and being affected in this context. As one participant commented:

“Engineers, developers, and manufacturers are highly influenced or influencing the adoption at the corporate level.” (DR2-34-A)

3.4.1.2.6 Other entities

Apart from the above major categories, a series of stakeholder groups with limited similarities to the group were categorised as “other entities”. This category includes other traffic and shared infrastructure users; insurance service providers; external health and safety experts; local residents and communities; external research and training institutions; media; lobby groups; and unions. The participants indeed recognised the roles of the external stakeholder groups such as health and safety experts and research and education centres, although their degree ratings in either dimension were low (ratings ranged between 3 and 3.4):

“I suggest other related industries (supportive industries), apart from those mentioned as technology providers, are affected and impacted to a greater or lesser degree. For example, energy providers, HR specialists, education/training institutions”. (DR2-33-A)

Local communities are rated the lowest range of external groups in both dimensions. Although assumed by one participant:

“Considering the COVID-19 impact, the lockdown of the city, I believe the supply chain will be reshaped by AVs and the acceptance of AVs will be accelerated by the public”. (DR2-26-P)

The assumed accelerated acceptance of AVs among the local communities does not embody the rating of either being affected or affecting.

Concerning the three newly added items, media received a low rating, and it is discussed in detail in the low agreement section in Appendix F. Unions received higher ratings for both two dimensions of influence degrees. The lobby groups potentially represent the AV suppliers with interests-related purposes to promote the adoption of AVs in the supply chain, so it is normal that they were rated slightly higher in the affecting than the being affected dimension. In comparison, the insurance providers are much more highly rated in “being affected”. One participant implied the relations between the regulation frameworks with the insurance providers and the lobby groups in the third round:

“There is increasing interest in autonomous vehicles and the legislative framework around their use in public spaces (as opposed to restricted spaces).

- Insurance implications;
- The emergence of lobby groups who are trying to influence outcomes” (DR3-24-P)

3.4.2 Social impacts

Compared to the social impacts and the SCSS indicators initially identified from the literature, this Delphi study refined 19 positive and 15 negative impacts that are relevant to seven SCSS indicators (13 positive, seven negative impacts, and six indicators in the literature) in the AV adoption context. All of the impacts were ranked by importance within each corresponding indicator category, on the basis of their average rating values. Table 3-9 (new items marked with “*”) highlights the most important issues for each SCSS category and expands SCSS in the AV adoption context, developing context-specific indicators, following the suggestions by Ahi and Searcy (2015). More than 76% of the items reached a consensus following the “51-80 rule” on the importance rates. Some participants recommended that impacts can be linked with multiple SCSS indicators rather than just one:

“I suggest that several of the social impacts (+ and -) apply to more than one of the SCSS indicators, which in turn affects the SCSS indicator links. For example, negative impact number 15 can apply to the indicator ‘Health and Safety’ (particularly mental health) as well as Welfare.” (DR3-17-A)

Some of the impacts indeed intersect with multiple SCSS indicators and many impacts under different indicators are potentially interrelated. However, in this study, the social impacts are categorised under the most relevant and straightforward SCSS indicator (only one), according to the definitions of the indicators and the author’s interpretations of the words. The most direct links between impacts and indicators provide a concise view of the impact categorisation and prevent chaos in analysing the importance of the items. In addition, the average importance of positive impacts shows a slight increase and a slight decrease for the negative average importance between the second and the third round. This supports one comment from the industry:

“Technology always has an impact in society. However, the positive aspects are above the negative issues that AVs may create”. (DR3-19-P)

The sequence of presenting each SCSS indicator under positive and negative groups also follows the rank of average ratings of the impacts in the category.

Table 3-9 Social impacts of AV adoption ranked with importance

SCSS indicators	Positive impacts	Negative impacts
Health and Safety	<ol style="list-style-type: none"> 1. Road traffic safety; 2. Workforce physical safety and health; 3. Fast response in emergencies for life-saving; 4. Customers or recipients' health and safety; 5. Workforce mental health* 	<ol style="list-style-type: none"> 1. Safety incidents due to crashes, failures, and attacks; 2. Psychological and physical strain for those confronted by new technology adoption*; 3. Deteriorated employee health due to reduced exercise in the workplace*.
Customer Satisfaction	<ol style="list-style-type: none"> 1. Faster and more customised delivery services; 2. Customer experience improvement*. 	
Transparency	<ol style="list-style-type: none"> 1. Data and information integration and real-time visibility; 2. Asset and product security 	<ol style="list-style-type: none"> 1. Privacy and cybersecurity concerns; 2. Loss of control over the systems
Employment	<ol style="list-style-type: none"> 1. Create new high-skilled jobs; 2. Fill labour shortage; 3. Reduced inefficient jobs*; 4. Improved working environment and employee satisfaction*; 5. Initial reduction of poorly-paid job opportunities*. 	<ol style="list-style-type: none"> 1. Initial job opportunities reduction and short-term structural unemployment; 2. Unable to change due to the lack of change management*; 3. Fewer available jobs in some regions – reduced prosperity*; 4. Employment disruption in supportive industries; 5. Overdependence on technology*.
Diversity and Equality	<ol style="list-style-type: none"> 1. Better accessibility for remote areas*; 2. Improved gender equality for mitigating the stereotype of truck drivers as “male jobs” 	<ol style="list-style-type: none"> 1. Not accessible for some social classes and inequality 2. Not ensuring participatory development with diverse users*.
Welfare	<ol style="list-style-type: none"> 1. Reduced congestion and better use of road spaces; 2. Work-life balance and improved living standards* 	<ol style="list-style-type: none"> 1. Reduced human contacts and interactions; 2. Alienation of workers in the operations*; 3. Increased congestion*
Reputation*	<ol style="list-style-type: none"> 1. Modern image as “innovation” for the branding* 	

3.4.2.1 Positive impacts

3.4.2.1.1 Transparency

Transparency is the top-ranked SCSS indicator in terms of the average importance of the impacts. This Delphi study highlights the extreme importance of the two initially identified impacts – improved data and information integration

and visibility; and security of assets and products. These two impacts are enabled by the advanced sensors and telecommunication technologies equipped in the AVs that require minimum human interference and realise real-time data transformation during operations. This significantly benefits the security of the products and thereby, the transparency of supply chains.

3.4.2.1.2 Customer Satisfaction

Ranked the second most important, this indicator categorises two essential positive impacts that are tightly related to customers, one of the key external stakeholders. Customer satisfaction presents the customers' thoughts, preferences, and expectations in terms of the products or services offered by the supply chain organisations (Ahi and Searcy, 2015). In this context, the initial impacts under the customer satisfaction indicator include faster and more customised delivery in commercial and humanitarian logistics, which represent improved delivery services. According to the experts, this item is the most prominent impact in the positive impact list. The improved services thereby benefit customers' experience when they are served by AVs. One participant highlighted the impacts in the comment:

“Better quality of supply chain, faster deliveries, the satisfaction of end users (an average person is free to have more family life quality).” (DR2-18-P)

3.4.2.1.3 Health and Safety

As another indicator with an average importance rating exceeding 4, the health and safety category is broadly recognised as a crucial benefit brought by AVs in supply chains. The initial four impacts that were identified from the existing studies all reached consensus and three of them reached consensus even in the second round, with road traffic safety rated as the top.

Customers or recipients' health and safety received a consensus with comparatively lower importance rates. Despite more than 25% of experts believing this is an extremely important positive impact, the majority of them (55%) selected the secondary level of importance. Two participants even selected the “slightly important” option. It seems that the AVs' role in this impact is no longer that crucial in the post-COVID era. The newly added impact –

employees' mental health – was mentioned by three participants in the first round and received a rating of considerable importance from nearly half of the respondents. Accordingly, the employee's mental health can benefit from having more pleasant work to do and reduced stress. The elimination of repetitive and hazardous jobs indeed helps mitigate employees' mental and physical pressure, so that there is improved mental and physical health.

3.4.2.1.4 Reputation

The newly identified impact “New image as innovation and branding” was linked to the new indicator “reputation”. “Reputation” is defined as “the image of an organisation which represents public sentiment in terms of the actions of the organisation” (Carter and Rogers, 2008). In the Delphi study, the “considerably important” was selected by 60% of experts with No. 4 in terms of importance. Indeed, it is important for organisations adopting AVs to present an “innovative” and “modern” image to attract new customer orders as well as investments. Although reputation can be affected by performance in other categories (safety improvement, labour well-being, fair trade etc.), this indicator is currently linked with the only impact that it most directly represents.

3.4.2.1.5 Employment

This indicator concerns issues including labour inputs and outputs, unemployment, labour rights, and employee satisfaction etc. (Yawar and Seuring, 2017). In this context, creating new high-skilled jobs and filling labour shortages were initially identified in the literature and both of them reached a consensus as being considerably important. Additionally, the reduction of inefficient jobs was also recognised by the majority of the respondents as a considerably important positive impact. While the initial reduction of poorly paid opportunities seems similar to the previous item, this impact received a much lower importance rate. The reduction of inefficient and poorly paid jobs helps optimise the overall employment structure – more resources can be invested in creating higher productivity and efficiency for the supply chain. The generation of new technologies in the industry will diminish old jobs and create new ones simultaneously. In addition, adopting AVs is believed by most experts to be an

ideal and crucial remedy for the future labour shortage in the logistics sectors – especially truck drivers. Furthermore, with the advanced working environment that the AVs provide (i.e., conducting jobs that are hazardous for human employees), employee satisfaction in working is believed to improve, which was recognised by the panel as considerably important as well.

3.4.2.1.6 Welfare

In this context, welfare addresses the impacts including human interactions and traffic congestion that cannot be represented by other sustainability indicators but indicate human life quality and well-being. This Delphi study, therefore, identified two impacts to be categorised in this indicator – reduced congestion and better use of road space; and work-life balance and improved living standards. The first impact synthesised the two impacts initially captured from the literature that described reduced use of ground traffic space and smoother road traffic flows. The importance of this impact was supported by 52% of participants who rated it as “considerable”. The second impact was captured from three participants’ answers from the first round. The increase in automation relieves the employees’ workload (especially the operational level employees) so that they potentially have more leisure time to stay with their families to enjoy a work-life balance. This impact was rated in the range of “moderately” and “considerably” important by 83% of participants and the mean value of importance remained the same from Round 2 to Round 3. The experts held their consistent belief regarding the importance of this impact.

3.4.2.1.7 Diversity and Equality

In general, the “diversity and equality” indicator covers gender equality, diversity, disabled people inclusion, minority development, etc (Carter and Rogers, 2008; Yawar and Seuring, 2017). This study initially included gender equality issues for reduced stereotypes (Kim et al., 2022), and it was rated as the lowest importance among the whole list of impacts. The adoption of AVs reduces the social stereotype that freight trucks are dominantly controlled by male drivers. However, the respondents did not consider this to be a prior impact. In comparison, a newly identified impact “improved accessibility for remote areas” was evaluated at a

much higher importance. This indicates that it is crucial for AVs to provide product delivery services for remote areas that contribute to improved equality. As a result, although the average importance rating for the impacts of diversity and equality is the lowest among the seven indicators, the benefits of better access to improved equality still cannot be overlooked.

3.4.2.2 Negative impacts

3.4.2.2.1 Transparency

As argued in Chapter 2.5.1.2.3, the transparency indicator considers information sharing and monitoring among stakeholders (Carter and Rogers, 2008). This means that the stakeholders' privacy and cybersecurity issues should be categorised under transparency. Similar to the positive impacts, respondents also rated the negative impacts regarding transparency with the highest importance. Although neither of the two impacts reached a consensus, both these items received the most participants' selection in the "considerably important" choice. Among all of the rated impacts, the impact "privacy and cybersecurity" was rated the second most important, followed by the loss of control. "The loss of control" was added from the first round of the Delphi study and it is closely related to cybersecurity (Javaid et al., 2012; Mraković and Vojinović, 2019). Once there is a hacking into the AV system of a business, not only do the internal managers lose control of the AV fleet, but the overall systems including the data are also at risk – safety incidents around the AVs, and also a potentially damaged reputation. This is supported by one participant:

"Negative impact seems to be limited. E.g., (picking just one) Reputation: not using the proper procedures might lead to adverse reputation (see company X's incident in losing customer data)." (DR3-7-A)

These two impacts potentially relate to various stakeholder groups – customers, local communities, and internal operational and managerial level employees.

3.4.2.2.2 Health and Safety

The average importance rate for negative impacts categorised in health and safety was ranked No. 2. Safety incidents due to crashes, failures, and attacks remained the most significant negative impact. These issues are currently the

major risks that prevent AVs from being widely adopted in supply chains. This is followed by psychological and physical strains for the employees who are confronted with AVs. This can be related to the previous impact – the stakeholders who directly face AVs also potentially face the safety risks that cause casualties, which makes them nervous. However, the newly added impact, deteriorated employee health due to the isolations and reduced exercise received a group agreement on a low importance rate.

“I think workforce physical health and safety can also be a negative impact. Less physical and mental exercise can have a negative impact on employees, i.e., walking/moving from A to B.” (DR2-33-A)

Insufficient physical activities and sedentary behaviour at workplaces potentially harm employee health conditions (Zhu et al., 2020). However, deploying AVs in supply chains does not necessarily keep operational employees motionless at their workstations for hours. Hence, most of the experts were not convinced this impact was highly important or relevant.

3.4.2.2.3 Employment

Unemployment was one of the most frequently mentioned negative impacts in the literature for AV adoption. Various types of “job loss” form the overall “unemployment”. Structural unemployment in the logistics sector is one of the types mentioned by most of the participants in the first round. This also includes the poorly paid jobs in the operational levels of the supply chain nodes – unskilled assembly, manual production, and intralogistics transport – that are currently not as efficient as AVs and can be automated (Palier, 2019). Although some employees are poorly paid, this still can be better than unemployment. It is not surprising that this item was ranked at the top in this category. Because of its high importance, the disruptions are to be managed through long-term plans:

“These changes (especially the structural ones) happen over 5-10 years (at least). Thus, some of the above questions are not easy to be answered. E.g., labour disruptions should be planned in advance (and actually it is planned).” (DR2-8-A)

Another impact that reached consensus is the fewer available job opportunities in some regions which reduces regional prosperity. If one region is fruitful in the workforce while the supply chain nodes located in this area adopt AVs, there will be fewer jobs available there and increase the regional unemployment rate. This impact relates directly to unemployment, while it can be potentially related to equality as well. The unemployment in conventional supply chain supportive industries was identified from the literature, while it did not receive much agreement in importance – 97% of responses fell into the range between slight to considerable importance, and 45% selected the neutral option. Although the AVs also require maintenance, the supporting items can vary significantly, compared to conventional vehicles.

“Unable to change” and “overdependence on technology” are the new impacts categorised in this category and have not received challenges from the participants. A detailed illustration of allocating these two impacts is presented in the Discussion section. These ratings proved the importance of developing change management strategies for adopting new technology in supply chains. It is crucial for organisations to be able to change the working modes and set appropriate standards and agendas (Caldarelli et al, 2021).

3.4.2.2.4 Welfare

Following the definition of welfare in this context, three impacts which relate to well-being and traffic congestion were evaluated. Reduced human contacts and interactions synthesised “reduced communications among workers” and “reduced human interactions between recipients and service providers” from the literature. The participants were probably not sure about the integrated rating for the impact that represents several stakeholder groups, which led to diverse opinions regarding the rating of this item (R3 SD=0.92, the highest in Table 3-12). In comparison, the alienation of workers in the operations presents more specific reduced interpersonal communications among particular stakeholders. These two impacts received very close ratings for importance – both lower than “moderately important”. For “increased congestions”, it is possible that the road traffic will be more crowded if the AVs are adopted more widely – the intelligent telecommunication systems equipped on the AVs automatically optimise the

distance from the surrounding vehicles, so that less “buffering space” is needed. Thus, UGVs implemented for freight transport may exacerbate road congestion (Jing et al., 2020). Currently, this impact received the lowest importance rate, with a consensus reached among 83% of participants.

3.4.2.2.5 Diversity and Equality

Although AVs expand the delivery services to remote areas, some social classes that have not received relevant education and are not financially capable of affording the services and the personal mobile equipment (smartphones) that support the services still cannot access them, which worsens the inequality. Meanwhile, the newly identified impact – not ensuring the participatory development with diverse users, means that the exclusion of some key stakeholders with their demands overlooked undermines the equality of the supply chain in this context. However, both these impacts were not considered important by the majority of the panel, which left this indicator with the lowest importance rate within the indicator list.

Tables 3-10 and 3-11 describe the changes in the ratings regarding the individual items of positive impacts while Table 3-12 depicts the changes in the negative impacts respectively.

Table 3-10 Positive Impact Rating Part A

Rank	Indicator	Impact	R2 Mean	R2 SD	R3 Mean	R3 SD	R3-R2 ΔM	R3-R2 ΔSD	Consensus
1	TP	Data & information integration and real-time visibility	4.13	0.86	4.33	0.66	0.20	-0.20	Y
		Assets and Products Security	3.82	1.00	4.00	0.74	0.18	-0.26	Y
4.17									
2	CS	Faster and more customised delivery services	4.13	0.85	4.37	0.72	0.23	-0.13	Y
		Customer experience improvement	3.92	0.92	3.93	0.87	0.01	-0.05	Y
4.15									
3	HS	Road traffic safety	4.29	0.79	4.29 (R2)				Y
		Workforce physical safety and health	4.23	0.97	4.23 (R2)				Y
		Fast response in emergency for life-saving	4.05	1.19	4.05 (R2)				Y
		Customers or recipients' health and safety (especially in the pandemic)	3.95	1.05	3.90	0.82	-0.05	-0.23	Y
		Workforce mental health	3.66	1.13	3.90	0.72	0.24	-0.41	
4.07									
4	RPT	Modern image as "innovation" for marketing and branding	3.74	0.99	3.93	0.78	0.19	-0.21	Y
3.93									
5	LI	Create new high-skilled jobs	3.92	0.97	4.17	0.75	0.25	-0.22	Y
		Fill labour shortage	3.82	1.22	4.13	0.86	0.31	-0.36	Y
		Reduce inefficient jobs	3.92	0.89	4.03	0.81	0.11	-0.08	Y
		Improved working environment and employee satisfaction	3.95	0.88	3.73	0.78	-0.22	-0.10	Y
		Initial reduction of poorly-paid job opportunities			3.18	0.9			
3.85									

Table 3-11 Positive Impact Ratings Part B

Rank	Indicator	Impact	R2 M	R2 SD	R3 M	R3 SD	R3-R2 ΔM	R3-R2 ΔSD	Consensus
6	WF	Reduce congestion and better use of road space	3.97	0.81	4.00	0.71	0.03	-0.10	Y
		Work-life balance and improved living standards	3.62	1.10	3.62	0.78	0	-0.32	Y
					3.81				
7	DE	Better accessibility for remote areas	3.74	1.12	3.97	0.76	0.23	-0.36	Y
		Improved gender equality for mitigating the stereotype of drivers as "male jobs"	2.89	1.26	2.60	0.77	-0.29	-0.49	Y
					3.29				

HS: Health and Safety

CS: Customer Satisfaction

DE: Diversity and Equality

TP: Transparency

WF: Welfare

RPT: Reputation

EMP: Employment

Table 3-12 Negative impact ratings

Rank	Indicator	Impact	R2 M	R2 SD	R3 M	R3 SD	R3-R2 ΔM	R3-R2 ΔSD	Consensus
1	TP	Privacy and cybersecurity concerns	3.54	1.08	3.83	0.79	0.29	-0.29	
		Loss of control over the system	3.74	0.98	3.73	0.87	-0.01	-0.11	
					3.78				
2	HS	Safety incidents due to crashes and failures	3.97	1.14	4.00	0.82	0.03	-0.32	Y
		Psychological and physical strain for those confronted by new technology adoption	3.50	0.97	3.30	0.92	-0.20	-0.05	
		Deteriorated employee health due to reduced exercise in the workplace.			2.57	0.90			Y
					3.29				
3	LI	Initial reduction of poorly paid job opportunities and short-term structural unemployment	3.69	0.94	3.47	0.82	-0.22	-0.12	Y
		Unable to change due to the lack of change management	3.36	1.12	3.43	0.82	0.07	-0.30	Y
		Fewer available jobs in some regions - reduced prosperity	3.51	1.06	3.27	0.69	-0.24	-0.37	Y
		Employment disruption in supportive industries, e.g., petrol stations	3.18	0.93	2.97	0.82	-0.21	-0.11	
		Over-dependence on technology	2.82	1.20	2.93	0.91	0.11	-0.29	
					3.214				
4	WF	Reduced human contacts and interactions	3.05	1.20	2.90	0.92	-0.15	-0.28	
		Alienation of workers in the operations	3.11	1.13	2.86	0.79	-0.25	-0.34	Y
		Increased congestion	2.89	1.14	2.43	0.77	-0.46	-0.37	Y
					2.73				
5	DE	Not accessible for some social classes and inequality	2.92	1.06	2.61	0.74	-0.31	-0.32	Y
		Not ensuring participatory development with diverse users	2.73	1.08	2.52	0.83	-0.21	-0.25	Y
					2.57				
Deleted		Being forced to adopt AVs under competitors' pressure	2.95	1.08					

3.5 Discussion

This section further illustrates the findings from the Delphi study and relates the findings to the existing concepts. Discussions regarding stakeholders are first presented, followed by the social impacts.

3.5.1 Stakeholder grouping

After capturing the degrees of influential dimensions of both internal and external stakeholders, this section seeks to analyse the characteristics of the stakeholders with similar degrees of “being affected” ratings and “affecting” ratings. Table 3-13 lists the series numbers for the stakeholders shown in Figures 3-3 and 3-4.

Through visualising the stakeholder positions against the two dimensions of influence, this study analyses the relevant stakeholders in this context in detail. The three categories, nine groups of internal stakeholders, and six categories, 17 groups of external stakeholders are identified as the relevant entities in the context of AV adoption in supply chains. Additionally, the two influential dimensions imply the first attempt at understanding “How important are these stakeholders?” (Stieb, 2009). This mechanism provides the basis for further research into how these stakeholders are relevant to the social impacts. By explicitly listing the stakeholders, this study reemphasises the substantial role of stakeholders in SCSS research (Huq et al., 2014).

Table 3-13 Stakeholder series

Internal stakeholders	No.	External stakeholders	No.	External stakeholders	No.
C-level managers	1	Competitors	1	Other traffic users	10
Change managers, HR, and Project managers	2	Customers	2	Insurance providers	11
Mid-level managerial employees	3	Logistics services providers (3PL, 4PL)	3	Health and Safety experts	12
Shareholders, owners	4	Vendor-managed Inventory suppliers	4	Local communities	13
Technology maintenance team	5	Government and legislative authorities	5	External research and training centres	14
Operational employees	6	Traffic control officers	6	Media	15
Procurement department	7	Software suppliers	7	Lobby groups representing AV suppliers	16
Finance and Accounting colleagues	8	AV manufacturers	8	Labour unions	17
Health and Safety Colleagues	9	External maintenance team	9		

3.5.1.1 Grouping the internal stakeholders

Figure 3-4 presents the plot mapping of the internal stakeholders regarding the degree in two dimensions of influence: being affected vs. affecting. This section presents an analysis of the internal stakeholders that share similar ratings in influential degrees in the two dimensions. There are two main groups with two discrete stakeholders discussed in this section. The discrete stakeholders: Financial and accounting (F&A) colleagues (No. 8) and C-level managers (No. 1) are located far away from the other stakeholders; while F&A colleagues are ranked the lowest in both directions, and C-level managers are relatively less affected, but have the strongest affecting power. The F&A department belongs to the firm infrastructure in the value chain (Porter, 2001), rather than the primary departments that are directly involved in the operations and decision-making. As pointed out, the F&A team is responsible for documenting and analysing the financial performance after the organisation adopts AVs in the supply chain, or providing the budget and expected financial performance for the senior managerial groups to make strategic decisions. The F&A team is important for the organisation, especially for supporting the decision-making (which is why the affecting degree is slightly higher). However, their working modes or processes are not significantly changed. On the other hand, as highlighted in the previous section, C-level managers are the stakeholders that make strategic decisions in AV deployment, including the scale, of deployment, as well as the key skills and capabilities required to manage the AVs. Hence, the degree of affecting is unsurprisingly the highest among the internal groups. However, their decision-making can be affected by the budget produced by the F&A department – the quantity of AVs to deploy annually, whether it is necessary to receive external financial support etc. The significant difference between the degree ratings of the two dimensions leads to the location of this item on the map being away from other stakeholder plots.

There are four stakeholders showing both influential dimensions in the mid-range (between 3 and 4): shareholder (No. 4), change manager (No. 2), procurement department (No. 7), and health and safety colleagues (No. 9). Although the key decisions are sometimes decided by the shareholders, they do not directly

participate in organisational decision-making processes for operations, such as whether to deploy AVs or not (Boatright, 1994). That is why shareholders can be either internal or external stakeholders (Sarkis et al., 2010). In this study, participants mentioned this group as an internal stakeholder in the first round of the Delphi study, so the shareholders are listed in the group of internal stakeholders. Change managers, on the other hand, facilitate what upskilling and reskilling training programmes should provide to the existing employees, who are to be recruited and laid off, based on the strategic decisions of deploying AVs from the C-level managers. Therefore, both shareholders and change managers are rated relatively higher in affecting degrees, while the two support function groups are comparatively lower in affecting rates. Similar to the F&A department, the procurement department is the supporter of the AV deployment campaign (Porter, 2001). These two departments collaboratively work out the feasible procurement plans and realise the deployment of AVs for the operations in supply chains. The Health and Safety (H&S) department also supports the operations, while colleagues emphasise the workforce H&S in the AV adoption context. They share a very similar affected rating degree with change managers because they are responsible for enacting the tailored H&S indices to regulate, monitor, and assess the measures that present workforce physical and mental well-being. They can be affecting in providing tailored risk-mitigating solutions to those who work with AVs and highlighting the importance of H&S issues to the senior decision-makers to focus on responsible strategies, but they have restricted power in changing the deployment decisions of AVs in the supply chain.

The final three stakeholders: technology maintenance (No. 5), mid-level managers (No. 3), and operational employees (No. 6) all present high affected ratings, with diverse affecting ratings from 3 to 4. All these internal groups are directly affected by AV deployment in the organisation. The technology maintenance team needs to have the new skills to maintain the vehicles if necessary. They are influential for their performance in conducting technical maintenance – they can positively impact the overall operations of the AV fleet and the vehicles are able to conduct the tasks under good conditions without faults. The shop-floor employees are obviously the most directly and strongly

affected by AV adoption, as their roles are executors of the strategic and operational decisions and tasks, rather than playing the leading roles that influence the decisions. Mid-level managers enact proper production plans and safety rules for the operational employees to execute. Therefore, they can show comparatively higher ratings for affecting degrees than the other two stakeholders.

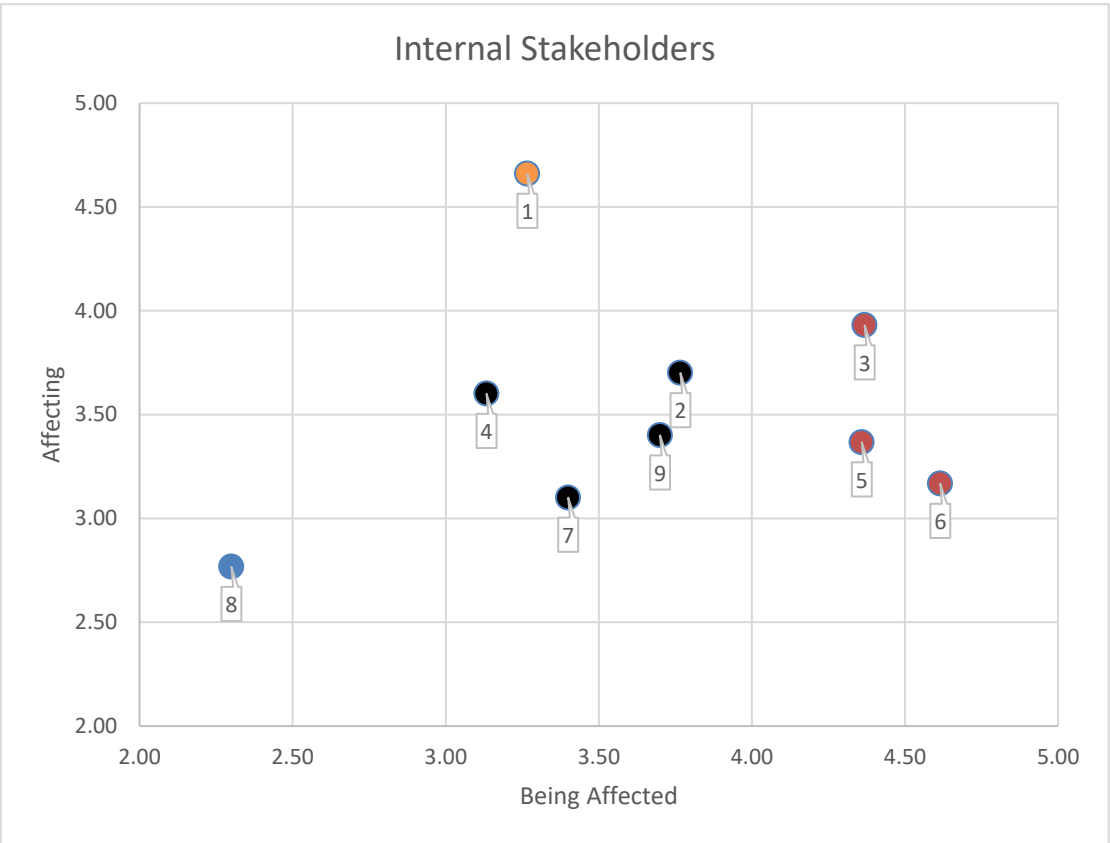


Figure 3-4 Internal stakeholder positions

3.5.1.2 Grouping the external stakeholders

Similar to the previous section, this section also presents the grouping of the external stakeholder plots on the basis of Figure 3-5.

The media's (No. 15) rating plot is located far away from other stakeholders, with the lowest degree of being affected. Media can critically affect public perceptions and ethical operations in supply chain organisations, which can be crucial for organisations' reputations (Nikolaeva and Bicho, 2011, Soroka, 2003). In this context, the media's impacts mainly fall into urging organisations to focus on their

CSR operations and performance, rather than affecting the decisions of organisations to adopt AVs in their operations. The voice of media can be affected by some lobby groups (No. 16) in promoting the advantages of adopting AVs in industries, with limited discussion of the weaknesses, in order to achieve their purpose (Binderkrantz, 2005), while not being directly affected by the deployment of AVs in supply chains. That is a potential reason for the media to be an outlier in this context.

The rating plot for the government (No. 5) is also located far away from the main groups. Meixell and Luoma (2015) recognised a strong influential degree of government as a stakeholder to pressure organisations to operate sustainably. This is in line with the findings in Chapter 3.4.1.2.4. The regulations enacted by governments restrict or guide the implementation of AVs in supply chains. Meanwhile, governments and policymakers can be affected by refining the restrictive regulations into instructional guides as the technologies become increasingly reliable and mature (Dolfsma and Seo, 2013). This means that the improved safety performance provided by the technology providers and adopters potentially affects safety and security regulatory frameworks in implementing AVs in supply chains.

Stakeholders NO. 12, 13, 14, and 16 were rated closely in being affected degrees, with a minor diversity in affecting ratings. External research and education institutions (No. 14) and H&S experts (No. 12) are similar in the rating of both influential dimension degrees. They are not closely related to the technology adoption in supply chains, but they provide supportive services and consulting to the institutions that adopt AVs in their operations in terms of health and safety assessment, knowledge and skill development, etc. for the employees to work well with the AVs. However, the internal H&S department and the training sessions provided by AV manufacturers are more tailored to the focal organisations, so the affecting ratings for these two external stakeholders are at a low level. Lobby groups (No. 16) can lobby and convince institutions and legislative authorities to achieve their interests or purposes (Browne et al., 2000; Ovaere et al., 2013) (i.e., in this context, to have a wider AV adoption). Therefore, their affecting ratings are higher in this group of external stakeholders. With a

similar value of the degree of being affected, the local community (No. 13) is rated the lowest among the external stakeholders regarding the affecting degree. Taking Starship Technologies, a grocery delivery robot provider as an example, their deployment largely depends on their collaborations with the local council or government and the grocery brands (Co-op, 2023). Local communities and citizens, however, are limitedly involved in the early stages of deployment. This potentially enlarges the inequality within the local community, as the marginalised groups are not participatory and potentially being neglected by the services (Valdez et al., 2021). Therefore, local communities are more affected by the AV adoption, than affecting.

Stakeholder NO. 1, 2, 4, 6, 10, 11, and 17 are rated within a similar range of being affected, with a comparatively diverse affecting rating degree. Insurance providers (No. 11) are rated the lowest at both dimensions of influential degrees in this group. Although not directly related to AV deployment, the insurance providers are responsible for offering insurance services that cover a wide spectrum of items including health, safety, privacy, etc. (Palmié et al., 2020). Therefore, this means that clear legislative frameworks should be ensured to provide legal evidence for insurance companies to develop service portfolios (Balasubramanian et al., 2021). Hence, although the insurance providers affect organisations' choices, they are dependent on the clarity of the regulations regarding AV implementation in the supply chain. Customers (No. 2) and other traffic users (No. 10) directly interact with AVs. This means that they can be actively engaged in the organisations' decision-making in AV deployment that further relates to operation performance (Szalavetz, 2019). For customers, AVs serve as an additional option to select how their orders are to be delivered. Meanwhile, customers can affect AV adoption by providing feedback to the organisations, or determining whether to use the service next time. However, the traffic users, similar to the local communities, have limited influence on organisations' AV deployment status. Thus, the affecting rate for them is lower than for the customers. Unions (No. 17), traffic control officers (No. 6), and VMI suppliers (No. 4) share similar ratings in both dimensions. The unions are mainly formed from operational employees in supply chains, so they are considerably

affected. However, the gathering of employees can form a collective force to exert pressure on senior decision-makers (Farber, 1986), which means that their affecting rate can be considerably high (even similar to the lobby groups). Compared to the regulators, traffic control officers do not have legislative power, but can direct traffic for the AVs from accidents. VMIs were rated lower than LSPs (No. 3) in both dimensions for providing a less wide spectrum of services (only assets storage and inventory services). However, both of them need to provide tailored supply chain solution packages to the partner organisations if these organisations decide to adopt AVs in supply chains by adapting their operating processes, technologies, services, and infrastructures to meet these organisations' requirements. They can also impact the organisations' AV adoption by providing their expertise and capabilities to support the adoption process and even offer training sessions to enhance their employees' awareness of AVs. Competitors (No. 1) were rated with the highest affecting degree in this group. They can exert pressure on their peers on the basis of the changes in operation performance of AV adoption, and vice versa.

Both software (No. 7) and hardware suppliers (AV manufacturers, No. 8) are rated highly in the two dimensions. They are affected by the technology development trends, as well as the AV adoption decisions made by the organisations – the demands from the organisations for tailored hardware, software, and maintenance services. The reliability and quality of their outputs also affect the organisations' choices. Similarly, external maintenance (No. 9) and LSPs (No. 3) are highly affected by the choices of their partners in supply chains. However, they affect the organisations' and individual customers' choices based on the service quality they offer. If the technologies and services show significant competitive advantages compared to the existing conventional vehicles, the organisations indeed adopt AVs in supply chains broadly.

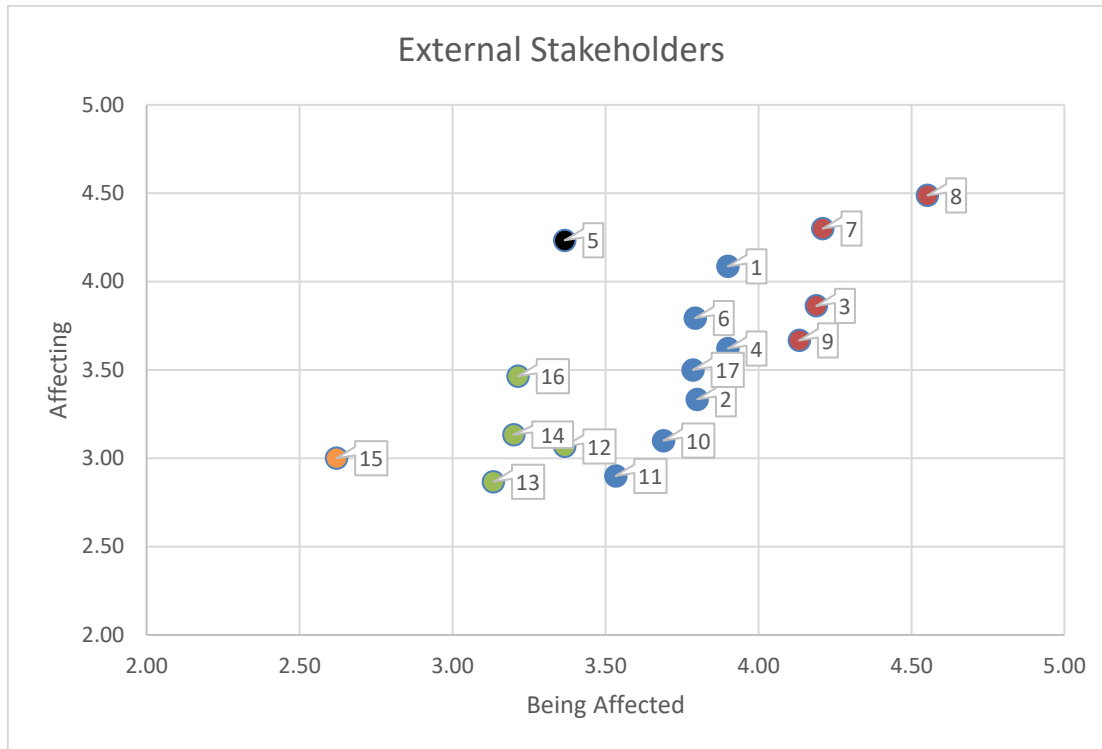


Figure 3-5 External stakeholder positions

3.5.2 Social Impacts and SCSS: Model Validation

Figure 3-1 presents the links between social impacts and SCSS indicators from the literature. After the 3-round Delphi study, the sizes of impact pools for both positive and negative impacts expand, as well as the relevant SCSS aspects. Hence, the model evolves after the study (shown in Figure 3-6). Apart from the changes in items that are covered in the findings part, this section especially emphasises the disputes regarding impacts in the employment category, the new SCSS indicator, and then the changes in the model. Such refinements present major contributions of this research to SCSS concepts.

3.5.2.1 New social impacts and SCSS aspect

3.5.2.1.1 Positive impact added to the employment indicator

In the second round, regarding the employment category, one participant doubted that the reduction of poorly paid job opportunities should appear as a positive impact.

“I don’t understand why “initial reduction of poorly-paid job opportunities” is negative. Isn’t that supposed to be a positive thing?” (DR2-4-A)

Although it seems that there are fewer available jobs, poorly-paid jobs, or low-income occupations, are strongly related to safety and health issues in working environments and living places, social inequities, labour rights etc (Baron et al., 2014). The replacement of these jobs with new opportunities is beneficial for the occupants to become well-trained to work with the AVs, to receive a guaranteed salary and living quality. Therefore, this item was added in the third round to be evaluated among the participants.

3.5.2.1.2 Negative impacts added to the employment indicator

In the first round, two impacts emerged and were not categorised into any of the sustainability indicators initially:

- Over-dependence on technology, and
- Being unable to change due to the lack of change management.

Overdependence on technology is an adverse consequence of adopting advanced technologies in the industry and human employees are unable to work efficiently without using the technologies (Campbell et al., 2007). Over-reliance on technology, or a limited source of technology increases risks on supply chains (Cousins et al., 2004). Outputs of the supply chain are severely delayed if there is a downtime of the technology in one node. In addition, overdependence on technology means limited reliance on the human workforce, which is definitely not ideal for local employment. Since overdependence on technology relates to labour output and unemployment, this impact is categorised under the category of employment.

The second impact, being unable to change, is vague and broad. In this research, this impact relates to unchanged social issues in organisations such as the organisational structure of operations, adoption standards and agenda, safety and security protocols, and employee working modes and styles are all potentially involved as relevant social issues and elements (Calderelli et al., 2021). If the original aim of applying AVs is to create an improved working environment, but

the aforementioned issues are not changed to match the AV adoption, the proposed positive impacts in employment are undermined. Hence, this impact also matches the definition of the “employment” category.

3.5.2.1.3 Additional SCSS indicator: Reputation

In the first round of the Delphi study, three participants mentioned that the use of AVs in the supply chain can be considered as a means to present a “modern image” for promotion and marketing to the public. Such a “modern image” can be regarded as a public sentiment. Among the current six social sustainability indicators, no one category covers this piece of information. However, this is included in another indicator, i.e., “reputation”, one of the indicators found in existing seminal social sustainability studies. By definition, “reputation” represents “the image of an organisation which represents public sentiment in terms of the actions of the organisation” (Carter and Rogers, 2008). Hence, “new image as innovation and branding” is regarded as a new positive impact, and to be linked with the “reputation” indicator. This additional SCSS indicator extends the SCSS concept of the AV adoption context. Therefore, seven indicators are relevant: health and safety, customer satisfaction, employment, transparency, diversity and equality, welfare, and reputation.

3.5.3 Refined model and Proposed mapping of stakeholders with the relevant social impacts

Based on the analysis of the Delphi results and Table 3-9, Figure 3-6 shows a refined model (from Figure 3-1) that concludes all the relevant social impacts and SCSS indicators of AV adoption in supply chains. In addition to the model, Table 3-14 presents the proposed mapping of the identified stakeholders and the refined social impacts. This table combines Table 3-9, Figure 3-5 (a conclusion of all the identified social impacts) and Table 3-13 (a conclusion of all the identified stakeholders). Stakeholders in Table 3-14 are marked with the serial numbers provided in Table 3-13.

The proposed mapping presents the affected stakeholders that relate to the respective social impacts. Hence, all the included stakeholders are related to the social impacts, which means that the “being affected” dimension of influence

specifically is emphasised. As a result, this table is the first attempt to relate the identified stakeholders to the identified social impacts in the AV adoption context. The table attempts to illustrate “who are relevant to what social impacts of AV adoption in supply chains”.

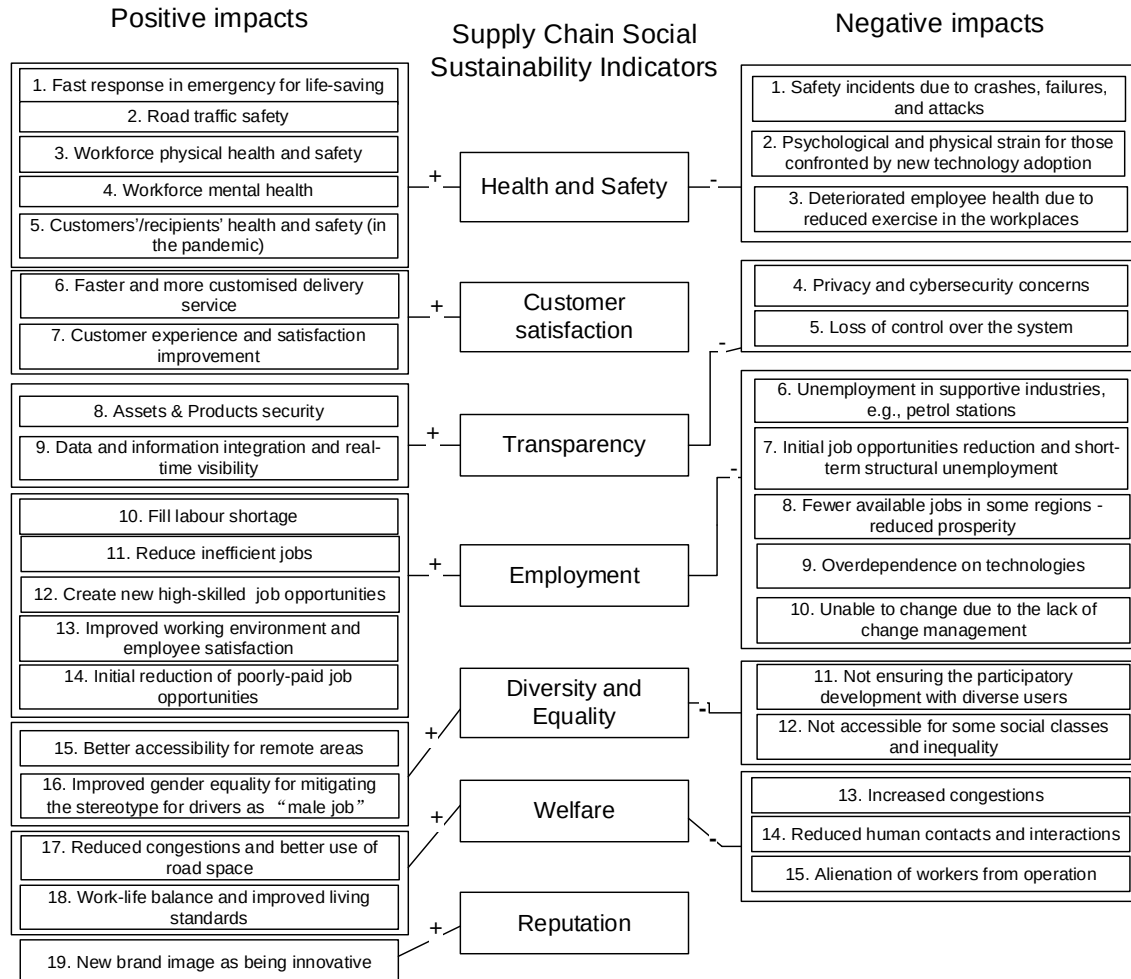


Figure 3-6 Refined links between social impacts and SCSS indicators

Table 3-14 Mapping the stakeholders and social impacts

SCSS indicators	Positive impacts	Stakeholders	Negative impacts	Stakeholders
Health and Safety	Road traffic safety	I6; E5; E10; E11	Safety incidents due to crashes, failures, and attacks;	I6; I9; E2; E5; E13
	Workforce physical safety and health	I6; I9;	Psychological and physical strain for those who are confronted by new technology adoption*	I6; I9
	Fast response in emergencies for life-saving	E2; E5; E6	Deteriorated employee health due to reduced exercise in the workplace*.	I6; I9
	Customers' or recipients' health and safety	E2;		
	Workforce mental health*	I6; I9		
Customer Satisfaction	Faster and more customised delivery services	E2; E3;		
	Customer experience improvement*.	E2; E3;		
Transparency	Data and information integration and real-time visibility;	I1; I3;	Privacy and cybersecurity concerns;	E2; E13
	Asset and product security	I1; I3;	Loss of control over the systems	I1; I3;
Employment	Create new high-skilled jobs;	I1; I2; I3; I5; I6; I8; E7; E8; E9;	Initial job opportunities reduction and short-term structural unemployment;	I6; E13; E17
	Fill labour shortage;	I2; I3; I6;	Unable to change due to the lack of change management*;	I1; I2; I3
	Reduced inefficient jobs*;	I2; I3; I6; I8	Fewer available jobs in some regions – reduced prosperity*;	I6; E13;
	Improved working environment and employee satisfaction*;	I6; I9;	Employment disruption in supportive industries;	I5; I6;
	Initial reduction of poorly paid job opportunities*	I2; I3; I6; I8	Overdependence on technology*.	I1; I3; I5; I7; I8
	Better accessibility for remote areas*;	E2; E13	Not accessible for some social classes and inequality	E2; E13
Diversity and Equality	Improved gender equality for mitigating the stereotype of truck drivers as “male jobs”	I6	Not ensuring participatory development with diverse users*.	E10; E13;
Welfare	Reduced congestion and better use of road spaces;	I3; E6; E10; E13	Reduced human contacts and interactions;	I6; I9; E2; E3;
	Work-life balance and improved living standards*	I6	Alienation of workers in the operations*;	I6; I9;
			Increased congestions*	I3; E6; E10; E13;
Reputation*	Modern image as “innovation” for the branding*	E1; E2; E15;		

I = Internal Stakeholders; E = External Stakeholders

3.6 Conclusion

This paper takes a deep look at the social sustainability of AV adoption in the supply chain and focuses on stakeholder groups, social impacts, and social motivators and barriers. Through a three-round Delphi study involving 39 experts, this paper contributes to the SCSS conceptualisation by recognising the internal and external stakeholder groups, the positive and negative social impacts that are related to the relevant SCSS indicators, as well as the relations between social impacts and the social motivators and barriers. Through evaluating the degrees of affecting/being affected of the stakeholders, this study attempts to assess “how important are these stakeholders?”. Such efforts fulfil the first research gap of this thesis: “A lack of evaluation of context-specific stakeholders in the AV adoption context.” In addition, by rating the importance of the social impacts, this study suggests the most important social issues to emphasise to achieve improved SCSS performance when adopting AVs. By the end of the paper, this study attempts to relate the two main outcomes together – the stakeholders and the social impacts, to illustrate who are affected and by what social impacts in the AV adoption context. All these elements provide the research community with a first systematic collection of the social implications of AV adoption in supply chains.

3.6.1 Contributions to knowledge

This research addresses the intersection of SCSS and AV adoption in an exploratory manner to expand the concept of research into social sustainability in a novel context. The study covers the social impacts and relevant stakeholders in both UAV and UGV adoption in the supply chain. It is, to the authors’ knowledge, the first piece of work to comprehensively analyse the social implications and SCSS of the two types of technologies.

Stakeholders are the first main part that this paper addresses. In the study, nine internal and 17 external stakeholders are identified, which contributes to the differentiation of stakeholder classification (Hussain et al., 2018; Olander, 2007). Through identification and classification, this study recognises contextual

stakeholders in detail in order to expand and refine the stakeholders extracted from the literature. It is the first step in understanding the social impacts of AV adoption on stakeholders in SCSS conceptualisation. This research also makes the first attempt to understand the question of “how important these stakeholders are” (Stieb, 2009) in this context. This is addressed by the exploration and evaluation of the degree of affecting/being affected of these stakeholder groups in this context. The analysis of the influential dimensions of the stakeholders creates a fundamental understanding of how salient those groups are in this context (Mitchell et al., 1997). These two aspects are the main intended contributions to the stakeholder analysis in the AV adoption context.

Apart from the stakeholders, the refinement of the social impacts and social sustainability of AV adoption in the supply chain is another main work covered in this study. The initial literature review identified 13 positive and seven negative impacts, and six relevant social sustainability indicators. Through this Delphi study, altogether 19 positive and 15 negative social impacts are related to seven social sustainability indicators: health and safety, customer satisfaction, employment, transparency, diversity and equality, welfare, and reputation. The importance rank of the impacts in each indicator also suggests the key social issues for future researchers to focus on in the AV adoption context. Through identifying and refining the stakeholder groups and the social implications, this paper expands the SCSS concepts in the AV adoption context and develops context-specific indicators and impacts (Ahi and Searcy, 2015). Furthermore, this study validates the method of investigating SCSS performance through the detailed social impacts and their relevant stakeholders. This approach can be implemented in other similar contexts that discuss SCSS.

We can therefore understand SCSS in the AV context as:

The social implications that are relevant to health and safety, customer satisfaction, employment, transparency, diversity and equality, welfare, and reputation perspectives of performance of the supply chain, with regard to the respective stakeholders through the adoption of UAVs or UGVs in supply chain operations.

In addition, the first attempt of relating stakeholders and social impacts made at the final stage of the paper illustrates who is affected by what social aspects of outcomes of AV adoption in supply chains. Sarkis et al. (2011) concluded stakeholder theory that internal and external stakeholders exert pressure on companies regarding the impacts on stakeholders, to urge those companies to reduce negative impacts and improve positive ones. The mapping of the impacts and stakeholders paves the way for conceptualising SCSS in AV adoption through the lens of stakeholder theory. Therefore, understanding the context-specific SCSS indicators as well as the stakeholder groups are the main contributions to knowledge.

3.6.2 Managerial implications

The output of this paper identified the relevant stakeholder groups, as well as the exact social impacts that relate to them. The stakeholders' influential dimensions prompt organisations to understand the essential internal and external stakeholders, as well as their relevance in this context. The importance rate of the social impacts illustrates what social issues the decision-makers should focus on primarily when adopting AVs. Concerning social sustainability, the established framework (Figure 3-5) clearly shows the categorisation of the individual social impacts and the social sustainability indicators. Organisations following the framework have an overview of the key stakeholders and social issues, so they benefit from addressing the social enquiries raised by relevant stakeholder groups, for improved social sustainability performance of their operations. Therefore, this paper provides suggestions on which stakeholders and social impacts to consider, and what issues to be primarily focused on so that organisations can potentially deploy AVs with a wider social approval by referring to this paper.

In addition, the exploration of SCSS in this context provides a guide for organisations that seek to improve Environmental, Social and Governance (ESG) performance, especially those adopting advanced frontline technologies such as AVs. ESG is an under-development rating tool to assess organisations' performance on environment, ethics, health and safety, and labour issues (Dai

and Tang, 2022). The ESG ratings are audited by the rating agencies to provide suggestions to the major institutional investors for financial support provision (Atkins, 2020). Hence, this research provides a guide for the ESG rating agencies to evaluate the ESG performance of the organisations that adopt frontline technologies in supply chains. Therefore, these agencies can update the assessment indicators by referring to the findings of this paper.

3.6.3 Limitations

Some limitations indeed exist in this paper. In this empirical study, the UGVs and drones are analysed together, rather than separately. As one of the participants from the Delphi panel argued, the affecting stakeholders' perceptions regarding UAVs might be very different from UGVs. They potentially evaluate differently regarding the different types of AVs. This paper structures an initial holistic overview that describes the key items regarding the stakeholders and the social implications in the context of both UAV and UGV adoption. The elements of this paper can inevitably be general. This suggests a reasonable future research path to refine more deeply the social impacts and stakeholders in specific scenarios.

In addition, since stakeholders are the groups to be influenced by or influence the operations by definition, it is reasonable to identify and distinguish the stakeholders into these two main groups. Although the questions identified the "affecting" and "affected" stakeholders, this paper only focuses on the "affected" groups, since this research seeks to investigate the social outcomes and the affected stakeholder groups of AV adoption in the supply chain. The affecting groups that affect AV adoption, or make decisions to adopt AVs in the supply chain are not within the scope or main focus of this study.

This study also suffers from participant attrition effects within the rounds. Due to the unexpectedly long data-collection period for the first round, quite a few panellists from the first round cannot remember what the content was or even forget having participated in the first round. Some academics and practitioners quit due to their changes in positions (e.g., retiring) or loss of interest in the study. Further, the imbalanced distribution of academics and practitioners potentially undermines the comprehensiveness of the outcomes of the third round,

especially the feedback from the industry. Some of the items lack sufficient evaluation from the practitioners, which potentially weakens the final practicality of the frameworks to be implemented in the industry. In addition, the five-point ratings only provide a general indication of how important the experts believe the impacts to be in a real-life scenario. Since the second-round questionnaire is very long, time-consuming and effort-taking, some participants inevitably selected the items with limited concentration and passion. Regardless of these critical limitations, we still strongly consider the outcomes to be valid and the contribution of the Delphi study is significant to the industry and academia.

3.6.4 Future research directions

The discussions and limitations mentioned above pave the way for future research. Firstly, the identified affecting stakeholders received less focus and required more emphasis on their roles in decision-making regarding sustainable supply chains in the AV adoption context. Also, based on the stakeholder groups identified in this paper, future research is suggested to classify the stakeholders on the basis of their attributes (Olander, 2007; Mitchell et al., 1997) in this context. This will not only benefit the key decision makers to appropriately manage the stakeholders through their attributes but also facilitate the conceptualisation of the stakeholder theory with SCSS in this context.

In addition, it is necessary to separate the research on the social impacts of the two types of AVs. Under the general framework provided for the research of the two types simultaneously, future research is encouraged to diversify the detailed differences of stakeholder involvement, the social impacts, and the social sustainability performance, separately. The importance of these elements varies by logistics sector and technology type. Hence, the framework can benefit from detailed further analysis. Future research is suggested to verify the framework in real-world scenarios – deeper verifying in organisations as case studies. Testing the framework via specific case studies can serve as a remedy for the lack of practitioner involvement in the original Delphi study. Based on the identified qualitative indicators, it is suggested to quantify the indicators into measurable indices in detailed and specific contexts in real-world cases. This provides a

solution to the difficulties in measuring social sustainability performance that exist in broader contexts.

This paper makes a first attempt to understand the relations between stakeholders and social impacts in this context by mapping these two identified elements together in the AV adoption context. It is worthwhile to investigate the dynamics between stakeholders and the social impacts of AV adoption further. Therefore, future research is recommended to use the stakeholders, social impacts and Table 3-17 as input to investigate the stakeholders' pressures and their implications on organisations in the AV adoption context. This suggests future research to conceptualise SCSS through the lens of stakeholder theory by using the outcomes of this paper as a starting point.

The most significant findings in this paper are the social implications of the AV adoption context, while the wide adoption of AVs in supply chains requires social approval. The mitigation of identified negative impacts is necessary and this requires the implementation of a series of actions. Therefore, future research is suggested to discuss the actions to address the identified social impacts (especially the negative ones) for an improved SCSS performance in this context.

Apart from the AV adoption, the outcomes of this paper can also set an example for deep investigation of the social implications of adopting other disruptive technologies in the supply chain. Hence, this paper will be beneficial to both academia and the industry to construct context-specific frameworks tailored to the particular scenario of research and practical implementation of other technologies in operations.

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4 Paper 3: Improving Supply Chain Social Sustainability in the Autonomous Vehicle adoption context: A Delphi study with expert interviews

4.1 Introduction

Autonomous vehicles (AVs) have been serving the logistics sectors for more than half a century and operating in defined territories such as harbours, warehouses, and manufacturing plants in the form of Automated Guided Vehicles (AGVs) (Flämig, 2016; Van Meldert and De Boeck, 2016). More advanced AVs emerged and evolved after Industry 4.0 (Schwab, 2016), such as uncrewed ground vehicles (UGVs) including autonomous mobile robots (AMRs) and self-driving vehicles, and uncrewed aerial vehicles (UAVs). AVs have been tested for their applicability in logistics operations and have proved their great potential in cost and environmental efficiency (Tang and Veelenturf, 2019). Based on prior laboratory-based statistics and field test results, UAVs are expected to be widely adopted in humanitarian logistics for their competitive advantages in fast responses to first-aid operations (Azmat and Kummar, 2020), while UGVs will be operating in commercial supply chains earlier and on a wider scale than UAVs (DHL, 2022). However, as mentioned in the previous literature review, the social dimension sustainability of AV adoption in supply chains is still controversial.

There are 19 positive and 15 negative social impacts identified that are associated with seven supply chain social sustainability (SCSS) indicators: Health and Safety, Customer Satisfaction, Employment, Transparency, Diversity and Equality, Welfare, and reputation. These social impacts and the relevant social sustainability aspects are of particular interest to the associated stakeholder groups that expect a series of actions to be taken to address them (Agyemang et al., 2022; Ghadge et al., 2021). On the one hand, the outcomes from the previous literature review fulfil the requirement raised by Ahi and Searcy (2015) to develop context-specific indicators for further conceptualising SCSS. On the other hand, these impacts and the relevant social sustainability indicators

serve as a conceptual base for deepening the understanding of how AV adoption affects SCSS.

Therefore, in parallel with the social impacts, the SLR provides a series of suggested actions extracted from the literature pool. These actions represent the authors' appeals to address the current social issues for the wider adoption of AVs in supply chains. Since addressing the social impacts benefits the achievement of wide social approval for adopting AVs in the supply chain (Kurniawan et al., 2021), it is important to implement actions to address the social impacts (especially the negative ones). The actions suggested for wider adoption should be able to address the social impacts that are associated with the social sustainability indicators. This means that the actions aiming to address the social issues potentially affect SCSS performance (Yawar and Seuring, 2017). However, there exists a research gap in that, the extant identified actions are proposed for wider AV adoption, instead of explicitly expressing as "addressing social impacts to realise wider AV adoption". Currently, from reviewing the literature, the actions are synthesised and categorised into four main groups, namely, pilot experiments; regulation improvement; education, promotion and training; and chain-wide (re)view.

In order to understand how organisations at various AV adoption stages implement the actions for improved SCSS performance, it is necessary to logically structure the refined actions and action categories. Therefore, this study adopts the Diffusion of Innovation theory (DOI) (Rogers, 2003) as a theoretical framework to understand the decision-making within individuals and organisations in supply chains when facing the adoption of disruptive technologies (Wamba and Queiroz, 2020). DOI explains what innovations are as well as the mechanism and process of how an innovation (technology or idea) spreads within a group of adoption units. In this theory, the organisational innovation process (IP) introduces a five-stage model for an organisation to adopt an innovation: agenda-setting, matching, restructuring/redesigning, clarifying, and routinising. On the basis of DOI, Innovation Adoption (IA) theories were developed that include initiation, adoption, and assimilation/routinisation applied by a series of studies investigating the factors of innovation adoption (Nam et al.,

2019; Hassan et al., 2015; Vu et al., 2023). These works categorise factors by using the technology-organisation-environment (TOE) framework (Tornatzky et al., 1990), to analyse how the innovation adoption process is affected by the factors.

As AVs can be described with the five attributes for technological innovations (i.e., relative advantage, trialability, observability, compatibility, complexity) (Yuen et al., 2020), it is applicable to use DOI in this context. The IP provides a solid model to organise the decisions of the organisations to make in each stage when adopting a disruptive innovation in their operations (Rogers, 2003). However, there is no existing research that applies this model to achieve SCSS performance in the technology adoption context.

The above-mentioned IP model provides a solid theoretical foundation for the actions to be verified in this study. To comprehensively understand how AV adoption affects SCSS, it is important to take two perspectives of elements into account. The first perspective describes the direct social outcomes of AV adoption, including the social impacts, relevant stakeholders, and potentially some of the social barriers. The second perspective covers the suggested action categories that address the social outcomes for a socially sustainable supply chain. Both perspectives form an integrated path to a holistic understanding of how AV adoption affects SCSS. While the first perspective was verified in the prior research, this study focuses on the second perspective with the following research question and objectives:

RQ: How should organisations act to address the social sustainability implications of AV adoption in supply chains

RO 1: To empirically refine and evaluate the suggested actions and action categories that companies can adopt to address the social impacts of AV adoption;

RO 2: To empirically evaluate the action categories for the organisations to employ at various stages of AV adoption in supply chains.

These ROs guide this study to further explore and refine the action categories proposed in the previous literature review, and then align these categories with

the DOI theory as a structured action plan. Hence, this study adopts a qualitative method to collect data for the exploratory nature of the study (Edmondson and McManus, 2007). Hence, a combined method including a three-round Delphi and a series of follow-up interviews are applied to identify and then further validate the action categories as well as the structured action plan. This study contributes to the concepts of SCSS by complementing the second perspective of the overall thesis (shown in Figure 1-3).

In addition to the actions, this study also refines the key research directions that were initially extracted from the literature. Although not serving the main ROs, these research directions suggest critical avenues for the development of future research on the social sustainability of AV adoption in supply chains.

This paper is organised as follows. Section 4.2 introduces the main concepts and theoretical foundations by reviewing the relevant literature. A description of the research methodology is presented in Section 4.3. The analysis of the Delphi study and the interviews are presented in Sections 4.4 and 4.5 respectively. Finally, Section 4.6 concludes the whole paper with limitations and implications of the research.

4.2 Literature review and Underpinning theories

This section introduces the review of the literature that is relevant to this study context. SCSS concepts in this context are reviewed first, followed by the Diffusion of Innovation (DOI) briefly introduced with the organisational innovation process. This eventually provides the review of the existing literature regarding the suggested actions for a socially sustainable supply chain in the AV adoption context.

4.2.1 Supply chain social sustainability

4.2.1.1 Supply chain social sustainability (SCSS) in the general context

In the general context, supply chain sustainability, as a series of seminal authors have defined, is the integration of economic, environmental, and social considerations with key inter-organisational business systems to effectively and efficiently manage operations, in order to meet stakeholder requirements and

improve profitability, competitiveness, and resilience over the short- and long term (Carter and Rogers, 2008; Seuring and Müller, 2008; Ahi and Searcy, 2013, 2015; Yawar and Seuring, 2017). However, there is no singular definition of social sustainability in the existing literature (Hussain et al., 2018). Social sustainability concerns the human side of sustainability (Huq et al., 2014), and the discussion of SCSS focuses on the aspects including equity, philanthropy, safety and health, human rights, welfare, labour, and product responsibility that are related to various stakeholder groups (Mani et al., 2016, 2018). These aspects, based on Ahi and Searcy (2015), are the indicators that qualitatively present the SCSS performance. While these indicators present SCSS performance in the general context, no single set of standards measuring social sustainability suits all supply chain contexts (Ahi and Searcy, 2015). Therefore, there is a need for developing context-based and specific indicators.

When investigating the social sustainability indicators, the concepts of social impacts cannot be ignored. Social impacts are the outcomes resulting from prosocial behaviour, that address social problems and are responsible for the environment, community, workers, customers, and governance, for improved welfare and life quality in society (Rawhouser et al., 2019; Esteves et al., 2012). The process of identifying and measuring these consequences is social impact assessment (Becker 2001). As Rawhouser et al. (2019) argue, the social impacts are important performance-based dependent variables that present the consequences as phenomena. For example, when discussing “employment”, multiple aspects are included: child labour, forced or compulsory labour, freedom of association and right to collective bargaining, discrimination at work, disciplinary practices, working hours, remuneration etc (SAI 8000, 2014). In this instance, the sustainability indicator “employment” is presented and measured by these multiple impacts. Therefore, we can generalise the social sustainability indicators to be presented by the corresponding social impacts in specific scenarios.

4.2.1.2 SCSS of AV adoption in the supply chain

Chapters 2 and 3 verified the social impacts and relevant SCSS indicators in the AV adoption context. Altogether 19 positive and 15 negative impacts are associated with seven relevant social sustainability indicators including Health and Safety, Customer Satisfaction, Transparency, Employment, Diversity and Equality, Welfare, and Reputation. Figure 4-1 (identical to Figure 3-5) presents the model of the links between social impacts and social sustainability indicators. They are the conceptual elements for this paper to be targeted at.

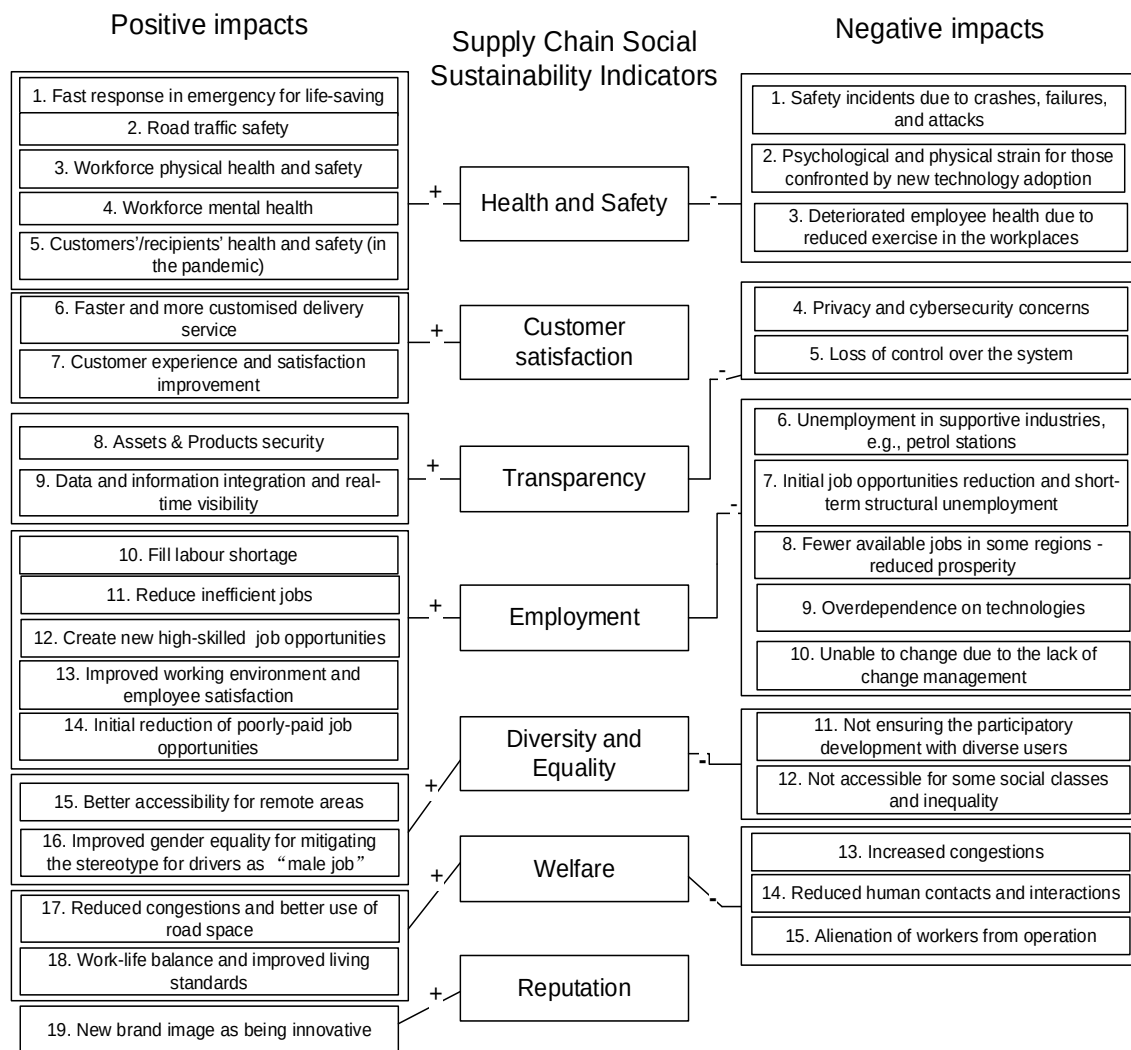


Figure 4-1 Links between social impacts and SCSS indicators

4.2.2 Suggested actions from the existing literature

Organisations are under pressure from stakeholders to implement socially sustainable actions, to address social impacts and satisfy their demands (Correia et al., 2024; Ghadge et al., 2021). The existing literature raised a series of actions that potentially address the social impacts of a socially sustainable supply chain. These actions were categorised into four groups, namely, field experiments; regulation improvement; education, promotion, and training; and chain-wide view/review. All four categories, as proposed in the literature review, are associated with the existing indicators that relate to negative social impacts (shown in Table 4-1).

The category “Field experiments and Tests” gathers three dimensions of arguments: general pilot tests and experiments, tests for improved AV designs, and tests for airspace-integrated usage. Nikitas et al. (2021) and Sohrabi et al. (2021) emphasised the need to conduct pilot tests and experiments in real-world scenarios. For improved safety purposes, Tatham et al. (2017) and Monios and Bergqvist (2020) argued that the pilot tests should be conducted in a controlled, small-scaled place. During the tests and experiments, new preventative measures should be combined into the AV designs (Kellermann et al., 2020). Apart from the technology itself, the integration of the AVs with the whole existing system should also be tested thoroughly (Poljak and Šterbenc, 2020). Rosser et al. (2022) especially mention the integration of the operating airspace of the AVs with other commercial aircraft.

The appeals to loosen the existing restrictions and improve appropriate guidance are extensively mentioned in the literature pool. These appeals include generic arguments for regulatory framework, legal considerations, and guidance (Rejeb et al., 2023; Wang et al., 2021) for health and safety issue prevention (Sohrabi et al., 2021, Haula and Agbozo, 2020), as well as the detailed items such as cybersecurity and data collection protocol, (Kellermann et al., 2020), and property rights (Rao et al., 2016) for transparency issues. Other suggestions such as the regulations to mitigate unemployment outcomes (Sen et al., 2020) and potential financial subsidies for AV adopters (Kapser et al., 2021) are also included.

The category Education, promotion, and training targets improving the awareness, skillsets, and knowledge of AV technologies and the applications in supply chains among various stakeholders. Promotion serves an important role in enhancing awareness, familiarity, and acceptance among end customers and local communities (Aydin, 2019; Eißfeldt et al., 2020). Therefore, it is important to promote and introduce a range of issues, such as the benefits and advantages (Sohrabi et al., 2021), and risk mitigation mechanisms (Nelson et al., 2019; Aydin, 2019). In the meantime, education and training sessions are provided to the internal employees to upskill them to requalify the new tasks and job positions after deploying AVs (Dadzie and Johnston, 1991; Klumpp, 2018), and also secure the existing employees' jobs (Nikitas et al., 2021).

Chain-wide (re)view focuses on the stakeholder engagement, planning, and constant improvement issues in this context. Socially sustainable supply chains require ethical operations throughout the whole supply chain among the stakeholder groups (Sen et al., 2020). This implies the importance of stakeholder engagement to mitigate the resistance attitudes of those stakeholders towards the technology adoption (Vlachos et al., 2023; Haula and Agbozo, 2020). Both internal and external stakeholders are involved in the planning and constant improvement processes (Kurniawan et al., 2021; Tatham et al., 2017). The planning actions, such as integrating UAVs into the smart city system and collaborating with other technologies (Mohamed et al., 2020), and allocating AVs into respective supply chain processes on the basis of their specifications (Perussi et al., 2017) are all essential. All these appeals highlight the importance of stakeholder involvement and communications (Ding, 2018).

Table 4-1 Actions suggested from the literature

Category	Actions suggested in the literature
Field experiments and tests	<ul style="list-style-type: none"> ● Preventative measures for drone designs; ● Thorough living lab experiments and tests in small-scale places preliminary; ● Tests the integration of airspaces.
Regulation Improvement	<ul style="list-style-type: none"> ● Regulatory Measures for safety, accountability, and privacy; ● No fly zones; ● Data collection and operations protocol; ● Transnational legislative approval; ● Regulations and legal guides, frameworks; ● Subsidising the delivery solutions; ● Regulations to mitigate the outcomes of unemployment; ● Federal guidance for adoption and certifications.

Education, promotion, and training	<ul style="list-style-type: none"> ● Promote public benefits and risk mitigation methods; ● Introduce AVs to the communities regarding their benefits to health and safety; ● Education and training to the employees via organisational education programmes; ● Re-skill strategies for less-educated and lower-skilled employees; ● A highly trained and experienced workforce is needed.
Chain-wide (re)view	<ul style="list-style-type: none"> ● Collective stakeholder engagement and participation for resistance mitigation; ● Build relationship between community and clinic; ● Integrate AVs into smart cities and collaborate with other technologies; ● Gain feedback and measure behaviours after the technologies are available and fully implemented in the communities.

Although some papers indicated the potential sequence of the action categories, it might not be generalised to fit every organisation or scenario. Tatham et al. (2017) suggested a three-step roadmap for UAV adoption in the humanitarian logistics context: pilot test locations for field experiments, involve communities and experts for evaluation; and improve the requirements and regulations for safer use. Similarly, Monios and Bergqvist (2020) also recommended a three-step approach: thorough tests in a small-scale geographical area; approved by the legislative authorities; and wide adoption of the technology. Both these studies emphasise the importance of field experiments as the first step, they do not refer to any of the existing theories to structure the roadmap, which undermines the validity of their propositions. Given this existing gap, this study attempts to structure the action categories into well-developed theoretical frameworks, while also refining these suggested actions and categorisation.

4.2.3 Theoretical frameworks

In section 2.3, the SLR records the theories and theoretical frameworks that are adopted in the literature pool and concludes them in Table 2-4. The frameworks mainly consider acceptance at the individual level (or a single stakeholder group, e.g., customers) (Kapser et al., 2021; Aydin, 2019), or the decision-making mechanisms and change process of the technology to a social system (or a single organisation) (Vlachos et al., 2023; Haula and Agbozo, 2020; Bechtsis et al., 2017). This research seeks to adopt such a framework that supports the structuring of the actions that various organisations at various AV adoption stages enact to facilitate social sustainability improvement in supply chains. Therefore,

none of the theoretical frameworks identified in the SLR applies to this research at this stage.

In this research, AVs are technological innovations (Schwab, 2016). The organisations which adopt AVs differ in their stages of adoption, as well as the actions they enact to address the social impacts to facilitate improved SCSS performance of AV adoption. Accordingly, the Diffusion of Innovation (DOI) theory (Rogers, 2003) which explains the diffusion process of innovations in a social system provides such a theoretical framework to understand the organisational-level adoption process of technology in supply chains (Wamba and Queiroz, 2020).

4.2.3.1 The Diffusion of Innovation Theory (DOI)

This study attempts to align these actions with appropriate theoretical models. This study seeks to apply an innovation adoption-relevant theoretical framework to align the actions and action categories into different stages of innovation adoption within organisations, in order to improve their SCSS performance when adopting AVs in their operations.

4.2.3.1.1 AVs as *innovations that fit the attributes*.

The UGVs and UAVs that emerged and matured after the Fourth Industrial Revolution are considered innovations for the industry (Schwab, 2016), while in academia, there are theoretical frameworks that define what characteristics a technological innovation should be equipped with. The Diffusion of Innovation theory (DOI) developed by Rogers (2003) defined the attributes the innovation consists of that can be perceived as technological innovation (Hameed et al., 2012). The five key attributes are relative advantage, compatibility, complexity, trialability, and observability of the innovation. According to Yuen et al. (2020), AVs have the attributes listed in the DOI theory: AVs have relative advantages in safety and environmental protection compared to conventional vehicles; AVs are compatible with existing traffic systems; AVs are perceived to be more complex; AVs can be tested before adoption; and the benefits of AVs can be observed. Therefore, AVs can be regarded as a technological innovation that fits the lens of DOI theory.

4.2.3.1.2 Organisational Innovation Process (IP)

DOI theory is considered the most widely deployed theory to study technological innovation solutions adoption (Pervan et al., 2005). As Rogers (2003) defined, diffusion of innovation is the process by which an innovation is communicated through certain channels over time among the members of a social system. Since DOI seeks to understand the diffusion process of an innovation within a group of adopters, individual-level adoption behaviour was originally the focal element (Hameed et al., 2012). With the increasing number of assessing organisational level adoption research, Rogers (2003) also developed a five-stage organisational innovation process (IP) model, presented as follows:

- Agenda-setting – an organisational problem is defined and a performance gap is identified to create a perceived need for the innovation;
- Matching – the problem is fitted with an innovation to plan and design the match;
- Redefining/restructuring – the innovation is re-invented to accommodate the organisation's needs and structure, and also for the organisation to fit the innovation;
- Clarifying – the innovation is more widely used in an organisation and is clearer to the internal members;
- Routinising – innovation has been incorporated into the regular activities of the organisation.

The five-stage innovation process accompanied by the overall DOI provides a theoretical base for understanding the decision-making in the supply chain when facing the adoption of technological innovations (Wamba and Queiroz, 2020).

The organisational IP model is used to analyse the adoption process within a certain organisation. Gong et al. (2022) adopt the 5-stage organisational IP to analyse the adoption of blockchain technology in supply chain finance in a focal organisation. Some studies attempt to apply the five-stage IP to a broader supply chain level. Wuttke et al. (2013) treat the focal company as a downstream customer of supply chain finance innovations and extend the use of organisational IP at a wider supply chain level perspective. Heaslip et al. (2018)

extend the use of DOI from the organisational level to the supply chain level in their investigations into supply chain innovation management models in the humanitarian logistics context.

This study aims to investigate how the social sustainability implications of AV adoption can be addressed. Organisations adopting AVs in supply chains vary in the stages of adoption and act differently (Rogers, 2003). Hence, the actions taken by organisations to improve SCSS performance should be aligned with the processes of AV adoption in organisations. With the five-stage organisational innovation process (IP) model, the DOI theory provides the framework for organisations at various AV adoption stages to take actions to improve SCSS performance in this context. This study adopts IP to structure action categories to improve social sustainability performance within organisations. The social sustainability of each organisation along a chain consists of the sustainability performance of the overall supply chain. It is important for distinct organisations to implement responsible actions to manage relevant social issues to realise improved social sustainability performance in supply chains as a whole (Hohn and Durach, 2023).

4.2.3.2 DOI for organisational-level innovation adoption model for this research

The development of Innovations Adoption frameworks used DOI for reference. Despite Hameed et al. (2012) having developed a remarkable conceptual framework for the IT innovation adoption process, they only noticed the individual decision process of innovation in DOI theory. The organisational level innovation process involved in DOI theory was ignored during their model development. The five-stage organisational-level innovation process was mentioned in addition to the individual-level decision process in the fifth edition of the DOI theory (Rogers, 2003). Furthermore, this thesis does not focus on the factors that influence the technology-diffusing process. It seeks to use the process model as a tool to structure the suggested actions, for the organisations to address the social implications during the adoption of AVs in their operations. Therefore, the criticism against the DOI's limitations in organisational-level innovation adoption (Chau and Tam, 1997; Hameed et al., 2012) is not applicable to this study.

Although the adoption processes of the innovations have been discussed in the aforementioned literature, the aim of this paper, however, is not to seek how AVs are adopted in the supply chain. This paper attempts to align the suggested action categories that address the social sustainability indicators with the classical adoption decision stages of AVs in the supply chain, to discuss what actions and decisions the organisations can take or make to mitigate the potential negative impacts of a socially sustainable supply chain. The unit of analysis is therefore strictly at the organisational level, rather than individual level adoption frameworks (Davis, 1989; Venkatesh et al., 2020). Hence, this paper sticks with the original organisational innovation process proposed by Rogers (2003) as the targeting framework.

Based on the description of the research background and literature, the appropriate actions for addressing the SCSS implications remain to be refined. The actions and action categories need to be structured logically to guide organisations in various AV adoption stages to implement, to improve their SCSS performance. As mentioned in Section 2.5.4, the organisational IP model of DOI is a feasible tool for structuring the action categories with a logical sequence (Rogers, 2003). Therefore, this study applies IP as the theoretical framework to structure the action categories.

4.3 Research design and methodology

The data for this paper are collected from two phases. A three-round Delphi study in the first phase is to identify the main elements. From the Delphi study, the affecting stakeholders are identified, and the suggested actions for addressing the impacts are evaluated. However, the relations among the elements are not fully evaluated in the Delphi study, which calls for a supplementary means to enrich the outcomes. Identification of the individual issues in the key elements builds a conceptual base for the relations that connect the stakeholders, suggested actions, and the social impacts to be addressed. Hence, there is a need for another follow-up study to supplement the data. It is common to adopt follow-up individual or group interviews or surveys to further verify, and validate the Delphi results, especially to build relations and discuss the dynamics among

the pre-identified results and concepts from the Delphi study for supplementary. In supply chain management research, such combinations are applied in studies that investigate factors affecting decision-making in an advanced technology adoption context (Hassan et al., 2015); dynamics between uncertainties and strategies for sustainable supply chains (De Lima and Seuring, 2023); and the impacts of geopolitical disruptions in company location decision-making (Moradlou et al., 2021). In this study, the second phase seeks to further evaluate actions against the social impacts through a series of interviews. On the basis of the original main elements extracted from the Delphi, 14 interviews were conducted to clarify and enrich the logical structure of the suggested action categories, by referring to the Diffusion of Innovation Theory (DOI). The three-round Delphi study and the interviews are sufficient to provide data to establish a comprehensive framework for explaining how AV adoption affects SCSS. Figure 4-2 presents the overall structure of the two-phase study.

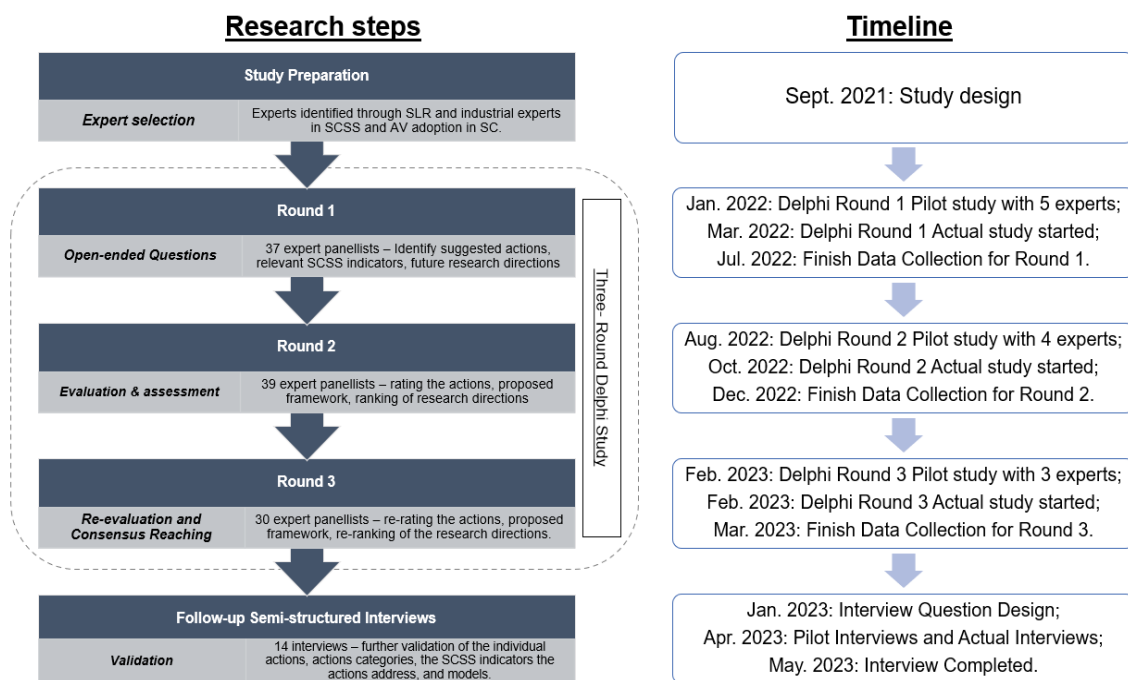


Figure 4-2 Overall structure and timeline for the two-phase study

4.3.1 Delphi Approach

The literature review identified a series of suggested actions that potentially address the existing negative social impacts. However, these actions were

neither systematically categorised, nor linked with the SCSS indicators or the stakeholders. The exploratory and evaluative nature of the Delphi method provides a reasonable means to fully explore the appropriate actions through iterative identification and assessment. A group of experts can provide their insights in the first round, and they have the opportunity to revise their answers and feedback in the following rounds during the assessment period and reach a consensus around which issues to discuss (Linstone and Turoff, 1975). The iterative rounds, (normally two to four rounds) support the richness and depth of the final research outcomes so that no further insights are achieved (Seuring and Müller, 2008). Therefore, the Delphi method is tailored to the studies which aim to reach a group consensus and develop conceptual frameworks (Reefke and Sundaram, 2017). Regarding this research, it is sensible to use the Delphi method to invite a group of experts to identify and evaluate the appropriate actions that address the social impacts of AV adoption in the supply chain, to improve the SCSS performance. It is also reasonable to invite these experts to evaluate the applicability of using the IP model to structure the action categories.

4.3.1.1 Expert Selection

Experts with various backgrounds are required for a successful Delphi study to provide information from diverse perspectives, which makes expert selection a critical step (Hohn and Durach, 2021). Since the Delphi study serves both Chapters 3 and 4, many contents regarding methodology are identical, including expert selection, pilot study, etc. To avoid repetition, these sections in this chapter are omitted and linked to the previous chapter. Section 3.3.1.1 explains the expert selection criteria in detail.

All the participants were contacted via email and social networking platforms such as LinkedIn. Google Scholar, University official websites, and the publishers' sites served as efficient sources for the contacts of academics. The detailed descriptions of invitations and reminders are shown in Section 3.3.1.1.3.

The consensus and termination standards of the Delphi study remain the same as Sections 3.3.3 and 3.3.4 explained. By using the 51-80 rule and the

convergence effects of the individual items, the Delphi study was terminated after three rounds.

4.3.1.2 Pilot study

Pilot testing is essential for the validity and applicability of the study. The pilot testers were invited to give feedback on the layout, overall logic, the time taken and ease of use of the study. In addition, the testers are expected to comment on the clarity of the definition of the terms, the applicability of the questions, and potential errors. The testers identified ambiguities in the framework figure, the statements of the aim and the questions. The valuable feedback led to further development and improvement of the questionnaire. Detailed illustrations of pilot tests are presented in Section 3.3.2 and Appendix B.

4.3.1.3 Delphi Process

4.3.1.3.1 Round 1

The questions for the first round mainly asked for participants' thoughts on the potential actions that can address the social impacts. The participants were expected to provide as wide and deep opinions as possible to enrich the outcomes. The questions posed to the participants are listed:

1. Suggested responsive actions/measures/processes
 - What are the actions/measures/processes recommended or applied to mitigate/reduce/prevent negative social impacts?
 - What are the actions/measures/processes recommended or applied to maintain/ensure/improve positive social impacts?
2. Open comments
 - Please feel free to share or suggest any further research directions regarding the adoption of autonomous vehicles in the supply chain.

The participants were required to provide answers that were as detailed as possible for these open-ended questions. Among the 37 participants, 21 were from academia, 15 were from industry, and one government officer eventually provided their insights on the questions.

The analysis process of Round 1 follows the process presented in Section 3.5.5.1.

4.3.1.3.2 Round 2

The main role of the second-round Delphi study is to assess and evaluate the round one results, by using a range of numerical measures, to achieve potential consensus among the individual evaluated issues (Reefke and Sundaram, 2018; Kache and Seuring, 2017). A suitable rating scale is necessary under this requirement. Three main objectives of this round are listed: a). to rate the importance of the actions; b). to evaluate the validity and applicability of the proposed roadmap; c). to rank the five most important future research directions for this context. This round acted as a key stage in transforming the diverse opinions from the experts to a series of consensus.

Based on the objectives and the role of this round, Five-point Likert scales ranging from “very low” (rating 1) to “very high” (rating 5) are implemented for rating. The scales also include an option “Not applicable” for the items that the participants are unsure of or to express “it depends” (Kache and Seuring, 2017; Melnyk et al., 2009). The scales are used for rating the importance of the suggested actions and the agreement of the proposed roadmap. Table 4-2 presents the rating options for this round. At the end of this round, the participants are required to select a maximum of five most important research directions out of the 12 items identified from the existing literature and the first round.

Table 4-2 Rating Scale

Numerical value	1	2	3	4	5	N/A
Importance Scale	Not at all	Slightly	Moderately	Considerably	Extremely	No idea/Not Known
Agreement Scale	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree	No idea/Not Known

4.3.1.3.3 Round 3

Round 3 further evaluates the results gained from the previous round that present divergence among the respondents, to reach a consensus on more issues. The participants were presented with the Mean (M) and Standard Deviation values (SD) regarding the importance ratings of the individual actions. These two indicators present the average value and the spread of the importance degree ratings (Reefke and Sundaram, 2017). Among the 43 items, four items reached

the consensus standard of the “51-80 rule” in the second round, leaving the remaining 39 items to be re-evaluated in the final round. Ultimately, with no additional items added, 31 items met the “51-80” rule. All the other items which did not yet meet the rule also showed a convergence of opinions among the experts. Based on the termination standard of the Delphi study, this study did not go through further rounds.

The invitations to the third round were only sent to the 39 participants who contributed to the second round. No extra experts were invited. Ultimately, 30 valid responses were received from the participants, consisting of 18 academics and 12 practitioners. In spite of the inevitable attrition effects, this round still received a more than 75% valid response rate that captured sufficient feedback from both academia and industry. Therefore, the results of this round are valid. The conclusions of the participants for each round are presented in Table 4-3.

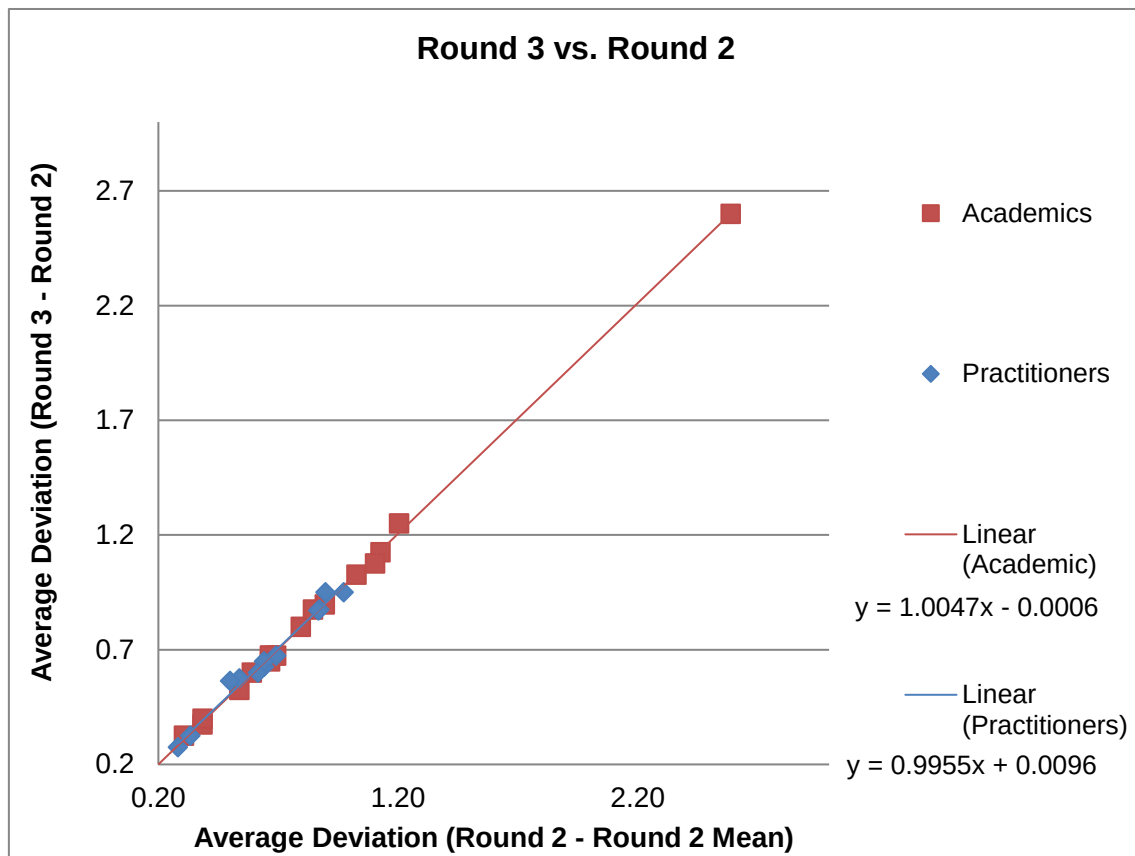
Table 4-3 Participant distributions

Panel	Round 1	Round 2	Round 3
Academics	22	22	18
Industrial Experts	14	17	12
Government	1	0	0
Total	37	39	30

4.3.1.4 Participant average deviation

The 51-80 rule and the convergence effect in the SD values provide a concrete set of criteria for consensus, while the existing Delphi studies also suggest an analysis of the average deviations among the respondents (Reefke and Sundaram, 2017; 2018; Moradlou et al., 2021). The participants’ average deviation is measured by how much the individual participant adjusts the answers across rounds after being informed of the average values in the previous round. Therefore, the plots and trend lines shown in Figure 4-3 visualise the average deviation between the academics' and practitioners' results in the second round against the average results, and against the average deviations between the results of the second and third-round ratings. This process only analyses the 30 participants who responded to both rounds. There is only a slight difference between the two main groups and the plots show a strong convergence in

opinions, so that confirms a significant consensus among the panellists. The participants showed a similar trend in adjusting their answers, among academics and practitioners, which suggests that they shared a high-level agreement in terms of the actions to take for social sustainability, as well as the importance of these actions.



to gather information from various people and seek knowledge on phenomena in social science research (Symon and Cassell, 2012). Research interviews provide a reliable way to know the rationales of social phenomena by collecting opinions from qualified interviewees.

It is not rare to combine the Delphi study with additional interviews in exploratory and qualitative research. Researchers commonly apply a round of follow-up interviews or surveys to verify, generalise, or extend the results collected from the previous Delphi study (Skulmoski et al., 2007). In the medical field, Sharwood et al. (2017) supplement the Delphi results with a series of interviews with stakeholders and patients regarding spinal trauma care standards improvement. In the supply chain management field, Hassan et al. (2015) conducted a Delphi study regarding the factors of technology choice decisions in warehouse management with 107 participants and 19 following interviews to further evaluate the results from the previous Delphi study. Nearly half of the participants (nine experts) are from the Delphi panel list of that study.

In this paper, the Delphi study identified actions and action categories. However, deeper relations between the identified actions and the social implications, as well as the alignment of the actions with the theoretical framework require further rationale to build. Follow-up interviews provide qualitative insights to supplement and corroborate the results collected through the Delphi study (Moradlou et al., 2021; Hassan et al., 2015). Hence, the second phase of this study adopts interviews to further validate the identified actions and action categories by confirming their relations to the pre-identified social sustainability indicators; and to structure the action categories in a logical sequence.

4.3.2.1 Semi-structured interviews

Based on the research aim of this paper, the theme suggested actions and how the actions address social impacts (another theme) are to be validated in the interviews. These themes are pre-set as the main objectives of this paper and they serve as a logic guide for the interview. Unlike the standardised (or structured) interviews that aim to record the answers and data in a standardised manner that can be quantifiable, this paper seeks to explore each theme with the

participants to validate and reveal the qualitative facts (Saunders et al., 2019). Hence, the interviewees' points of view and insights are important. They can provide their thoughts and opinions under the scope of the main themes freely in order to enrich the results. In the meantime, interviewees are encouraged to reflect on their previous answers as the interviews proceed so that they can adjust their thoughts to offer more considered feedback, which ensures the rationale and flexibility of the interviews (Bryman and Bell, 2011).

In this context, this paper aims to further clarify the items and themes collected from the previous Delphi study. The outcomes of the Delphi study have already revealed major themes (social impacts, stakeholders, actions) and proposed the connections between social impacts and social sustainability indicators. However, there are themes still left unsolved. The structure of the actions with DOI, accompanied by the relations between actions and the stakeholders and social impacts, for example, are far too complex for the Delphi study. The rationales of relating respective social impacts to the actions, and aligning the action categories with an innovation process (IP) model cannot be fulfilled through the Delphi study. Based on the requirements of further developing the structures and relations, a series of logical interviews is sensible. Conducting interviews enables the interviewees to explain and further develop their previous opinions provided in the Delphi. The iterative process not only strengthens the existing answers but also clarifies the arguments from the original open-ended questions in the first round of the Delphi so that more robust results can be expected.

As a result, a series of semi-structured interviews are valid to provide supplementary data for this paper and help form the overall framework of the feedback action plan to improve SCSS. In the semi-structured interviews, the questions are based on the pre-set themes that guide the overall interview flow and process (Saunders et al., 2019). As the interviews proceed, the participants can probe and converge their previous answers and build refined opinions (Saunders et al., 2019). The semi-structured interviews guarantee both the flexibility and rigour of the qualitative data.

4.3.2.1.1 Main topics and related questions for the interviews:

Based on the outcomes of the previous Delphi study as well as the main aim and objectives of this paper, the interviews mainly cover the following topics:

- The validation of the suggested actions and categories in addressing the social impacts under the seven SCSS indicators.
- The alignment of the suggested action categories with the organisational Innovation Process under the Diffusion of Innovation Theory.

These topics include the main themes (i.e., actions and action categories, SCSS indicators, IP) to be evaluated and validated in the interviews. The interview questions are therefore designed on the basis of the themes. Since the match of the suggested actions with the innovation-decision process stages is the main aim, the core question is formed: what actions would you suggest to adopt in order to improve the SCSS performance in each of the stages of the process? The detailed interview protocol is presented in Appendix H.

4.3.2.1.2 Interviewees

As previously argued, the interviews are serving as supplementary to the Delphi study in terms of the empirical data. Also, the answers are to be further and more deeply developed based on the original Delphi study outcomes. Those who are involved in the interviews should have a clear logic regarding this research topic and context, as well as the previous Delphi questions and answers. Also, these interviewees are recognised as experts in the supply chain, and disruptive technologies, so their opinions are insightful for this study. On the other hand, these participants have already been connected with this research via the Delphi study prior to the interviews. They can therefore use the interviews as opportunities to reflect and evaluate the results from the Delphi study so that the outcomes can be further developed with higher rigour (Saunders et al., 2019). From the personal contact perspective, they are more willing to participate in the interviews than those who are randomly selected or identified and not contacted before, to be interviewees. Hence, the external validity of the interviews can be guaranteed (Mani et al., 2016) and it is sensible to invite the participants originally from the Delphi study to be the interviewees.

The interviews are conducted on a one-to-one basis, using online real-time video communication software (e.g., Teams). When restrictions in time and location exist, online video interviews provide a feasible solution for the researchers and participants to stay in their own safe and familiar places (Saunders et al., 2019). According to Guest et al. (2006), a group of six relatively homogeneous interviewees provides most of the necessary information while double this number of people in the group is sufficient for data saturation. Following this argument, this research conducted two pilot interviews in advance, and 12 interviews for the main study. Since only minor changes existed in the questions between the pilot and main studies, the data collected from the pilot interviews are also valid for analysis. Hence, 14 participants were eventually involved as interviewees and data saturation was reached with no further information being perceived.

4.3.2.2 Interview data analysis

The analysis process is similar to the analysis of the first round of Delphi study data. However, the themes in the interviews were straightforward, as well as the qualitative data were manageable amount, A thematic analysis (Hassan et al., 2015) was adopted and the analysis proceeded through Excel.

The video of each interview was recorded, and the audio was transcribed with the support of Otter.ai, an online transcription application. In addition, manual checks of the transcriptions were conducted for enhanced reliability and accuracy.

The interviews validated the themes refined from the Delphi study, the themes and codes for interview analysis were pre-set. Under each action theme, the researcher aligned the mentioned SCSS impact themes and codes, with a label of the source (the interviewees) to maintain traceability and anonymity (Beitzen-Heineke et al., 2017; Reefke and Sundaram, 2017). Regarding the IP model evaluation, the researcher aligned the action themes into each of the IP stages, according to the interviewees' quotes. Appendix I provides examples of interview evidence.

4.4 Findings from the Delphi study

This section provides detailed illustrations of the action categories captured from the Delphi study. Only the final round results are presented here, while other rounds, such as the evolution of the models and questions from the second and the third rounds, are shown in Appendices D and E.

The actions are defined as the measures, initiatives, and solutions to address social implications, which shows that these actions target both positive and negative impacts. Hence, this study investigates the actions that potentially improve positive impacts, as well as mitigate the negative impacts. The positive and negative impacts are simplified as “two directions”, while the actions to address these impacts are simplified as “two lists” in the following sections.

The actions for two directions identified in the first round were evaluated throughout the second and third rounds of the Delphi study. The importance rates for each item as well as the changes in rating values between the two rounds are presented in Tables 4-4 and 4-5. The importance ratings for 35 actions out of 43 (81.4%) eventually reached a consensus by following the 51-80 rule.

4.4.1 Actions to improve positive impacts

The actions involved in this list aimed to enhance the positive implications of AV adoption in supply chains. Based on the initial positive impacts, the introduction of the actions is proposed to further reinforce and improve the benefits. In this list, 16 out of 20 actions (80%) reached a consensus among the respondents and no single item received low agreement (lower than 40% in one category or 70% in two adjacent categories), in terms of the importance of these actions. Table 4-4 presents the actions to improve positive impacts.

Table 4-4 Actions addressing positive implications

Category	No.	Action	R2 M	R2 SD	R3 M	R3 SD	R3-R2 ΔM	R3-R2 ΔSD	Consensus
RWE	1	Trials of AVs to prove the concepts and benefits	4.13	0.85	4.57	0.57	0.44	-0.28	Y
RI	2	Clear regulations on approving each type of technology in different scenarios	4.08	1.05	4.37	0.61	0.29	-0.43	Y
CI	3	The constant development of AV technologies	4.08	0.92	4.33	0.76	0.26	-0.16	Y
		Active change management	4.10	0.81	4.27	0.64	0.16	-0.17	Y
		AV lifecycle status transparency for better service	3.69	0.96	4.10	0.72	0.41	-0.24	N
		The constant development of a working environment for existing employees	3.82	0.81	3.82(R2)				Y
					4.23				
SI	4	Stakeholder involvement and engagement in developing, planning, and implementation.	3.87	0.91	4.20	0.61	0.33	-0.30	Y
C	5	Clear communication through the whole supply chain among stakeholders	4.13	0.69	4.13(R2)				Y
CSR	6	Regular security and safety checks for reduced stakeholders' risks	3.90	0.90	4.03	0.67	0.14	-0.23	Y
PL	7	Data and information integration	4.21	0.91	4.21(R2)				Y
		Designing, and integrating technologies into supply chain processes	4.18	0.78	4.18(R2)				Y
		Appropriate business environment	3.69	0.96	3.90	0.66	0.21	-0.30	Y
		Appropriate Governance, Risk and Compliance (GRC) measures, balanced scorecard and data analysis capabilities	3.62	0.92	3.80	0.71	0.18	-0.21	Y
		Route planning	3.54	1.06	3.67	0.84	0.13	-0.21	N
					3.95				
PRM	8	Quantify the benefits compared to the past	3.92	0.92	4.20	0.61	0.28	-0.31	Y
		Promote and introduce the AVs to the public about the trial samples, the benefits and improvements	3.59	1.03	3.90	0.61	0.31	-0.42	Y
		Promote to the employees for the system capabilities and interconnectivity	3.62	1.00	3.72	0.80	0.11	-0.21	N
					3.94				
HRM	9	Internal upskilling and training programmes	3.90	0.96	4.20	0.66	0.30	-0.29	Y
		Cooperation with external training institutions	3.21	1.04	3.50	0.73	0.29	-0.31	Y
		Financial subsidies for AV operators and AV adopters	3.26	1.01	3.30	0.88	0.04	-0.13	N
					3.67				

C: Communication

CI: Continuous Improvement;

CSR: CSR focus;

HRM: Human Resource Management;

PL: Planning;

PRM: Promotion;

RWE: Real-World Experiments

RI: Regulation Improvement

SI: Stakeholder Involvement

4.4.1.1 Communications, Stakeholder Involvement

In the list that gathers the actions for improving positive social impacts, good communications aim to ensure successful operations and business vision alignment among stakeholders. Communications help reinforce the success factors for AV technologies in supply chain operations.

Clear communications are closely related to stakeholder involvement. In this list, improved stakeholder participation in various stages leads to better services and benefits in the implementation of AVs. According to the participants' rating, 90% of responses fell into the "extremely" and "considerably" important categories with no responses in the "not important" and "slightly important", presenting an absolute agreement in the high importance of this stakeholder involvement in supply chains. This is recognised by one comment:

"Society always needs to be involved in the AV development and application."
(DR3-19-P)

4.4.1.2 Continuous Improvement

Continuous improvement focuses on the constant development and improvements in technologies and working environments for improved social sustainability performances. In this list, apart from the items that reached a consensus in Round 2, the rest three items all received higher than four in importance ratings. The constant evolution of technology attracts the highest attention. The advancement in technology improves the system reliability and consequently, the health and safety benefits, which also applies to the mitigation of the negative impacts. This is followed by "active change management". Change management is described as the management of the business improvement process with the leadership and direction of the process of organisational transformation, especially in addressing resistance to change from stakeholders (Fincham and Rhodes, 2005; Atilgan and McCullen, 2011). This action in this context, therefore, presents the constant improvement of the business models and employee treatment when adopting AVs (which are constantly developing) in the operations. The only item that has not yet reached a group consensus, although very close (79% of participants selected 4 and 5),

is to provide better AV lifecycle status transparency. This action was raised by one scholar with expertise in AV technology. Sen et al. (2020) assessed the life-cycle sustainability of autonomous heavy-duty trucks in terms of environmental pollution and employment rate changes. The life-cycle status of AVs is transparent to the supply chain internal stakeholders to realise the system security, battery health, and energy consumption status throughout the whole service period through blockchain (Cheema et al., 2022). This benefits the internal stakeholders in decision-making and service-providing, and external stakeholders in policymaking and service satisfaction (Sen et al., 2020).

4.4.1.3 Corporate Social Responsibility (CSR) Focus

CSR focus in this list mainly covers the regular check of safety and security to assure the perceived social outcomes. Mainly emphasising the current safety and security aspect, this category seeks to include as comprehensive the indices of CSR as necessary in the context of AV adoption in supply chains. The considerably high importance of this action in improving social impacts is also acknowledged by the majority of the participants, with no disagreement.

4.4.1.4 Human Resource Management

The actions included in employment are mainly about upskilling and financial support to the adopters and AV operators. The former actions cover the internal and external upskilling and training programmes. Both approaches guide the existing employees to be qualified to collaborate with AVs in the supply chain without laying them off. The group agreement indicates that the internal training programmes are more important than joining apprentice programmes provided by external entities (training centres and universities). The internal training sessions can be more tailored to the employees than the external programmes. The latter group calls for financial encouragement including subsidies and higher salaries to the organisations and the employees in the organisations that adopt AVs in supply chains. However, this item received a lower agreement and importance rating, which implies that the financial stimulations are not perceived as effective actions in addressing social impacts.

4.4.1.5 Planning

In addition to the two actions that reached a consensus in Round 2, the other three actions in the planning category were re-evaluated and two of them reached a group agreement in importance rating. The business environment is a very broad term that includes internal and external factors that are influential (Craig and Campbell, 2012). These factors cover but are not limited to the legal environment, local communities' acceptance, local infrastructure, and the skill level of the employees that the organisations require to survive and utilise to create values (Christopher and Towill, 2002). An appropriate business environment that supports the deployment of AVs in the supply chain indeed benefits organisations as they can operate with reduced barriers. Therefore, this item received the highest importance rating in the list among the items that remained to be reassessed in the third round. In addition, the appropriate design of GRC (Governance, Risk, and Compliance) measures and data management capabilities provides organisations with a comprehensive spectrum of aspects that lead to successful performance (Mitchell, 2007). The development of GRC measures benefits organisations in improved information quality, reduced errors, employee satisfaction, and reduced costs (Mitchell, 2007). Route planning surprisingly received diverse distribution in importance rating among the respondents. Effective route planning regarding an individual vehicle or a fleet of vehicles is proven to be essential in the literature for efficient operations (Ha et al., 2018). Efficiency includes faster and more flexible delivery services; reduced costs and emissions, reduced use of road traffic, and improved location visibility. All these aspects address both positive and negative aspects of the existing social implications.

4.4.1.6 Promotion

Promotion is an action category well-accepted by the participants that improves communities' awareness and knowledge of AV adoption in the supply chain. Especially, promoting the benefits of safety and reliability through successful business samples helps strengthen the affection among communities. The promotion effects can be further enhanced by quantifying the benefits compared to the past so that the branding is perceived to be more persuasive. Consistent

branding and promotion also relate to the improvement of the organisation's reputation as an "innovative company". On the other hand, promoting the AV capabilities to the employees is beneficial to their passion for working with these new machines, and therefore, their satisfaction.

4.4.1.7 Real-World Experiments

The actions raised in the promotion category require proof of AVs' benefits, which highlight the importance of living lab pilot trials in real-world scenarios. The real-world experiments are believed by nearly all of the respondents (97%) to be highly important in the proof of concepts and benefits for promotion. This action category provides the factual basis for promotion.

4.4.1.8 Regulation Improvement

In terms of regulations, 93% of respondents perceived the regulations that clarify each type of technology in different scenarios as being highly important. Although the lack of legislative frameworks is considered a major barrier that prevents AVs from wider adoption in the supply chain, a clarified regulatory framework that guides the normative use of AVs in diverse contexts is still important for improving positive impacts. For example, the rules in the detailed deployment time zone for freight transport UGVs potentially further benefit traffic flows.

4.4.2 Actions to mitigate negative impacts

The actions involved in this list are suggested to mitigate the negative social impacts of AV adoption in supply chains. Among 23 items, 19 reached a group agreement (82%) with no low agreement items following the aforementioned standards. A considerable number of actions apply to both dimensions of social implications. This section only discusses the items that specifically address negative impacts. Items that address both dimensions of social implications are not emphasised repetitively. Table 4-5 presents the actions to mitigate negative impacts.

Table 4-5 Actions addressing negative impacts

Category	No.	Action	R2 M	R2 SD	R3 M	R3 SD	R3-R2 ΔM	R3-R2 ΔSD	Consensus
RWE	1	Trials of AVs to prove the concepts and benefits	4.10	0.78	4.47	0.57	0.36	-0.21	Y
C	2	Provide information and set expectations among supply chain processes	4.05	0.90	4.17	0.70	0.12	-0.21	Y
CI	3	Active change management	4.05	0.99	4.30	0.53	0.25	-0.45	Y
		Constant improvement via feedback loops	4.13	0.91	4.27	0.64	0.14	-0.27	Y
		Constant technology research development	3.90	0.98	4.20	0.66	0.30	-0.32	Y
		AV lifecycle status transparency for better services	3.67	0.94	3.87	0.82	0.20	-0.12	N
						4.16			
CSR	4	Regular security and safety checks and ensure reduced stakeholders' risks	3.90	0.90	4.13	0.57	0.24	-0.33	Y
		Businesses to be responsible for their actions and focus on CSR	3.87	0.97	4.07	0.74	0.19	-0.23	Y
								4.10	
PRM	5	Quantify the benefits compared to the past	3.87	0.91	4.20	0.71	0.33	-0.20	Y
		Inform the public of the advantages and applications of AVs via business cases	3.72	0.96	4.10	0.71	0.38	-0.25	Y
		Promote to employees about the system's capabilities and interconnectivity	3.67	1.05	3.97	0.73	0.30	-0.31	N
								4.09	
RI	6	Regulations detailing the AV operation zone, time and social issues	3.92	0.92	4.17	0.59	0.24	-0.32	Y
		Social-wide policies to deal with job loss due to automation	3.62	0.89	3.77	0.63	0.15	-0.27	Y
								3.97	
SI	7	Integrate with stakeholders and communities	3.67	0.94	4.07	0.52	0.40	-0.42	Y
		Continuous team meetings with different levels of employees	3.74	0.98	3.93	0.69	0.19	-0.29	Y
		Stakeholder journey mapping to check social changes	3.62	0.95	3.83	0.75	0.22	-0.20	Y
								3.94	
PL	8	Designing and integrating new technology into supply chain processes	3.85	0.98	4.07	0.58	0.22	-0.39	Y
		Appropriate GRC measures, balanced scorecard and data analysis capabilities.	3.59	0.93	3.80	0.81	0.21	-0.12	Y
		Route planning	3.31	1.14	3.63	0.85	0.33	-0.29	N
								3.83	
HRM	9	Retrain and upskill the employees to requalify the higher-skilled positions	3.74	0.93	4.03	0.61	0.29	-0.31	Y
		Create new job positions to prevent the loss of positions due to AV adoption.	3.69	0.94	3.80	0.76	0.11	-0.18	Y
		Employee psychological supports	3.44	0.93	3.43	0.82	0.00	-0.11	Y
		Financial subsidies for AV adopters	2.95	1.06	3.07	0.91	0.12	-0.15	N
								3.58	

4.4.2.1 Communications, Stakeholder Involvement

Compared to the actions in the previous list, the actions that address negative impacts are more specific. In addition to the actions in the previous list arguing “what to do” in the category, these actions took a step towards “how to do”, i.e., who to engage with; and how to execute the communications in the supply chain. Continuous team meetings with various levels of employees ensure the supply chain nodes operate in line with the pre-set expectations. Integrating the local communities and various other stakeholders is key to mapping stakeholder journeys to understand the stakeholder demands and provide values throughout a period (Chirumalla et al., 2022; Randhawa et al., 2021). This mechanism provides an evidence base for continuous improvement in services. The actions under communications and stakeholder involvement received considerably important rating scores among members of the panel.

4.4.2.2 Continuous Improvement

The action “constant improvement via feedback loops” is mainly targeted at receiving feedback from the customers and local communities where the AV operate delivery services. The improvements in the feedback loop mechanism on the one hand improve customer satisfaction and also mitigate potential health and safety risks and privacy concerns from the local communities by using more appropriate routes.

4.4.2.3 CSR Focus

Apart from the regular safety and security check, the category “CSR focus” in this list includes suggestions to businesses for being responsible for their activities. This is conducive to preventing potential negative impacts at the strategic level. By combining social responsibility with high-level strategies, organisations realise long-term social sustainability through their top-to-bottom practice (Beske and Seuring, 2014). The high importance rating is approved by 83% of the participants.

4.4.2.4 Human Resource Management

New actions in the employee management category mainly cover the creation of new jobs and employee psychological support. Both items received a group agreement in importance rating between “moderate” and “considerable”. New job creation relates to the “fill labour shortage” and “create new high-skilled jobs” in the positive impact list. This action simultaneously fills the gap in the labour market that is left by the reduction of job opportunities. Dadzie and Johnston (1991) argued that the adoption of disruptive technology always eliminates some of the redundant positions and simultaneously creates new jobs. This happens in every Industrial Revolution era. Further, providing psychological support to the employees mitigates psychological and physical strain for those who are confronted by the new technology adoption. This action also controls the alienation of workers in the operations for the welfare indicator of SCSS.

4.4.2.5 Planning

All three actions of planning are included in the previous list. As mentioned in Chapter 4.4.1, the GRC measures are the management control techniques for embodying risks for the organisations to govern and comply with (Cu et al., 2023; Mitchell, 2007). Hence, not only the unethical outcomes can be avoided, but also the multiple spectrums of risks (i.e., health and safety; cybersecurity; brand; politics etc.) are addressed (Green, 2015). In this context, there exists a series of negative implications including health and safety, transparency (cybersecurity), unemployment etc. that are related to the risks under the scope of GRC. Therefore, developing GRC measures is a considerably important action for improving the social sustainability performance of supply chains in the AV adoption context.

4.4.2.6 Promotion

The three actions for addressing negative impacts ranked the same as for the positive impacts. Quantifying is still considered the most important action that showcases the stakeholders to understand how much they could benefit. This is especially important and persuasive to mitigate the negative social impacts as well as the stakeholders' negative attitudes. This action receives the fourth

highest rating among all the actions, presenting its importance in negative implication mitigation. The other two items receive slightly higher ratings than for positive impact addressing, staying at the middle range of the action list. The average importance rating for the promotion category is ranked 5th, which means that promotion is comparatively more important to address negative impacts than positive outcomes.

4.4.2.7 Regulation Improvement

In addition to the clear guidance for each type of AV usage in each scenario, this list further proposed detailed regulations in operation zone, time, data collection issues etc. The detailed rules provide clear action protocols for organisations to understand what they can and cannot do. Hence, with the protection of the regulations, the communities are relieved regarding their concerns about privacy and safety issues when confronted with AVs. Concerning unemployment, this list suggests policies to address job loss due to automation. It is important to consider the potential solutions for those who are laid off from governmental and legislative perspectives – government reinvestments (Institute for Employment Studies, 2022), redundancy payment from the employer, or retraining programmes schemed by the national government (PwC, 2021) etc. All the actions for regulation improvement received group agreement on considerably important ratings.

4.4.2.8 Real-World Experiments

In this list, the category “real-world experiments” is also ranked as the most important category to provide proof of benefits as well as improvements in reliability for reduced safety risks for promotion. On the basis of the proofs, the promoting actions can therefore deliver the outcomes from the experiments for reduced public resistance and improved acceptance.

4.4.3 The combined action categories from the two lists

According to the results captured from the Delphi study, actions that address positive impacts and negative impacts are grouped into nine main categories, namely, Communication, Continuous Improvement; CSR Focus; Employment; Planning; Promotion; Real-world experiments; Regulation Improvement; and

Stakeholder Involvement. Since these nine categories exist in addressing both positive and negative impacts, they are merged into an integrated table that gathers the individual actions collectively addressing the two dimensions of social implications. There are 14 distinct actions found to address both positive and negative impacts. The combination of the action categories is presented in Table 4-6. In the table, the “P” represents the actions for addressing the positive impacts, “N” for the negative impacts, and “P and N” means the actions are raised to address both positive and negative impacts. In conclusion, there are 29 actions proposed to address the social implications in this context.

Table 4-6 Combining actions for two lists of implications

Category	Individual Actions	P or N
Communication	Clear communications through the whole supply chain among stakeholders;	P
	Providing information and setting expectations among supply chain processes	N
Stakeholder Involvement	Continuous team meetings with different levels of employees	N
	Integrate with stakeholders and communities	N
	Stakeholder journey mapping to check social changes	N
	Stakeholder involvement and engagement in developing, planning, and implementation	P
Continuous Improvement	The constant development and research of AV technologies	P and N
	Active change management	P and N
	The constant development of the working environment for existing employees	P
	AV lifecycle status transparency for better services	P and N
	Constant improvement via feedback loops	N
CSR focus	Regular security and safety checks for reduced stakeholders' risks	P and N
	Businesses to be responsible for their actions and focus on CSR	N
HR Management	Financial subsidies for AV operators and AV adopters	P and N
	Internal upskilling and training programmes for employees to requalify the high-skilled positions	P and N
	Cooperation with external training institutions	P
	Employee psychological support	N
	Create new job positions to prevent the loss of positions due to AV adoption	N
Planning	Route planning	P and N
	Designing and integrating technologies into supply chain processes	P and N
	Appropriate GRC measures, balanced scorecard, and data analysis capabilities	P and N
	Appropriate business environment	P
	Data and information integration	P
Promotion	Promote the employees for the system's capabilities and interconnectivity	P and N
	Promote and introduce the AVs to the communities about the trial results, benefits, advantages, and improvement	P and N
	Quantify the benefits compared to the past	P and N
Real-world Experiments	Trials of AVs to prove the concepts and benefits	P and N
Regulation Improvement	Clear regulations on approving each type of technology in different scenarios	P and N
	Social-wide policies to deal with job loss due to automation	N

4.5 Discussion

The discussion section analyses how the actions address the SCSS implications. The actions and action categories are refined by comparing them with the outcome of the literature review. Through the 14 follow-up interviews, the detailed SCSS aspects are suggested to be addressed by the refined actions. Ultimately, the action categories are aligned with the stages of innovation adoption through the Innovation Process of DOI (Rogers, 2003) for a structured sequence and logic.

4.5.1 Action category refinement: combining and synthesising

This section defines the actions and action categories by comparing the insights from the literature review and the Delphi study. The refinement of action categories is presented in Table 4-7, with the refinement rationale for each category explained below.

Chain-wide consideration from the literature review widely covers communications and stakeholder engagement (Vlachos *et al.*, 2023), effective design and integration of AVs into operations and smart cities (Mohamed *et al.*, 2020), continuous improvement for better services (Tatham *et al.*, 2017; Kurniawan *et al.*, 2021), and socially sustainable operations in each node of supply chains (Sen *et al.*, 2020). They present four distinct aspects of considerations in this context. Therefore, the actions in this group are allocated into four categories: communications and stakeholder involvement; continuous improvement, CSR focus, and planning, and combined with the identified actions from the Delphi study.

Actions for education, promotion, and training groups mainly highlight improving the knowledge and skills of AV technology among diverse stakeholders in supply chains. Since different stakeholders vary in the means and purposes of knowledge/skill improvement, it is wise to separate the actions into two categories according to the audiences. Actions regarding employee upskilling, and training (Klumpp, 2018) relate to the “employment” category, whereas the actions considering knowledge, awareness, and benefit improvement among local communities and consumers are merged under the “promotion” category.

Real-world experiments and regulation improvement categories remain unchanged, with additional actions involved. The aim of conducting experiments is to ensure safety application (Monios and Bergqvist, 2020), and this should be conducted in several stages of tests, from small-scale to public areas, with preventative designs involved (Tatham *et al.*, 2017; Kellermann *et al.*, 2020). These actions all form the rationale of the category Real-World Experiments. Meanwhile, the regulation improvement category also inherits the actions from both sources, including the financial subsidies for AV adopters (Kapser *et al.*, 2021) and reasonable regulations to mitigate social issues such as health, safety, security, and unemployment (Kellermann *et al.*, 2020; Sohrabi *et al.*, 2020; Sen *et al.*, 2020).

The Delphi study suggests a close relationship between communications and stakeholder involvement. Communications exist among the targeted stakeholder groups, while stakeholder involvement is realised through clear and high-quality communications (Rane *et al.*, 2021). Clear communications, on the one hand, provide a concrete foundation for CSR actions to generate an intrinsic improvement in internal stakeholders' well-being (Yang and Basile, 2022). On the other hand, communications with external stakeholders support subsequent CSR actions to present a symbolic status and reputation to attract more financial support (Yang and Basile, 2022). Communications among both internal and external stakeholders diffuse the company's real motives and action plans so that the involvement of stakeholders in communications substantively reduces risks and conflicts (Beecher *et al.*, 2005). Therefore, communications and stakeholder involvement are merged into one category.

Table 4-7 Action refinement

Action synthesised from the literature	Categories from the	Rationale	Action Categories from the Delphi Study	Rationale
Chain-wide consideration		Involving and engaging with various stakeholders along supply chains for continuously improved decision-making, services, and technologies.	Planning	Mapping and analysing how AVs serve the supply chain and stakeholders before adoption and implementation.
			Continuous Improvement	The constant development of the technologies, the research into the technologies, as well as the improvement in services and working environments in the supply chain.
			Communications and Stakeholder Involvement	Clear communications and active engagement with the internal and external supply chain stakeholders.
			CSR Focus	Holistic considerations and implementations of Corporate Social Responsibility (CSR) in supply chains in the AV adoption context.
Field experiments		Small-scale experiments and testing for concept proof before broad applications.	Real-world experiments	The appeals to test the reliability of the technologies and prove the concepts, as well as safety assurance and risk prevention in real-world scenarios.
Regulation Improvement		The appeals to loosen the existing restrictions and improve appropriate guidance.	Regulation Improvement	Refining the existing regulatory frameworks to address various social issues, and to regulate the usage of AVs in various scenarios based on the AV types and specifications.
Education, Promotion, and Training		Improving the awareness, skillsets, and knowledge of AV technologies and their applications in supply chains among various stakeholders.	Human Resource Management	Actions for preparing the employees and organisations in supply chains for qualifying for the AV adoption jobs and working mode.
			Promotion	Awareness and knowledge improvement of AVs among the various stakeholders

4.5.2 Defining the eight categories of actions

Based on the discussions above, this part concludes the definitions of the 8 action categories (shown in Table 4-8).

- *Communications and stakeholder involvement* – clear communications and active engagement with the internal and external supply chain stakeholders for information sharing and expectation clarifying, collective group knowledge and awareness improving for resistance and miscommunication mitigating (Ding, 2018; Vlachos et al., 2023).
- *Continuous improvement* – the constant development of the technologies, the research into the technologies, as well as the improvement in services and working environments in the supply chain. Multiple elements such as Just-in-time (JIT), Zero defects, effectiveness, Total Quality Management (TQM) (Singh and Singh, 2013), and change management are included, that extensively concern the renewing of organisations' structure, directions, and capabilities for satisfying stakeholders' needs (By, 2005).
- *CSR focus* – holistic considerations and implementations of Corporate Social Responsibility (CSR) in supply chains in the AV adoption context, from high-level decision-making, to operational-level regular checking.
- *Human resource (HR) management* – upskilling, reskilling, training, and supporting the existing employees, the recruitment of new, high-skilled and experienced employees, and new job creation. These actions are included under the various aspects of Human Resource Management Practices about employees (i.e., people resourcing, employee wellbeing, and employee learning and development) (Armstrong and Taylor, 2020). All these aspects seek to prepare the employees and the supply chain organisation for AV adoption and to qualify for the jobs.
- *Planning* – mapping and analysing how AVs serve the supply chain and stakeholders before adoption and implementation. This would cover long-term, supply chain-wide mechanisms for the integration of AVs in the supply chain, as well as the short-term, floor-level scheduling for operations with AVs

(Robinson et al., 1985).

- *Promotion* – awareness and knowledge improvement of AVs among the various stakeholders (mainly external stakeholders).
- *Real-world experiments* – the appeals to test the reliability of the technologies and prove the concepts, as well as safety assurance and risk prevention in real-world scenarios (Poljak and Šterbenc, 2020; Kellermann et al., 2020).
- *Regulation improvement* – refining the existing regulatory frameworks to address safety, employment, and privacy issues, and to regulate the usage of AVs in various scenarios based on the AV types and specifications. These suggestions aim to loosen the extant restrictions for a broader AV adoption in supply chains (Rao et al., 2016).

Table 4-8 Finalised eight categories of actions

Category	Individual actions after refining
Communication and Stakeholder involvement	<ul style="list-style-type: none"> ● Clear communications through the whole supply chain among stakeholders (D); ● Providing information and setting expectations among supply chain processes (D); ● Continuous team meetings with different levels of employees (D); ● Integrating with stakeholders and communities (L+D); ● Stakeholder journey mapping to check the social changes (D); ● Stakeholder involvement, engagement, and participation in developing, planning, and implementation for resistance mitigation (L+D).
Continuous Improvement	<ul style="list-style-type: none"> ● The constant development of the technologies and the research of AVs (D); ● Development of working environment for the existing employees (D); ● Change management (D); ● AV lifecycle status transparency for improved services (D); ● Constant improvement via feedback loops and behaviour measures after the technologies are fully available in the communities (L+D).
CSR focus	<ul style="list-style-type: none"> ● Regular security and safety checks for reduced stakeholders' risks (D); ● Businesses to be responsible for their actions and focus on CSR (D).
HR Management	<ul style="list-style-type: none"> ● Internal organisational upskilling and training programmes for employees to requalify the high-skilled positions (L+D); ● Cooperation with external training institutions (D); ● New job positions creation (D); ● Recruiting more highly trained and experienced workforce (L); ● Developing reskill strategies for less-educated and lower-skilled employees (L); ● Employee psychological support (D).
Planning	<ul style="list-style-type: none"> ● Route planning (D); ● Designing and integrating technologies into supply chain processes (D); ● Integrating AVs into smart cities and collaborating with other technologies (L); ● Appropriate GRC measures, balanced scorecard, and data analysis capabilities (D); ● Appropriate business environment (D); ● Data and information integration (D).
Promotion	<ul style="list-style-type: none"> ● Promoting to the communities the benefits and risk mitigation methods (L); ● Introducing AVs to the communities regarding their benefits to health and safety (L+D); ● Promoting the system's capabilities and interconnectivity to the employees (D); ● Quantifying the benefits compared to the past (D).

Real-world experiments and tests	<ul style="list-style-type: none"> ● Trial of AVs to prove concepts and benefits in small-scale places preliminary (L+D); ● Preventative measures for drone designs (L); ● Tests the integration of airspaces (L).
Regulation improvement	<ul style="list-style-type: none"> ● Regulatory Measures for safety, accountability, and privacy (L); ● No fly zones (L); ● Data collection and operations protocol (L); ● Transnational legislative approval (L); ● Regulations and legal guides, frameworks for approving each type of technology in different scenarios (L+D); ● Subsidising the delivery solutions (L+D); ● Social-wide regulations to mitigate the outcomes of unemployment due to automation (L+D); ● Federal guidance for adoption and certifications (L).

L: items extracted from the literature;

D: items identified from the Delphi study;

L+D: items mentioned from both literature and the Delphi study.

4.5.3 Validating the actions: actions and action categories addressing SCSS

Based on the Delphi outcomes, this main section evaluates what social sustainability aspects are addressed by each of the eight categories of actions. Through 14 semi-structured interviews, participants provided their opinions about the actions, the action categories in this context, and how these actions address SCSS. After that, the actions are structured through IP as a proposed action plan.

4.5.3.1 Actions categories and SCSS

This section aims to illustrate what social sustainability aspects are encompassed by each of the action categories. The interviewees presented their opinions on what the primary/prior social sustainability aspects are that the action categories address since interviewees generally mentioned all of the aspects are relevant. Hence, it is sensible to delineate and classify the aspects that the actions directly relate to. The detailed analysis of each action category is shown in Appendix D, and Table 4-9 summarises the following analysis.

Table 4-9 Actions addressing SCSS indicators

Action category	Actions	Addressed SCSS Indicators						
		HS	CS	EMP	TRP	DE	WF	RPT
Communication and Stakeholder involvement	● Clear communications through the whole supply chain among stakeholders;	X	X	X	X	X		X
	● Providing information and setting expectations among supply chain processes;	X			X			
	● Continuous team meetings with different levels of employees;			X	X	X		X
	● Integrating with stakeholders and communities;		X		X	X		X
	● Stakeholder journey mapping to check the social changes;		X	X				
	● Stakeholder involvement, engagement, and participation in developing, planning, and implementation for resistance mitigation.		X		X	X		X
Continuous Improvement	● The constant development of the technologies and the research of AVs;	X	X					X
	● Development of working environment for the existing employees;			X				
	● Change management;			X				
	● AV lifecycle status transparency for improved services;		X					X
	● Constant improvement via feedback loops and behaviour measures after the technologies are fully available in the communities.		X					X
CSR focus	● Regular security and safety checks for reduced stakeholders' risks;	X	X	X	X			X
	● Businesses to be responsible for their actions and focus on CSR.	X	X	X	X	X	X	X
HR Management	● Internal organisational upskilling and training programmes for employees to requalify for high-skilled positions;	X		X		X		X
	● Cooperation with external training institutions;		X	X		X		X
	● New job positions creation;			X		X		
	● Recruiting a more highly trained and experienced workforce;			X		X		
	● Developing reskill strategies for less-educated and lower-skilled employees;			X		X		
	● Employee psychological support.	X		X				

Planning	● Route planning;			X			X	X
	● Designing and integrating technologies into supply chain processes;	X	X			X	X	
	● Integrating AVs into smart cities and collaborating with other technologies;	X	X			X		X
	● Appropriate GRC measures, balanced scorecard, and data analysis capabilities;	X			X	X		
	● Appropriate business environment;				X			
	● Data and information integration					X		
Promotion	● Promoting to the communities the benefits and risk mitigation methods;	X				X	X	X
	● Introducing AVs to the communities regarding their benefits to health and safety;	X				X	X	X
	● Promoting the system's capabilities and interconnectivity to the employees;				X			
	● Quantifying the benefits compared to the past.			X		X		X
Real-world experiments and tests	● Trial of AVs to prove concepts and benefits in small-scale places preliminary;	X	X			X		X
	● Preventative measures for drone designs;	X				X		X
	● Tests the integration of airspaces.	X				X		X
Regulation improvement	● Regulatory measures for safety, accountability, and privacy;	X				X		
	● No fly zones;	X	X				X	
	● Data collection and operations protocol;			X		X		
	● Transnational legislative approval;							X
	● Regulations and legal guides, frameworks for approving each type of technology in different scenarios;	X			X			
	● Subsidising the delivery solutions;			X			X	X
	● Social-wide regulations to mitigate the outcomes of unemployment due to automation;				X		X	
	● Federal guidance for adoption and certifications.	X			X			X

HS: Health and Safety;
CS: Customer Satisfaction;

EMP: Employment;
TRP: Transparency;
DE: Diversity and Equality;

WF: Welfare;
RPT: Reputation

4.5.3.1.1 Health and Safety

The interviewees believed that all the action categories significantly address the social impacts of Health and Safety. Indeed, decision-makers should take health and safety into account as a priority when drawing up the plans, so that the follow-up actions also place health and safety as the primary issue to address. This is one of the most important social aspects that concerns stakeholders:

“Health and Safety should be a number one priority in any plan and to ensure that people are safe.” (In2-P)

Regarding various stakeholders, the actions encompass diverse aspects of health and safety, i.e., the psychological stress of employees, and incidents that cause physical injuries to the local communities and employees. These are mainly resolved by upskilling, mental support, and risk mitigation methods from the employment and promotion categories. As for the regulators, argued by one interviewee that health and safety issues are even more important, such as zero-tolerance to potential accidents:

“The regulator doesn’t care so much if you don’t make any money or it turns out to not be a good strategy from a business perspective. But they care about if there’s one accident in which an AV kills one person, that is a disaster.” (In3-A)

Therefore, health and safety issues are the priority to real-world experiments, the risks should be managed and mitigated before checking the functional benefits. As suggested during an interview:

“And I think the same will be pretty much true of trialling autonomous vehicles. So, first of all, you want to check there is actually safe on the roads to be able to do it. Then the second thing you want to trial is how useful is it for moving goods around or whatever it is you’re trying to do.” (In11-P)

As a result, there is potentially a sequence in the affected targeted groups of the tests: health and safety come first, and usefulness follows. Only the safety issues are fulfilled, and further impacts under customer satisfaction are met.

4.5.3.1.2 Customer satisfaction

Customer satisfaction is the other social sustainability aspect that is addressed primarily by all of the proposed action categories. It is obvious that communication and stakeholder involvement, planning, promotion, real-world experiments, and continuous improvement directly encompass customer satisfaction by raising the customers' awareness of the benefits as well as the actual services that reach them. This section discusses two categories that also address customer satisfaction, with comparatively indirect paths.

Among the categories, regulation improvement provides a unique angle to improve customer satisfaction – financial subsidies. Interviewees believed that financially subsidising the delivery service providers from the government helps benefit the customers – the customers can receive AV delivery services with lower prices and reduced thresholds. By gaining financial assistance, the organisations that adopt AVs in their operations provide meritorious services with reduced concerns about operational costs and cash flows (Xiang and Worthington, 2017). One interviewee took the Electric Vehicles (EV) subsidy in China as an analogy that, government provide subsidies to the EV manufacturers and customers can own EVs with lower costs:

“For example, like EV subsidies. Customers are really satisfied by that kind of product solutions. You can adopt it easily, so, that is relevant to the customer satisfaction.” (In12-P)

In addition, some interviewees proposed upskilling programmes for the AV maintenance provided for the various supply chain nodes that also potentially relate to customer satisfaction. From a holistic view, disruptions in a single node of supply chains potentially lead to a ripple effect or risk propagation that disrupts the whole network, which undermines customer satisfaction (Xu, 2020). Therefore, providing appropriate training sessions for preventative technology maintenance is crucial to avoid these negative impacts from happening. One academic proposed that appropriate training sessions for preventative maintenance are critical to avoid such disruptions from happening:

“I do some plan preventative maintenance on it rather than it to break down halfway through the cycle of operations. It is a very integral part of the network. If that fails, it has a ripple effect and it’s only got a failure for 10 or 15 minutes and then it will have a significant ripple effect throughout that shift.” (In7-A)

This is similar to the AV lifecycle status transparency in the Continuous Improvement category. On the basis of the vehicle lifecycle status, a series of trainings on preventive maintenance can be developed to improve the services and reduce the potential downtime and disruptions.

4.5.3.1.3 Employment

Apart from the actions covered in real-world experiments, the other action categories all address the employment aspect of social sustainability. Actions such as creating an appropriate business environment (i.e., information, human, regulation resources) (Dess and Beard, 1984), organisational change management (i.e., organisational operation structure, adoption standards and agenda, safety protocols, employee working modes and styles) (Calderelli et al., 2021), focusing on employee well-being in workplaces (Pérez et al., 2013), regulations to prevent job-loss (Sen et al., 2020), and the whole “HR management” action category all address the employment aspect of social implications. Various levels of internal stakeholders are the core relevant groups. Interviewees highlighted change management:

“Change management is important to whatever you do right, particularly for employment. If you go with the idea that you are getting the feedback from the face of people who are using these things, it would be your employees.” (In4-A)

“The impacts on your employees and the people that you employ is part of being responsible and ethical in the decisions that you make.” (In2-P)

Since unemployment is the major negative social implication in this context, upskilling, training, creating new jobs, and recruiting new employees are dedicated to mitigating unemployment. This results in understanding the roles to be changed, the employees to recruit, upskill, and lay off, the new skills to require, and training to develop and how. Such role changing process is challenging,

especially for the freight transport sector (Hopkins and Schwanen, 2023). As confirmed by a practitioner:

“It’s all about how the skill mix changes. [.....] You need to really plan the transition as you move from one to the other. Some of the reskill programmes probably do not work. Actually, a lot of the drivers won’t be able to make that transition, and a lot of them won’t want to do it either. [.....] the first thing to identify is what capabilities you actually need – maintenance skills in terms of the robots, are they different to the capabilities you have already have or is it essentially the same.” (In11-P)

4.5.3.1.4 Transparency

The action categories which address transparency are communications and stakeholder involvement, promotion, planning and regulation improvement. Clear communications among the stakeholders in supply chains deliver real-time messages and information through regular team meetings (internal), and active integration and feedback sessions (external) to achieve transparency. Making sure that the information is clear to the stakeholders and establishing trust are essential to push the AV adoption forward and make social changes. As argued by interviewees:

“If you don’t have transparency, you generally don’t get trust, you’ll struggle with change management and the implementation of these transformational changes within an organisation.” (In2-P)

“I think people want to be able to trust the communications, that come from transparency. Transparency is absolutely critical.” (In4-A)

Planning is also a critical step for mitigating misunderstanding and mistrust from the initial stage of AV adoption (Pani *et al.*, 2020). Planning how to collect data from the stakeholders and manage them primarily addresses stakeholders’ concerns about privacy issues (Tang and Veelenturf, 2019). It also benefits the internal stakeholders with improved data visibility for decision-making (Sellevold *et al.*, 2020). This is recognised by a couple of interviewees:

“Mistrust is a lack of understanding of the vision and the holistic impact of that vision. If plans are not to an appropriate level transparent, what you create is mistrust, such mistrust in technology actually undermines all positive impacts.” (In2-P)

“Planning the information sharing and cybersecurity and so on, transparency is probably the key one.” (In3-A)

4.5.3.1.5 Diversity and equality

The Diversity and equality aspect is closely accompanied by other sustainability indicators such as customer satisfaction and employment. Regarding the end-customers, people with different genders, age groups, education backgrounds, social classes, neighbourhood locations etc. (Yawar and Seuring, 2017) are involved in planning at the early stage of AV deployment in supply chains that serve the local communities. It is also essential to understand the demands of different groups living in remote regions where conventional delivery vehicles are costly to access.

“We gain the consideration of diversity and equality there and make sure that this technology doesn’t work just for those who are able to afford it. That’s the key.” (In2-P)

“It’s very, very important. If you are doing urban mobility initiatives, you need stakeholder involvement. Actually, most of the tools out there require a lengthy involvement of the stakeholders and participation, so the participatory events.” (In13-A)

Regarding employment-related diversity issues, improved female involvement is highlighted. AV deployment in supply chains creates new job positions and requires new skill sets. Hence, the new positions are gender-neutral positions and require higher-skilled talents. The new job positions to be created should welcome employees of either gender. Therefore, this will especially mitigate the stereotype that the logistics sector is a “male predominant” industry.

“Women may not have been involved in certain sectors before. But now because of AVs, they too can become a part of this system. So that it applies

to new job positions being created, and reskilling strategies, both male and female.” (In5-A)

In addition, developing promotion strategies that target audiences with various religions, races, and social classes and then tailoring the promotion strategies is considered an effort to be equal. A widespread education among various social classes is necessary to ensure they have knowledge of and awareness of AV technologies. Hence, candidates from various social classes have opportunities to compete for AV-related positions in supply chains. This is supported by a practitioner:

“We need to promote this type of technologies and the capability and the interest in coming into these industries to a diverse audience of people to ensure that we get the best chance of innovation. We ensure that it works for them all and not just the majority.” (In2-P)

“There is a racial disparity between wealth and education, and that we have to address, otherwise the disparity between those communities is going to grow. The higher-skilled jobs that we create, the less equal our world will become because there will be a smaller pocket of higher paid people.” (In2-P)

Cooperation with external research and education institutions also brings theoretical concepts and knowledge about equal treatment of human resources to organisations for diversity and equality improvement (De Fuentes and Dutrénit, 2012).

4.5.3.1.6 Welfare

Welfare in this research only includes traffic congestion and inter-human communication.

Efficient route planning under the planning category is closely related to welfare. When integrating AVs with smart cities, the technology-assisted capabilities for route selection and planning empower road congestion mitigation (Bezai et al., 2021; Guevara and Auat Cheein., 2020; Yaqoob et al., 2019). Interviewees also supported the arguments, saying:

“With welfare there, traffic congestion, and also, smart cities relate to that.” (In3-A)

“We are taking it from a planning perspective, probably one of the most important aspects to consider the welfare of the society in which that (AV) serves.” (In2-P)

Real-world experiments also address congestion and interactions among humans and between humans and machines (Klumpp, 2018). One interviewee extended the context into the testing of airspace integration of drones with other conventional civil aircraft applies to addressing air traffic situations and the well-being and feelings of human pilots:

“If you extend welfare from road traffic congestion (into the air space), human interactions. Here we are talking about potential air-human interaction. So, if I understand correctly, the welfare is getting in, in terms of the interaction of airspaces, I think.” (In6-A)

4.5.3.1.7 Reputation

Although reputation is a newly identified indicator in Chapter 3, it is extensively mentioned by the interviewees in this chapter, in that nearly all the action categories directly address this aspect. Hence, the actions to improve reputation address needs far beyond the reputation of being “innovative”, but also the reputation of being long-term socially responsible as the organisational culture (Pollach, 2015). As mentioned by the interviewees, it is equally crucial for organisations to act socially responsibly, and to be seen as socially responsible. This on the one hand showcases the ESG rating agencies that they are trustworthy for being ethical enough to be invested in with large amounts of financial funding. On the other hand, it determines the customer choices, as highlighted in the interview:

“I think you are going to see more consumer choice move away from organisations that don’t show a strong CSR governance.” (In2-P)

For organisations that only pretend to be socially responsible without acting sustainably, stakeholders will ultimately lose trust in them, which is a long-term deficiency in their reputation. This is argued by an academic:

“I think quite a few of the companies do greenwashing. Their reputation is improved if they promote themselves as a business as having the CSR focus.”
(In5-A)

Therefore, reputation is not achieved only through promotion and presentation of performance, it is also achieved through the processes of actually doing them.

Showcasing the experiments and tests of AVs to the stakeholders is more persuasive than listing the social sustainability performance of AVs on display boards. This is mentioned by an academic:

“If you don’t do this, people might be in doubt about how you did this. It’s the reputation perceived also by the government and other stakeholders. So, if you test the integration of airspaces, you improve your reputation in front of the stakeholders.” (In14-A)

4.5.4 Action categories aligned with the Innovation Process

This section aims to analyse how the action categories can be structured into the IP to serve organisations that adopt AVs for improved SCSS performance. A brief description of the proposed alignment of the action categories with the stages in the process is provided first. Through the follow-up interviews, the alignment is refined and an evolved model is presented.

4.5.4.1 Proposed action alignment into each stage after the Delphi study

There was an initial refinement of the model between the two evaluation rounds of the Delphi study based on the participants’ comments (details are shown in Appendix E). This section briefly illustrates the alignment after the Delphi study.

- **Agenda-setting: planning**

According to Roger’s definition (2003), organisations at the agenda-setting stage identify the needs, problems, knowledge of the innovations, and the gap between the expected and actual performances. Hence, planning is the category that

organisations implement. Actions such as seeking key resources for the business environment, and designing the process to suit the technology all potentially exist at this stage.

- Matching: planning, real-world experiments

The organisations at the matching stage assess whether the innovation fits the organisation and the identified problems or not (Rogers, 2003). Hence, a series of experiments and tests are to be conducted to check the feasibility and intended benefits of the technology in organisations. The organisations compare the pilot test outcomes with the initial plans and designs, and determine whether to move the adoption process forward to the implementation stages or to reject it (Rogers, 2003). However, regarding the SCSS implications, as the interviewees mentioned, health and safety should be checked prior to other functions or advantages in real-world experiments. Therefore, planning still plays an important role at this stage.

- Redefining/restructuring: planning, promotion, continuous improvement

After the previous initiation stages, implementing the innovation starts from this stage. As the first stage in the implementation process, the organisations at the redefining/restructuring stage modify the organisational structure to fit the innovation, and the innovation is modified to be more tailored to the organisation (Rogers, 2003). This means continuous improvement starts from this stage, such as change management, constant working environment development, and constant technology development and research (Caldarelli et al., 2021; Fincham and Rhodes, 2005; Atilgan and McCullen, 2011). Planning is still crucial to refine appropriate performance measures and capabilities during this “mutual adoption of the innovation and the organisation” period (Rogers, 2003). The short-term, floor-level scheduling for operations is planned and refined to create an appropriate “fit” (Rogers, 2003; Robinson et al., 1985). For organisations adopting radical innovations (i.e., using disruptive technologies), effective internal promotion is necessary to mitigate uncertainties and resistance from the internal stakeholders (Rogers, 2003). Introducing the capability and quantifying the

advantages would benefit the employees' acceptance, so as to ease the difficulties in implementation.

- Clarifying: HR management, promotion, continuous improvement, CSR focus

The technology is more widespread in organisations at the clarifying stage, leading to a potentially large range of resistance, especially among internal stakeholders (Rogers, 2003). It is crucial to inform them in detail of the advantages and teach them how to use or interact with the technology (i.e., upskilling), so as to achieve a common understanding (Rogers, 2003). Hence, actions regarding promotion and HR management should be implemented. During the technology deployment, it is also necessary to keep checking the CSR performance, to monitor the potential risks at this period. This is followed by continuous improvement in that, operation modes, structure (Caldarelli et al, 2021), and technology evolve as the resistance occurs. Therefore, HR management, promotion, continuous improvement, and CSR focus are proposed to be enacted at the clarifying stage.

- Routinising: CSR focus, continuous improvement.

Routinising is the stage where the innovation has been integrated into the organisation as part of its identity (Rogers, 2003). This means that, at this last stage of IP, the innovation is widely adopted in the organisation. At this stage, Rogers (2003) pointed out the long-term sustainability of the technology in the organisation – whether the innovation is capable of solving the unexpected new problems that are consistently challenging the organisation. Therefore, this still requires continuous improvements regarding the constant technology development and constant change management that call for constant organisational transformation in operation structure, agendas, working modes, etc. (Caldarelli et al, 2021; Fincham and Rhodes, 2005; Atilgan and McCullen, 2011). Therefore, continuous improvement remains the key action category at this stage. In the meantime, CSR performance of implementing technologies still needs to be supervised, which makes CSR focus non-negligible as well.

The entities which enact regulation improvement are mainly not the organisations themselves, but the government and legislative authorities that were identified in

Chapter 3.4 instead. Although regulation improvement is suggested to be enacted for wider AV adoption, the initial testing and deployment of AVs should obey the existing regulations (Kurniawan et al., 2021). Hence, the approval of existing regulatory frameworks should be presented prior to the initial AV adoption process. Furthermore, the proposed actions are initially aimed at improving the SCSS performance, so as to gain social approval with AV adoption in supply chains. Based on the arguments in Chapter 2.4.3.2, the improved social impacts of AV adoption potentially benefit the ease of regulations, or the improvement of regulations (Fagnant and Kockelman, 2015). Therefore, the category “regulation improvement” is proposed to be presented at the end of the IP, after the other actions are implemented.

Since the category “communications and stakeholder involvement” is considered to be fundamental to all of the other categories (Yang and Basile, 2022), it is listed at the bottom of the model (shown in Figure 4-4).



Figure 4-4 Proposed alignment of action categories with IP

4.5.4.2 Refining each stage of the action alignment

By conducting the interviews, the proposed model was further refined in detail by analysing the suggestions provided by the interviewees. The following section provides the refinement of the action category alignments with each stage of organisational IP according to the DOI theory and the interviewees' comments.

4.5.4.2.1 Agenda-setting

Most interviewees who mentioned the changes of actions in the agenda-setting stage recommended adding the CSR focus. A strategic plan for integrating AVs with operations, as well as CSR considerations is essential at the early stage of AV adoption. The organisations ensure strategic CSR vision is incorporated throughout the AV adoption process and is integrated as part of the organisational culture (Slack et al., 2015). As mentioned by an interviewee:

“It goes into how we do things around here within the organisation. I still think that needs to be higher up the earlier if you like in the decision-making process”. (In6-A)

Therefore, CSR focus is included in the agenda-setting stage of IP.

4.5.4.2.2 Matching

Similar to the Agenda-setting stage, CSR focus was suggested to be added into Matching as well. By definition, organisations seek to design a fit between the technology and the identified problems at this stage (Rogers, 2003). Hence, it is crucial to highlight CSR issues of AV adoption and design a plan to mitigate the negative impacts. One practitioner argued that these happen at the matching stage.

“I think that there needs to be a CSR focus on matching because you need to be matching technology that aligns with your CSR needs.” (In2-P)

Real-world experiments are conducted at this stage to check whether the technologies, as well as the solutions to the problems, fit in the organisations, and organisations determine whether to move forward to the implementation stages or not (Rogers, 2003). With the proof of concept, regulations need to improve according to the experiment outcomes at this stage, enacted by legislative authorities (external stakeholders) for the follow-up implementations of AVs in operations. Otherwise, practical deployment of AVs is not feasible. As interviewees argued:

“Regulation improvement is required. There is probably a stop check here. Some people wonder why even bother planning to do it if you can’t do it. If we don’t do it, and we don’t show experiments, how are we going to put pressure on legislators to change the legislation? We’ve got to prove that it’s technically feasible, that there are benefits and therefore, we can put pressure on changes. I don’t think that’s the last step in this process.” (In1-A)

“We cannot integrate it into the internal organisation if there is no regulation improvement. How can we use it in organisations?” (In14-A)

Only if the improved regulations approve and regulate the use of AVs in supply chains properly, will there be real deployment on a wide scale. Therefore, it is reasonable to place the regulation improvement category prior to the implementation stages.

In the earlier analysis regarding the proof of benefits, real-world experiments provide evidence for legislative authorities to improve the regulations (Marsden et al., 2018), and also for organisations to promote the advantages to communities. Hence, at the matching stage, the organisations design and plan the promotion strategies, regarding who is to receive what information, and what advantages to show, before the deployment. This is the same with HR management. When seeking a fit between problems and technologies, the decision-makers analyse what new skills and positions are needed, and what departments are redundant. These serve as the initial steps of employment in this context, which are proposed by the interviewees to exist in the matching stage:

“Matching is about planning and promotion.” (In13-A)

“CSR focus, regulation improvement, HR management.” (In3-A)

As a result, the action categories involved in this stage are CSR focus, real-world experiments, promotion, regulation improvement, employment, and planning. Multiple internal and external stakeholders are in charge of these actions.

4.5.4.2.3 Restructuring/Redefining

As the first stage of the implementation subprocess, it requires a modification between organisations and the innovation for the fit (Rogers, 2003). This means continuous improvement starts from this stage, such as change management, constant working environment development, and constant technology development and research (Caldarelli et al., 2021; Atilgan and McCullen, 2011). Planning, especially the short-term, floor-level planning, scheduling, and checking is refined to reach an appropriate “fit” (Robinson et al., 1985). After implementing the technology, effective internal promotion, as well as upskilling programmes, are necessary to mitigate uncertainties and resistance from the internal stakeholders to ease the difficulties in later implementation (Rogers,

2003), and to enhance employees' confidence in interacting with AVs. As one interviewee confirmed:

“Employees might need to know earlier that they are going to have these technologies adopted by the company.” (In9-A)

4.5.4.2.4 Clarifying

Interviewees had limited comments about the clarifying stage since the model has already covered the necessary categories, while at this stage, promotion of the benefits of AV usage is further encouraged through clear communications. AVs are broadly deployed in organisations at this stage so that the advantages and benefits compared to the conventional modes are more obvious. They serve as stronger proof for promotion and branding.

4.5.4.2.5 Routinising

At this stage, AVs are widely adopted and incorporated into the regular activities of organisations, and become a part of those organisations (Rogers, 2003). Therefore, CSR focus and continuous improvement still apply to this stage, for routinised checking and improving, while employment was pointed out to be added into this stage. This calls for continuous upskilling and psychological support for the employees.

Although an identical action category potentially applies to multiple stages of the decision process, the detailed actions to be implemented can be different depending on the stage of AV adoption the organisation is positioned at. Taking CSR focus as an example, organisations are suggested to be aware of CSR from the top managerial level to the operational level from the initial adoption stage to the routinising stage. While the emphasis of this category in each stage varies, at the initial stage, it is more the responsibility of high-level managers to realise the importance of CSR and set the goals and visions to maintain CSR performance. This is about decision-making regarding CSR within the organisation, as mentioned earlier. At the later stages, CSR performance should be ensured through refining the measures and regularly checking the measuring indicators at the operational level. The differences even exist in the final two stages of the process. As mentioned by an academic:

“When you are clarifying, it is the different CSR focus you have when you are routinising because, for me, that is about measurement. It is not just a focus because it is much more than that. It is about measurement.” (In1-A)

The same arguments apply to other action categories. It is not feasible to consider route planning of AVs at the agenda-setting stage, and it might be too late to realise the importance of the integration of technologies into supply chain processes after the restructuring stage. Therefore, distinct individual actions under the identical action category apply to different adoption stages.

4.5.4.3 Continuous improvement and cyclic logic

In the implementation subprocess, the continuous improvement category was related to the Deming cycle by several interviewees. One interviewee argued:

“When I saw this, I was immediately put in mind of the Deming continuous improvement cycle.” (In7-A)

The Deming cycle provides a visualised tool to illustrate a cyclic constant improvement structure (Moen, 2009; Moen and Norman, 2006; Taylor et al., 2014). Continuous improvement in this context includes actions aiming to constantly advance the technologies and working environment to improve performance. Such a cyclic mechanism realises continuous performance gap checking and determines what changes to implement for improvement (Moen, 2009).

“You do the innovation and come up with an assessment of what was okay or went wrong. You take this feedback into your design and redesign loop again and again. Once we start implementing it into a larger scale proof of concept or pilot, a lot of our premises or our assumptions will change.” (In13-A)

4.5.4.4 The refined model

Based on the discussions above, Figure 4-5 presents the refined model. This presents a novel application of the DOI theory in innovation diffusion research. Each of the eight action categories is aligned with the relevant diffusion stage of the IP model, using suggestions from the initial literature and insights from the interviewees. The IP model is, therefore, used to develop the process of SCSS

improvement with the action categories enacted by organisations at various AV adoption stages. As a result, in this paper, the DOI theory is used as a tool and AV adoption in supply chains as a context to understand how organisations act to facilitate improved SCSS performance in the AV adoption context. This is different from other literature that applies the DOI theory to analyse the technology diffusion process in supply chains (Gong et al., 2022; Wamba and Queiroz, 2022) or to analyse the diffusion of sustainability concepts among supply chains (Zhu et al., 2012). In addition, this model proposes a separation of action categories based on whether they are implemented by internal stakeholders within the organisation or external stakeholders (or both). For example, appropriate promotion strategies are enacted by internal decision-makers whereas the regulations are improved by the policy-makers who are external groups. Therefore, when integrating the action categories with the DOI theory, such separation is also involved in the model. Since stakeholder analysis is essential in SCSS research (Hussain et al., 2018), involving stakeholders in the IP model helps strengthen the structure of action categories that aim to improve SCSS performance in the AV adoption context.

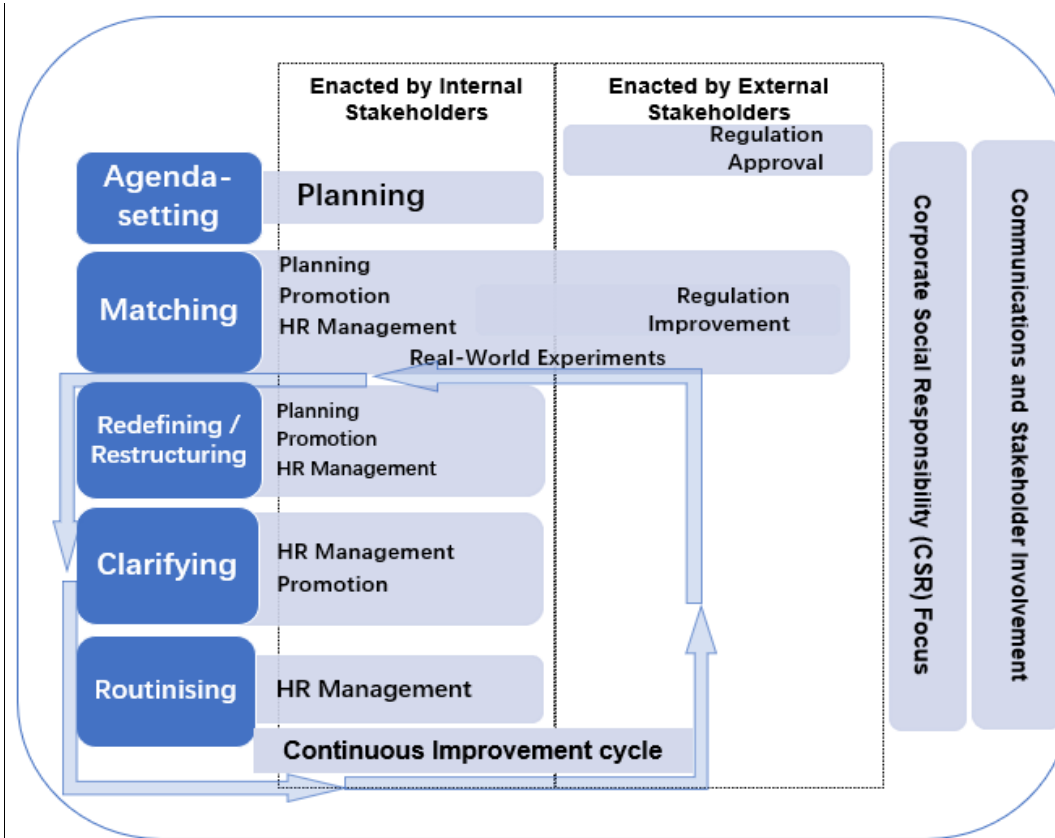


Figure 4-5 Refined model and Action plan for improving SCSS performance in the AV adoption context

4.6 Conclusion

This paper answers the research question and fulfils the research objectives and the second research gap by empirically identifying the actions and action categories recommended for various organisations to enact to address the social impacts of AV adoption in supply chains. Through a 3-round Delphi study and 14 follow-up interviews, the actions and categories are structured into a logical model referring to the organisational IP. Analysis of the results shows how the structured action categories support the organisations to address social impacts at each stage of innovation adoption, to gain wide social approval in adopting AVs in supply chains and to improve SCSS performance.

4.6.1 Contributions to knowledge

This study contributes to knowledge in several ways. First, this exploratory study contributes to the research domain of SCSS of AV adoption by expanding and

evaluating the eight action categories that address the social sustainability implications of AV adoption in supply chains. The Delphi study groups the actions into eight categories: communications and stakeholder involvement, continuous improvement, CSR focus, human resource management, planning, promotion, real-world experiments, and regulation improvement. The alignment of these action categories with the IP model provides a comprehensive list of logically structured actions to realise improved SCSS performance of AV adoption.

Second, this study applies the DOI theory (Rogers, 2003) to structure the action categories to improve the organisations' SCSS performance during their adoption of AVs. It is the novel use of the theory as an instrumental framework to structure the actions for the aim of SCSS improvement. As a result, the organisational IP model is tailored to the AV adoption context with corresponding action categories at each of the innovation diffusion stages. For the actions implemented by various organisations, a separation of the action categories on the basis of being enacted by internal/external stakeholder groups is proposed on the refined IP model as well. Hence, this study contributes to the theory by supporting a novel use of the DOI theory by tailoring the organisational IP model to the AV adoption context with the structured action categories and proposing the separation of the action categories that are being enacted by internal or external stakeholders.

4.6.2 Managerial impacts

This study provides managerial contributions in two dimensions. First, this study provides a comprehensive overview of the actions with a structured action plan for the companies that adopt AVs in their operations to improve their SCSS performance. Organisations that adopt AVs can implement the actions that correspond to their adoption stage to manage their social sustainability. The policy-makers can improve regulations at early stages after the AVs have shown their reliability in real-world experiments, so as not to postpone the vast deployment of AVs in supply chains.

Second, the action plan serves as a trail of evidence for the regulators to supervise whether the organisations achieve SCSS performance by enacting the actions or by "greenwashing" (i.e., organisations pretend or promote to be socially

responsible without acting sustainably)” when adopting AVs. The organisations which claim to be socially sustainable but fail to show the evidence of practising the actions during the process of AV adoption are suspicious in “greenwashing”.

4.6.3 Limitations and future research directions

This study contributes to the actions and the grouped action categories in the category of AV adoption in the supply chain to address the social sustainability implications. It is broad to include the contexts of both UAVs and UGVs. Some of the critical items in the UAV context (e.g., setting no-fly zones in regulation improvement) are not applicable to the AMR context, and vice versa. It is suggested to separate the research and analysis into detailed scenarios in future research. Furthermore, the actions are not all context-exclusive. For example, clear communications and stakeholder engagement are necessary for all organisations to succeed, not only in the context of innovative technology adoption. In-depth explorations into what type of detailed actions, enacted by whom, to address what social impacts, and which stakeholders would be suggested. Deeper investigations into these aspects are beneficial to understanding how the industry addresses social sustainability implications when adopting AVs in supply chains. In addition, AVs are not broadly adopted in the supply chain yet (i.e., self-driving trucks are not available in the current road network at present). The actions raised are proposed and suggested to address the social impacts. Whether or not the actions with a high importance rating in this study benefit the social sustainability performance after the full deployment needs to be verified in follow-up studies.

This study highlights the adaptation of DOI theory for the actions in improving SCSS performance within organisations along supply chains. However, the view is limited to the organisations independently, instead of taking the relationship between organisations in supply chains into account. There exists a lack of focus on chain-wide dynamics among the multiple organisations which adopt AVs and the overall SCSS performance improvement. Therefore, future research can take a step forward to extending the use of organisational IP to the supply chain level

by discussing how the SCSS benefits from discussing the collaborations among organisations along the chains for sustainability performance improvement.

Apart from these observations, there are potential linkages among the action categories. Real-world experiments provide proof of concepts and benefits for the organisations to further promote their advantages, as well as for the legislative authorities to refine the regulations to guide the organisations to safely and ethically operate their supply chains with AVs. These proposed mechanisms are also worth discussion and investigation in future research.

Regarding the research method this study applies, i.e., the Delphi method with follow-up interviews also provides insights in a generic and broad sense. Detailed insights should be gathered in cooperation with other research methods that address the detailed mechanisms in real-life scenarios. For improved rigour, a real-life case study method is suggested to investigate in-depth after a wider AV deployment in the industry is realised, in order to verify the proposed actions and models (Yin, 2018). Therefore, all of the aforementioned research into separating contexts, detailed actions, and real outcomes of the actions require studies into real-world cases in the industries, to examine the proposed actions and the impact mechanisms of social sustainability performance.

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5 Conclusion

This thesis provides a two-perspective view of understanding the SCSS of AV adoption. The first perspective identifies positive and negative social impacts that are categorised under seven context-specific SCSS indicators with a conceptual framework. Key internal and external stakeholders, which are essential for SCSS conceptualisation, are also identified, with their degree of influence evaluated. On the basis of the social impacts, the thesis explores how organisations act to improve the positive and mitigate the negative impacts during their adoption process of AVs in supply chain operations. The second perspective includes the key action and action categories for organisations at different AV adoption stages to implement to improve the SCSS performance and realise wider AV adoption in supply chains.

This thesis contributes to the development of SCSS concepts by investigating contextual SCSS indicators and relevant stakeholders. This thesis also defines the actions and action categories that contribute to SCSS improvement and facilitate wider AV adoption in supply chains. In addition, this thesis shows a novel use of the DOI theory that uses the organisational IP model to develop the process of SCSS improvement with the action categories enacted by organisations at various AV adoption stages.

This thesis contributes to practice by providing an overview for organisations of the key social sustainability implications and key stakeholders to focus on when adopting AVs. Based on these social sustainability implications, this thesis also provides an action plan for these organisations to follow in order to improve the SCSS performance of AV adoption. Practitioners will gain wider social approval for broader AV adoption in supply chains by recognising the social impacts and implementing the action plan provided in this thesis.

5.1 Achievement of research objectives

This section presents the results of the PhD research on the social sustainability of AV adoption in the supply chain. This thesis follows a paper format whereby Chapters 2 – 4 each presents a paper. This thesis aims to understand the overall research question: How does AV adoption in supply chains affect SCSS? To answer this research question, four sub-research questions and seven research objectives are allocated into the three papers.

Sub-RQ 1.1: What are the social impacts of AV adoption in supply chains?

RO1: To identify the positive and negative social impacts of AV adoption in supply chains from the extant literature;

RO2: To identify relevant SCSS indicators in the AV adoption context and relate the identified social impacts to the indicators;

Sub-RQ 1.2: What are the actions organisations can take to address the social impacts of AV adoption in supply chains?

RO 3: To identify and synthesise the key suggested actions that organisations can employ to address the social impacts of AV adoption to achieve a socially sustainable supply chain;

Sub-RQ 2.1: What are the SCSS implications of AV adoption in supply chains?

RO 4: To empirically refine and evaluate the social impacts and SCSS indicators in the AV adoption context;

Sub-RQ 2.2: What are the key stakeholders involved in the context of adopting AVs in supply chains?

RO 5: To empirically identify and evaluate the key stakeholder groups in the context of AV adoption in supply chains;

Sub-RQ 3: How should organisations act to address the social sustainability implications of AV adoption in supply chains?

RO 6: To empirically refine and evaluate the suggested actions and action categories that companies can adopt to address the social impacts of AV adoption;

RO 7: To empirically evaluate the action categories for the organisations to employ at various stages of AV adoption in supply chains.

Table 5-1 Results against the questions and objectives

Research Questions	Answers to the Research Questions	Research Objectives	Summarised Results
1.1 What are the social impacts of AV adoption in supply chains? <u>Chapter 2 – Paper 1</u>	The positive and negative social outcomes that are related to health and safety, customer satisfaction, employment, transparency, diversity and equality, and welfare in the context of UGV and UAV adoption in supply chains.	1. To identify the positive and negative social impacts of AV adoption in supply chains from the extant literature; 2. To identify relevant SCSS indicators in the AV adoption context and relate the identified social impacts to the indicators;	<ul style="list-style-type: none"> Identifies 13 positive and seven negative impacts as the social impacts of AV adoption in supply chains; Extracts eight stakeholders, without classifications.
1.2 What are the actions organisations can take to address the social impacts of AV adoption in supply chains? <u>Chapter 2 – Paper 1</u>	The actions that are categorised under field experiments; regulation improvement; education, promotion, and training; and chain-wide integration, enabling wide social approval for adoption.	3. To identify and synthesise the key suggested actions that organisations can employ to address the social impacts of AV adoption to achieve a socially sustainable supply chain;	<ul style="list-style-type: none"> Identifies six SCSS indicators that are relevant to positive and negative impacts in this context: Health and Safety, Customer Satisfaction, Transparency, Diversity and Equality, Employment, and Welfare. Recognises the first research gap: stakeholders
2.1. What are the SCSS implications of AV adoption in supply chains? <u>Chapter 3 – Paper 2</u>	The social implications that are relevant to health and safety, customer satisfaction, employment, transparency, diversity and equality, welfare, and reputation perspectives of performance of the supply chain, with regard to the respective internal and external stakeholders through the adoption of UAVs or UGVs in supply chains.	4. To empirically refine and evaluate the social impacts and SCSS indicators in the AV adoption context;	<ul style="list-style-type: none"> Expands to 19 positive impacts, 15 negative impacts; Identifies Reputation as a new SCSS indicator in this context, and attains seven SCSS indicators. Transparency-related impacts are most important; diversity and equality are least important.
2.2. What are the key stakeholders involved in the context of adopting AVs in supply chains? <u>Chapter 3 – Paper 2</u>	The internal and external entities that affect or are affected by the adoption of AVs in supply chains to various extents.	5. To empirically identify and evaluate the key stakeholder groups in the context of AV adoption in supply chains;	<ul style="list-style-type: none"> Identifies three categories, nine groups of internal; six categories, 17 groups of external stakeholders; C-level managers are the most affecting, operational employees are the most being affected internal stakeholders; whereas AV manufacturers are affecting and being affected the most in the external group.
3. How should organisations act to address the social sustainability implications of AV adoption in supply chains? <u>Chapter 4 – Paper 3</u>	Organisations actively implement communications and stakeholder involvement, continuous improvement, CSR focus, human resource management, planning, promotion, real-world experiments, and regulation improvement at agenda-setting, matching, restructuring/redefining, clarifying, and routinising stages of AV adoption in supply chains.	6. To empirically refine and evaluate the suggested actions and action categories that companies can adopt to address the social impacts of AV adoption; 7. To empirically evaluate the action categories for organisations to employ at various stages of AV adoption in supply chains.	<ul style="list-style-type: none"> Identifies 20 actions to improve positive impacts, 23 to mitigate negative impacts; 40 after refinement, grouped into 8 categories; Real-world experiments are the most important actions, employment is recognised as the least important to address SCSS; Health and Safety and Customer Satisfaction are addressed by all of the categories. All the action categories are aligned with the IP model; Communications and Stakeholder involvement and CSR focus are the two categories presented throughout the whole adoption process; A Continuous improvement cycle is shown in the implementation sub-process.

The three papers in this thesis collectively and sequentially cover the research questions and the corresponding research objectives. Table 5-1 summarises the research findings against each research question and objective achieved by distinct papers. With its exploratory nature, this PhD thesis is constructed using an abductive research strategy with a qualitative research approach (Blaikie, 2007; Ketokivi and Choi, 2014). A combination of inducing the knowledge from the literature and Delphi experts, and deducting the connections among the identified key themes (i.e., social impacts and SCSS indicators, actions and social impacts, social impacts and stakeholders) was conducted collectively to comprehensively answer the overall research question (Ketokivi and Choi, 2014), which is to understand how AV adoption affects SCSS implications.

Sub-RQs 1.1 and 1.2 are addressed in the first paper. To answer Sub-RQ 1.1, this paper breaks down the question into two aspects as ROs: to investigate social impacts and the relevant SCSS indicators that include the impacts. By reviewing 58 papers through an SLR, this paper summarises two comprehensive lists of positive and negative social impacts shown in Tables 2-4 and 2-5. The 13 positive and seven negative social impacts are recognised when AVs are mainly adopted in transportation, warehousing, and manufacturing processes in commercial and humanitarian logistics contexts. Although not explicitly pointed out in the literature, the eight stakeholder groups, i.e., consumers, traffic users, local communities, operational employees, logistics managers/decision makers, government/policy makers, shareholders, and labour unions are extracted (shown in Table 2-7). These elements are the foundations for addressing the following objectives. RO 2 covers the second aspect of Sub-RQ 1.1. By comparing the definitions of the social sustainability indicators in general sustainable supply chain management concepts and the identified social impacts in the AV adoption context, six indicators from Table 2-6 are recognised as relevant: Health and Safety; Customer Satisfaction; Transparency; Employment; Diversity and Equality; and Welfare. A conceptual model is established that classifies the impacts under each of the six indicators, which is deduced from the literature. As a result, this review paper identifies and classifies the social

outcomes that are involved in the AV adoption context, which consists of the answer to Sub-RQ 1.1.

Sub-RQ 1.2 is addressed by RO 3 in Paper 1. Based on the identified social impacts, it is important to understand the actions the respective decision-makers enact to address the social impacts, so as to improve the SCSS performance and AV adoption in supply chains. This perspective supplements the social impacts and SCSS indicators highlighted in the first two ROs and forms a part of the overall research aim. As a result, this paper extracts 20 individual actions and classifies them into four categories that are proposed by the literature to enable wider AV adoption in the supply chain. These actions and action categories are evaluated in the empirical studies. Paper 1 grounds the conceptual base and identifies research gaps (i.e., stakeholder identification, and action evaluation) for the following papers.

The second paper answers Sub-RQs 2.1 and 2.2 by fulfilling ROs 4 and 5, which are developed upon the first two ROs. Data are collected through a three-round Delphi study involving 39 participants with diverse backgrounds from various geographical regions. To answer Sub-RQ 2.1, paper 2 refines and expands the social impacts into 19 positive and 15 negative impacts to be categorised into the SCSS indicators. In addition, “reputation” is identified as an additional indicator relevant in this context, making it seven SCSS indicators. These results refine the conceptual framework raised in Paper 1. To answer Sub-RQ 2.2, Paper 2 identifies the three categories, nine groups of internal, and six categories, 17 groups of external stakeholders. These entities are further evaluated on the basis of their influential extents by the degree of “being affected” and “affecting” in the context of AV adoption. This addresses RO5 and the first research gap. Paper 2 provides a holistic overview of the SCSS aspects and the included social impacts, but also a comprehensive view of the key stakeholders in terms of how they are related and to what degree, in the AV adoption context. The fulfilment of ROs 4 and 5 answers RQ 2.1 and 2.2 respectively, which concludes the seven SCSS indicators that are relevant to AV adoption in supply chains, with the key internal and external stakeholders involved. These outputs provide a conceptual foundation for the actions in paper 3 regarding what SCSS indicators to address.

The final Sub-RQ, accompanied by the last two ROs, is covered by paper 3, a two-phase study. In paper 3, eight categories (i.e., communications and stakeholder involvement, continuous improvement, CSR focus, human resource management, planning, promotion, real-world experiments, and regulation improvement) of 40 individual actions are identified through the first-phase three-round Delphi study; whereas the social implications these actions address are validated through 14 follow-up interviews. These efforts address RO 6 and fill the second research gap. The action categories are aligned with the organisational innovation process to provide an action plan for organisations to implement the appropriate actions at five stages of AV adoption to address social impacts. Among the action categories, communications and stakeholder involvement, as well as CSR focus are highlighted in all the AV adoption stages. The refined model also includes a continuous improvement cycle and a separation of the actions to be enacted by internal/external stakeholders. Such alignments and model refinement address RO 7. The fulfilment of the two ROs consists of the answer to the final Sub-RQ.

The SLR provides an overview of how social sustainability can be affected by AV adoption in supply chains from two perspectives: stakeholders, social impacts and SCSS indicators; and the actions taken in supply chains to address the social impacts (especially the negative ones). Papers 2 and 3 therefore follow these two perspectives respectively through two qualitative studies: the Delphi study and follow-up interviews. The combined qualitative outcomes construct the answers to the overall research question and the overall logic of the thesis is reflected in Figure 1-3.

5.2 Contributions

The contributions of this thesis are split into theoretical, methodological, and practical dimensions, and are summarised in this section.

5.2.1 Theoretical contributions

This section describes the three main theoretical contributions this PhD thesis makes to the SCSS concept expansion, stakeholder identification, and SCSS improvement in the AV adoption context. These contributions are established

from the appeal of exploring contextual SCSS indicators for concept development (Ahi and Searcy, 2015; Denu et al., 2023), as well as the discussions of social implications in the AV adoption context.

5.2.1.1 Overview of Contextual Social Sustainability Implications

This thesis contributes to the development of the supply chain social sustainability concept. In order to investigate SCSS, exploring the indicators that qualitatively present SCSS performance in specific scenarios is required, to understand context-specific social sustainability issues (Ahi and Searcy, 2015; Denu et al., 2023), since the SCSS indicators are not “one fits for all” (Hussain et al., 2018). Through a review of the literature, this thesis recognised six SCSS indicators which are relevant to the AV adoption context, namely, Health and safety, Customer satisfaction, employment, transparency, diversity and equality, and welfare. A model that relates the identified social impacts to these SCSS indicators is developed. Such efforts contribute to the SCSS concept by exploring the specific context-based social sustainability indicators.

In order to form a comprehensive understanding of AV adoption context-specific SCSS, this thesis synthesised four categories of actions for the aim of wider AV adoption and SCSS performance improvement. These categories include field experiments; regulation improvement; education, promotion, and training; and chain-wide integration. These action categories serve an alternative perspective of understanding SCSS implications of AV adoption in supply chains.

The literature review provides a solid conceptual foundation for the empirical research.

5.2.1.2 Refining stakeholders and SCSS in the AV adoption context

This thesis makes the first attempts at understanding the stakeholders and their influential attributes (i.e., being affected/affecting) in this context. As the core element of SCSS, stakeholders should have been highlighted explicitly in the SCSS research (Huq et al., 2014). With the limited conceptual underpinning of stakeholders in the literature, stakeholders are identified and classified into internal and external groups, which is considered the primary step of stakeholder

research through the lens of stakeholder theory (Sarkis et al., 2011). In addition, the attempts to investigate stakeholders into two influential dimensions (i.e., being affected and affecting) understand how important the identified stakeholders are in this context (Stieb, 2009). Although not yet strictly following the stakeholder attribute analysis (Mitchell et al., 1997), the influential dimensions provide a tailored method to analyse the importance and relevance degrees of the stakeholders in the AV adoption context. This thesis provides a first comprehensive analysis of stakeholder specification in the AV adoption context. This research provides an evidence base for future research to analyse contextual stakeholder salience and roles in the AV adoption context through the lens of stakeholder theory.

On the basis of the identified social impacts and the six relevant SCSS indicators from the literature, this thesis further extends the SCSS in the AV adoption context by identifying additional SCSS indicators and social impacts to form the definition of SCSS in this context:

The social implications that are relevant to health and safety, customer satisfaction, employment, transparency, diversity and equality, welfare, and reputation perspectives of the performance of the supply chain with regard to the respective stakeholders under the adoption of UAVs or UGVs in supply chain operations.

This thesis also discusses the social impacts of AV adoption in supply chains, which supplements the discussions of the “three pillars” implications (i.e., economic, environmental, social) (Elkington, 1997) in this context. This is achieved by investigating the distinct social impacts in relation to the SCSS indicators. This thesis makes efforts to understand the social implications of AV adoption in supply chains exclusively to mitigate the lagging of the research into the social side impacts of AV adoption.

In summary, this PhD provides the first in-depth conceptual and empirical investigation into social sustainability in the context of AV adoption in supply chains. On the one hand, this thesis highlights the stakeholders’ importance and analyses their characteristics. On the other hand, this thesis defines the SCSS

concept in this context through the seven aspects and respective social impacts. The investigation into social implications supplements the overall 3-pillar sustainability discussion of AV adoption in supply chains.

5.2.1.3 Defined and structured action categories and refined DOI theory in the AV adoption context

This thesis contributes to the research domain of SCSS by expanding and evaluating the eight action categories that address the social sustainability implications of AV adoption in supply chains, compared to the four categories that are extracted from the literature. The eight categories are defined as communications and stakeholder involvement, continuous improvement, CSR focus, human resource management, planning, promotion, real-world experiments, and regulation improvement. These action categories, as well as the refined actions, provide empirical evidence of improving the social sustainability performance of AVs for wider adoption of this technology in supply chains. These actions fill the second research gap of the thesis.

Furthermore, this thesis adopts the DOI theory (Rogers, 2003) as the theoretical underpinning to structure the action categories to improve the organisations' SCSS performance during the adoption of AVs. On the one hand, it is the novel application of this theory as a tool to structure actions for the aim of SCSS improvement. On the other hand, this thesis further refines the organisational IP model to tailor the AV adoption context by involving the corresponding action categories with each of the innovation diffusion stages, a continuous improvement cycle, and the internal/external stakeholder groups. The stakeholders in the model embody their essential role in SCSS concepts, which strengthen the relations of DOI theory with SCSS. Such a refined model illustrates the mechanisms of improving the SCSS performance of AV adoption in supply chains.

In summary, this PhD thesis understands SCSS of AV adoption from the perspective of how organisations act to improve SCSS of AV adoption in supply chains. Such efforts are augmented by the use of DOI theory for action

structuring. Meanwhile, the IP model is refined to tailor to the AV adoption context for the aim of SCSS improvement.

From a holistic point of view, this thesis contributes to knowledge through an in-depth investigation of SCSS concepts in the AV adoption context. It explores how AV adoption affects SCSS from two perspectives: social sustainability implications of AV adoption in the supply chain, and the actions organisations implement to address the implications to realise improved SCSS performance and wider AV adoption in the supply chain. This research defines SCSS of AV adoption with a conceptual framework that includes seven categories of social impacts on a variety of stakeholders. Such efforts contribute to the SCSS research by developing context-specific SCSS indicators. These social impacts are key to enhancing AV social approval to enable wide adoption in the supply chain. Therefore, organisations implement eight categories of actions according to their AV adoption stages to address the corresponding social impacts, improve their SCSS performance and realise wider AV adoption in the supply chain. By structuring the actions in a logical sequence, this thesis shows a novel use of the DOI theory that uses the organisational IP model to develop the process of SCSS improvement with the action categories enacted by organisations at various AV adoption stages. The two frameworks provide two perspectives for understanding the question “How does AV adoption affect supply chain social sustainability?”.

5.2.2 Methodological considerations

Both Chapters 3 and 4 apply the Delphi method to collect the main dataset for the empirical studies. In general, the Delphi method provides robust, generalisable, and valid results and conceptual foundations for future research (Sterling et al., 2023). In the context of analysing disruptive technologies in supply chains, the Delphi method is widely adopted to gather the potential opportunities, challenges, and sustainability impacts from a wide spectrum of experts (Hohn and Durach, 2021; Kache and Seuring, 2017). It is also a feasible method to explore and predict the research development directions of supply chain management under the support of a group of experts (Melnik et al., 2009; Seuring and Müller, 2008; Reefke and Sundaram, 2017). Therefore, this thesis

supports the Delphi method to be a robust research method to conduct social sustainability analysis in the context of AV adoption in supply chains. The use of the Delphi method in discussing the social sustainability implications of AV adoption in supply chains provides an example for future research to investigate the sustainability implications of other advanced technology adoption in industries.

In addition, the methodology section in Chapter 3 clearly states the use of consensus standards for termination protocols. This initiative supports the appeal of explicitly defining the consensus and termination standards for Delphi studies (Diamond et al., 2014; Von Der Gracht, 2012). For consensus standards, this research applies the “51-80” rule for consensus measuring – 51% of participants select one category of choice in a 5-point Likert Rating Scale, or 80% of participants select the two adjacent categories in the scale, as suggested by a series of existing Delphi studies (Reefke and Sundaram, 2017; 2018). An additional standard for consensus achievement that requires a convergence in ratings between the two evaluating rounds that supplements the 51-80 rule, is also suggested by existing Delphi studies (Moradlou et al., 2021). Due to a lack of inclusive standard guidelines of consensus rules for the Delphi method, this thesis supports the implementation of such combined consensus standards for the Delphi method used in the research regarding SCSS in the AV adoption context.

5.2.3 Practical contributions

This research provides significant practical contributions and offers numerous impacts for those organisations adopting AVs to understand the SCSS implications of their adoption and manage them. This research also contributes to the legislative authorities which regulate the guidance of AV deployment.

This thesis identifies numerous elements that are relevant to the SCSS concept, i.e., stakeholders, social impacts, and actions to achieve SCSS. Firstly, this research provides organisations with a holistic view of what social aspects of sustainability to focus on, who the potential stakeholders are that relevant to the deployment of AVs in supply chains, and the relevant social impacts on them.

The achieved insights regarding these themes and their importance support the organisations in the development of social indices on the performance measurement tools.

On the basis of the identified social sustainability aspects, it is crucial for organisations to achieve improved social sustainability performance. Therefore, the actions and action categories provided in Chapter 4 map a detailed action plan for decision-makers to enact socially sustainable actions when adopting AVs in supply chains. By aligning with the IP model, the structured action categories instruct the decision-makers regarding what to do at each of the AV adoption stages for a consistent socially sustainable performance. Hence, the use of the IP model supports organisations to develop tailored business models when deploying AVs in their operations. In addition, this research also suggests the most important SCSS aspects for organisations to prioritise – transparency, health and safety, and customer satisfaction. Transparency is the most critical social outcome in this context. The latter two aspects suggest that they are the primarily focused SCSS indicators for the actions and action categories to address.

This research contributes to organisations that seek to improve their Environmental, Social, and Governance (ESG) ratings, especially the social aspect, and to those that adopt advanced frontline technologies such as AVs in their operations. The ESG ratings are audited by external rating agencies to provide suggestions to the major institutional investors for financial sponsors, regarding the target organisations' performance on environment, ethics, health and safety, labour issues, etc. (Atkins, 2020; Dai and Tang, 2022). The contributions regarding ESG fall into two dimensions: 1) assistance in constructing the ESG rating criteria; and 2) emphasising the proof of evidence for the ESG ratings. The results of Chapter 3 underpin the first dimension. Chapter 3 identified the social impacts, relevant social sustainability indicators, and the importance of these implications considered by the participants. These elements support the forming of the ESG assessment criteria, in terms of the themes, detailed items, and the proportion of the items in the ratings. Chapter 4 focuses on the actions and action categories for SCSS, which contributes mainly to the

second dimension. Supplementing the “what to measure” that is covered in Chapter 3, “checking how the organisations achieve the rating” is supported in Chapter 4. The action plan provided in Chapter 4 serves as a trail of evidence to the rating agencies and regulators to check whether the organisations implement ethically to achieve high ESG ratings, or they only present the ESG scores by conducting unethical practices such as “Greenwashing”. Since the actions are suggested to address SCSS implications, they also serve as evidence of gaining the SCSS performance – what the organisations have done to achieve sustainability. Therefore, the outcomes from Chapters 3 and 4 collectively inform organisations on how to achieve an improved ESG rating, as well as advise the rating agencies to check how the organisations achieve such ESG ratings.

From a general and macro perspective, this thesis contributes to the social aspect of the SDGs raised by the United Nations (UN, 2023). In this thesis, seven social sustainability aspects are analysed in the context of AV adoption in supply chains, namely, Health and Safety, Transparency, Customer Satisfaction, Employment, Diversity and Equality, Reputation, and Welfare. As listed in Chapter 1, SDG 3 (Good health and well-being); SDG 5 (Gender equality); SDG 10 (Reduced inequalities); SDG 8 (Decent work and economic growth), and potentially SDG 17 (Partnerships for the goals) are the development goals relevant to social sustainability (ElAlfy et al., 2020). Hence, this thesis on the one hand highlights the key impacts under the relevant social sustainability and SDGs to consider. On the other hand, the action plan proposed for SCSS improvement in the AV adoption context provides a reference for the organisations that adopt advanced technologies to improve SCSS performance. This effort facilitates the achievement of SDGs in the Industry 4.0 era.

This research also has implications for government officers and policy-makers. As one of the external stakeholder groups identified in Chapter 3, the legislative authorities are ranked as the third most affecting stakeholders, out of 17, in this context. As identified in Chapters 2 and 4, an improvement in regulations and guidance is necessary to allow AVs to be widely adopted in supply chains, with the incremental maturity of AV technologies. Chapter 3 highlights the key social sustainability aspects and impacts that are relevant to AV adoption in supply

chains. These impacts, therefore, serve as evidence of the key aspects for the policymakers to focus and regulate on. In the meantime, Chapter 4 suggests the actions and action categories that help the organisations achieve SCSS or improve SCSS performance. These results support the policymakers with the legal guidance drafting how to ensure social sustainability performance including safety, security, diversity, employment, etc. aspects when deploying AVs in various supply chain scenarios.

In summary, this thesis provides a strong foundation of knowledge for the socially sustainable and wider adoption of AVs in supply chains. It provides an overview of social impacts and key stakeholders for organisations adopting AVs to focus on, as well as an action plan to manage the social impacts to realise wider AV adoption in the supply chain. Organisations can tailor their actions to their current degree of AV adoption to mitigate the negative impacts and advance benefits. Therefore, this research provides organisations adopting AVs with a social sustainability management strategy that guides them to understand and improve social sustainability, so as to enhance AV adoption. For regulators and ESG rating agencies, this thesis facilitates the development of rating tools that assess organisations' social performance. These institutions prevent “greenwashing” in the industry by using the action plan as a “trail of evidence” to supervise the organisations to practice socially sustainably when adopting AVs. Relating to UN SDGs, this thesis facilitates the achievement of SDGs in the Industry 4.0 era by deriving social sustainability in the AV adoption context.

5.3 Limitations

There are a few limitations that exist in this research. This section discusses the limitations from the perspectives of the use of theory and research methodology.

5.3.1 The limitations in the use of theory

Explorations of SCSS in the AV adoption context are emerging. A lack of comprehensive focus on stakeholders in the existing literature prompts this study to attempt to understand stakeholder roles and attributes through the degrees of “affecting” and “being affected”. Although explains how important stakeholders

are in this context, this attempt does not measure the salience of stakeholders under the structured theoretical frameworks. In addition, the refined model presents a general view of stakeholder involvement in the actions at various AV adoption stages for SCSS improvement. There is a lack of discussions about the relations among diverse stakeholders for SCSS improvement when implementing the actions. The robustness of the discussions about stakeholders in this context is expected to improve through the lens of stakeholder theory.

Meanwhile, this study highlights the adaptation of DOI theory for the actions in improving SCSS performance within organisations. Currently, the view limits at the organisational level, instead of taking inter-organisational relationships into account. There exists a lack of focus on chain-wide dynamics among the multiple organisations which adopt AVs and the overall SCSS performance improvement.

5.3.2 The limitations of the research method of this thesis

Both of the empirical papers adopt the Delphi method for data collection, the limitations of this method therefore exist in both papers. First, although there are significant attempts to remind the participants of the subsequent rounds, this study still struggles with attrition effects – participants were no longer available for the next rounds (i.e., retiring, interest loss, affiliation changes, etc.). This potentially leads to inconsistency in answers from round to round. In addition, there is an imbalanced distribution of academics and practitioners, especially in the third round. This implies that the final Delphi results are more representative of opinions from academia, rather than those of the practitioners (Reefke and Sundaram, 2018). Similarly, the experts who accepted to be interviewed were mainly the academics from the Delphi participants. There were only three interviewees from the industry. This would therefore limit the generalisation of the results for practitioners.

The empirical papers cover the social implications and actions in both UGV and UAV adoption contexts. Some of the critical items in the UAV context may not apply to the AMR context, and vice versa. For instance, the regulations and traffic control roles for drones may not necessarily apply to the UGV scenarios. The frameworks presented in the empirical papers provide a holistic view of social

implications covering a general AV adoption context, which is not specific enough for a more particular scenario. There exists a lack of detailed explanations regarding which impacts relate to which stakeholders, as well as which actions can address which specific social impacts. All these elements would benefit from further studies through real-world cases for refinement and validation.

5.4 Future Research Suggestions

There are a variety of future research avenues generated from this thesis. These avenues are gathered from the distinct chapters and limitations of the thesis.

5.4.1 The identified 14 research directions from the literature and the Delphi study

After the three-round Delphi study, in addition to the existing 12 directions identified in the SLR (Chapter 2.5), another 2 distinct research directions were identified. These two directions suggest further research to focus more on 1) the economic profits of the AV adopters; and 2) the business environments for AV usage. The perceived importance of the 14 directions was evaluated by the Delphi participants and the rank is shown in Table 5-2. The items with “*” are additionally identified through the Delphi study. In the table, the first 5 directions are mentioned both in the existing literature and the Delphi study. Therefore, these directions suggest key avenues for future research regarding AV adoption in supply chains.

Table 5-2 Research directions identified from the studies

Rank	Research Directions
1	Develop new business models for adopting AVs in the operations
2	More AV types and functions are to be explored in detailed and specific scenarios and scales
3	Real-world field data to be collected - empirical data in various supply chain processes
4	Interoperability with other technologies
5	More focus on human-robot interactions
6	More social impacts and barriers that correlated with the stakeholders for AV adoption to be investigated
7	Wider supply chain processes to cover
8*	Focusing more on the economic profits to the AV adopters and supply chain organisations, rather than general social benefits. *
9	Focus on a specific group of stakeholders (SMEs, customers)
10	More variables/measurements for quantitative research are to be explored
11	More data in wider geographic contexts for generalisation
12	Alternative methods for data collection - surveys, multi-case studies, quantitative methods, etc.

13	Transferrable concepts and results in other smart scenarios
14*	Consider the various business environments for AV usage - the locations where difficult to employ drivers. *

In Chapter 2, the research directions were categorised into 4 main groups: 1) conducting longitudinal research with appropriate methods; 2) in-depth research with more stakeholders; 3) managing AV adoption in supply chains and in a wider variety of contexts; 4) interactions with humans and other technologies. Since the additional identified directions are about the management of AV adoption in supply chains that consider involving economic profits and the business environment of AV adoption in strategy making, these items are categorised under the third group of research direction. The 14 research directions provide potential avenues for future research that investigate AV adoption in supply chains and its sustainability-related outcomes

5.4.2 The research suggestions derived from the limitations

In addition to the identified 14 research directions, the research limitations also provide avenues for future research.

The analysis of stakeholders in this context is currently not positioned under the frame of stakeholder theory. It is necessary to validate and refine the analysis of stakeholders through the lens of stakeholder theory, to consolidate the SCSS analysis in the AV adoption context. In supply chain sustainability research (especially the social dimension), analysing stakeholders' roles and their relations with the organisation's activities through stakeholder theory has become increasingly important (Hohn and Durach, 2021). The stakeholder approach provides companies with a solid theoretical framework to manage the relationship with strategic partners and other stakeholders for long-term performance improvement and success (Freeman and Mcvea, 2001; Co and Barro, 2009). Therefore, future research is recommended to analyse the stakeholders, social impacts, actions, and SCSS implications through the lens of stakeholder theory. Future research can classify stakeholders through normative attributes such as power, legitimacy, urgency; or necessity and compatibility for enhanced robustness in analysing stakeholders' roles (Friedman and Miles, 2004; Mitchell et al., 1997). In terms of validation of the relations between stakeholders and

SCSS implications as well as the actions, future research is also suggested to apply stakeholder theory for strengthened arguments. Furthermore, applying stakeholder theory supports the analysis of stakeholder relationship management for the studies to further explore the actions implemented for SCSS improvement. Indeed, further research into stakeholder theory consolidates the development of SCSS concepts, both in specific and general contexts. The focus on stakeholders is in line with the research direction about “focusing on specific stakeholder groups”.

As mentioned in the limitations, this study currently highlights the use of DOI theory at the organisational level. Considering the discussion of SCSS should take a chain-wide view of the social sustainability performance, future research is suggested to highlight the supply chain level to discuss the relationship among organisations along supply chains. Attempts such as taking a step forward to extending the use of organisational IP to the supply chain level (Heaslip et al., 2018), in order to strengthen the argument of sustainability performance in organisations to the overall supply chain. The mentioned limitation can potentially be mitigated through the discussions using systems thinking or a network approach and discussing SCSS by taking inter-organisational relationships into account.

Regarding the general results achieved from the Delphi study and the interviews, it is suggested that future studies should separate research into the various AV types in supply chains. the social implications as well as the suggested actions in the drone context are not necessarily applicable to the UGV scenario. Future research is, therefore, recommended to refine the contexts and investigate detailed contextual elements with specific types of AV adoption. This would eliminate the confusion regarding the stakeholder roles and social impacts (as shown by the neutral choices). Furthermore, after the exploratory studies provided in this thesis, the deeper investigation of the explored elements and further construction of the concepts require a case study methodology (Yin, 2018). Based on the existing results, the development of more detailed contextual elements requires in-depth research into specific cases. Longitudinal research

throughout the whole diffusion process of AVs is suggested for case studies to examine and refine the proposed action plan. Through long-term in-depth case studies, the action plan can be tailored to the focused scenarios for further development – detailed actions are aggregated to address the contextual social sustainability implications. Future research can even compare the similarities and differences of actions and SCSS in the contexts of UAV and UGV adoption to enrich the models proposed in this study.

In addition, the qualitative SCSS indicators and the detailed impacts construct the quantitative indices for measuring the detailed social sustainability performance of AV adoption, e.g., the reduction rate of incidents in workplaces, the employee turnover rate after deploying AVs, etc. This helps clarify how much better off is created by AV adoption in supply chains. As recommended by Edmondson and McManus (2007), the methods applied for the development of managerial theories and concepts from nascent to mature state transform from qualitative to quantitative. Hence, quantifying the identified SCSS indicators facilitates the development of SCSS concepts in academia and benefits the implementation of social sustainability performance indices in practice. The suggestions covered in this section are in line with the research directions about “alternative methods for data collection” and “more AV types and functions in detailed and specific scenarios and scales”.

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Appendices

The appendices supplement and support the contents in the main texts.

Appendix A Systematic Literature Review Appendices

Table A-1 Quality Assessment Criteria

Element	Level				
	0 Absence	1 Low	2 Medium	3 High	Not Applicable
Theory robustness	The article does not provide enough information to assess this criterion.	Poor awareness of existing literature and debates. Under- or over-referenced. Low validity or theory.	Basic understanding of the issues around the topic being discussed. The theory is weakly related to data.	Deep and broad knowledge of relevant literature and theory relevant for addressing the research. Good relation theory-data.	This element is not applicable to the document or study.
Methodology	The article does not provide enough information to assess this criterion.	Flawed research design.	Research design may be improved	Research design is robust: sampling, data gathering, data analysis is rigorous	This element is not applicable to the document or study.
Finding	The article does not provide enough information to assess this criterion.	Finding is related poorly to the research aim or question.	Finding is related to the arguments, though there are some gaps.	Finding tightly answer the research question.	This element is not applicable to the document or study.
Contribution	The article does not provide enough information to assess this criterion.	Does not make an important contribution. It is not clear the advances it makes.	Although using others' ideas, builds upon the existing theory	Further develops existing knowledge, expanding the way the issue was explained so far.	This element is not applicable to the document or study.

Source: Adapted from Pittaway et al. (2004)



SAE J3016™ LEVELS OF DRIVING AUTOMATION

		SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?		You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			You are not driving when these automated driving features are engaged – even if you are seated in “the driver's seat”		
		You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
What do these features do?	These are driver support features				These are automated driving features		
	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/acceleration support to the driver	These features provide steering AND brake/acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions	
	Example Features	<ul style="list-style-type: none">• automatic emergency braking• blind spot warning• lane departure warning	<ul style="list-style-type: none">• lane centering OR adaptive cruise control	<ul style="list-style-type: none">• lane centering AND adaptive cruise control at the same time	<ul style="list-style-type: none">• traffic jam chauffeur	<ul style="list-style-type: none">• local driverless taxi• pedals/steering wheel may or may not be installed	<ul style="list-style-type: none">• same as level 4, but feature can drive everywhere in all conditions

For a more complete description, please download a free copy of SAE J3016: https://www.sae.org/standards/content/J3016_201806/

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Figure A-1 SAE Levels of Driving Automation

Source: SAE (2021).

Appendix B Delphi pilot study

The purpose of the pilot studies was to provide feedback on the overall design, content, logic flow, and expression of the questionnaire. The feedback from the pilot testers provided essential evidence in refining the holistic view, as well as the individual questions. All the three rounds of the Delphi study experienced a series of pilot tests among the personnels expertise in the relevant domains.

B.1 Approaching emails

All of the three rounds of the pilot studies adopted the same format of approaching email for the consistency.

Dear XXX (Pilot tester),

We have been working on the first/second/third-round survey for our Delphi study on the social impacts and social sustainability of autonomous vehicle (AV) adoption in the supply chain. This study is primarily exploratory in nature and will be the foundation for investigating the improvement of AV adoption in the supply chain.

Some background information on the Delphi process:

The Delphi Study is an iterative process that involves sending 3 rounds of questionnaires to the selected group of experts, seeking their insights into the social impacts and social sustainability performance of AV adoption in the supply chain. The participants of this Delphi Study are all experts in the field and they will be grouped into panels representing their main background. Round 1 is based on an initial questionnaire and is used to elicit initial answers to social impacts, stakeholder groups, and feedback actions. These findings will be categorised and become the input to the second round which involves ranking and comparison by the participants. The purpose of round 3 is to re-evaluate the rankings and possibly refine the results. Round 3 may then conclude with interviews with representative participants in order to provide additional explanations to the study results. The following overview illustrates this process:

Your Feedback:

We would greatly appreciate it if you could try the survey and provide us with some feedback on the following aspects:

- **Purpose:** Do you think the survey will elicit what we hope it will? Are the questions framed/phrased in an appropriate fashion?
- **Understanding:** Do you see any issues with the way it is designed or the explanations?
- **Ease of use:** Any problems in using the website or the questionnaire?
- **Time:** How long did it take you?
- Any important details that you think are **missing** and should be included
- Any **additional** comments

Keep in mind that participants will be provided with additional information (Participant Information sheet) and are also 'experts' in the area.

Here is the link to the survey:

As you might have guessed we would like your comments as soon as possible!

Thanks for your help,

Kind Regards,

Chengzhen GU

B.2 Round 1

The first round aims to identify the key elements involved in this study. It is the foundation for the following studies as well. Therefore, it is crucial to ensure the applicability of the questions and the logic in the questionnaire. In the first round, participants were invited to openly express opinions. The researchers used the feedback to check whether the pilot testers understand the research, and to evaluate whether the answers fit the design of the questionnaire.

B.2.1 Participants

The selection of these panellists followed the expert selection criteria of the Delphi study (Reefke and Sundaram, 2017; 2018). All the expertise had strong knowledge background in at least two of the three areas (sustainability, supply chain management, autonomous vehicle adoption). The experts were instructed

on the purpose of the study, along with the detailed aspects being asked to provide feedback. Table B-1 presents the profiles for the participants

Table B-1 Pilot testers Round 1

Expert	Role	Expertise
Expert 1	Professor Cranfield School of Management	SCM, Sustainability
Expert 2	Senior Associate SYSTEMIQ GmbH.	SCM, Sustainability.
Expert 3	Reader Cranfield School of Management	Social sustainability, Digital disruption.
Expert 4	Reader Cranfield School of Management	SCM, Sustainability, Delphi method.
Expert 5	Professor Cranfield School of Management	SCM, Sustainability, Delphi method.

B.2.2 Feedback

According to the pilot study protocol, the experts present feedback outlined in Table B-2.

Table B-2 Pilot test feedback Round 1

	Feedback
Expert 1	<ul style="list-style-type: none"> ● Understanding: Do you see any issues with the way it is designed or the explanations? <ul style="list-style-type: none"> 1 - Nothing major. 2 - You may ask Q3 in two steps: internal and external separately. ● Ease of use: Any problems in using the website or the questionnaire? <ul style="list-style-type: none"> 1 - The font size in the "Terminologies" page was too small for me. ● Time: How long did it take you? <ul style="list-style-type: none"> 1 - 15 minutes but I was also responding to your questions here; so, it may be shorter. ● Any important details that you think are missing and should be included <ul style="list-style-type: none"> 1 - Do you need the participants to return the consent form to you? The survey start page does not say anything about it. 2 - It may be preferable to explicitly include "Mental Health" under your social sustainability indicators owing to the government's increased attention on mental health amid the pandemic. ● Any additional comments <ul style="list-style-type: none"> 1 - "every reasonable step will be taken to anonymise the data." is vague and not reassuring. I recommend you be specific and not leave it open that you may fail to anonymise. 2 - Thinking about all three types of AVs was difficult for me. If you asked to focus on AVs for the last mile or AVs for the warehouse or AVs for the production, it would have been easier for me to answer your questions. 3 - You may provide the terminologies as a separate link because a participant may wish to return to the definitions as they progress in the survey.

	4 - "Higher than level 3 automation" is not informative without other levels of automation. I do not know what I should understand from "conditional automation".
Expert 2	<ul style="list-style-type: none"> ● I would write out "AV" into autonomous vehicle, people might forget what it stands for. ● I think your Delphi is fine. I would also talk to your supervisor and see if you also try to do some interviews in parallel. My worry about the Delphi is that it is very open – you give the participants a lot of freedom to come up with answers. I just don't know how they will write in the Delphi. ● Overall, I think the questions are straightforward and clear. Maybe it could help if you would add three pictures of AVs in the supply chain to help prompt respondents to what is meant. That could be a bit easier to grasp than the definitions in the beginning. Also, I would reduce the text for the definitions.
Expert 3	<ul style="list-style-type: none"> ● I have had a go at the pilot survey. It was quite difficult to respond meaningfully because it all seemed very broad with lots of opportunity to comment. The trouble is, if you are given too much scope for comment then the inclination might be just to comment minimally. That is, the response is either a long essay (which most respondents will not do) or something that 'feels like enough'. As a result, I think my responses were 1) not as fulsome as they might be and 2) not as useful to you as they might be...? ● I did not find the definitions very helpful in framing my responses. I would like to see some context – what does AV in the supply chain look like? ● I was a little troubled by your levels and units of analysis. They were not very clear to me. See, for example, my comment about ownership of and influence of actors in the supply chain. ● I guess it took about 20 minutes, which is fine. I would have liked to see a progress bar so I know how much I have left to do.
Expert 4	<ul style="list-style-type: none"> ● Purpose: Do you think the survey will elicit what we hope it will? Are the questions framed/phrased in an appropriate fashion? The questions are clear, but I am not sure if you will be able to collect rich data through this way... Learnt from my previous experience, Delphi is most effective when you already have a list of indicators/criteria from literature or case studies. You can then use Delphi to collect whether or not the experts agree or disagree with identified indicators to certain extent. ● Understanding: Do you see any issues with the way it is designed or the explanations? I suggest that you should explain briefly the applications of AV in supply chain. The first page explained the terminology of AV, SC social sustainability and indicators, but I still don't quite understand for what companies would adopt AV in supply chains. I assume that logistic companies might use AV to transport goods, or use it to replace work which causes health and safety issue for human. However, I might have missed some important applications of AV in supply chain. It would be helpful if you could explain the application at the beginning. ● Ease of use: Any problems in using the website or the questionnaire? No ● Time: How long did it take you? About 25mins ● Any important details that you think are missing and should be included Explain the context more. ● Any additional comments

You might want to do case study before Delphi.

- Expert 5**
- Terminology section: it is necessary to explain terminology and the content is good (except there is a heading “Autonomous Vehicle applications in the supply chain” which is not completed and maybe not required). However, thinking of the ease of response, it would be better if any definitions could be accessed by the respondent by hovering over the highlighted key word in the questions, so they don’t have to read through all the definitions before they start their response. Further, the definitions should be brief and concise, e.g., for AV’s you don’t need to say that they emerged from the Fourth Industrial Revolution.
 - Part 1: for Q3 and Q4 you should be clear about what you mean by internal and external. Internal/external to the company or supply chain?

B.2.3 Synthesis of feedback

The feedback from the experts provided numerous important directions to improve the Delphi questionnaire. A number of changes are implemented to reflect the suggestions described in Table B-3.

Table B-3 Synthesised feedback

Synthesised Feedback	Items	Change implemented
Definition of the terms	Not clear definitions of the terminologies	<ul style="list-style-type: none"> ● Refined the definitions of the terms at the first page; ● Shorten the definitions of SCSS and SCSS indicators with refined expressions; ● Presented the SCSS indicators as a list to clearly show the key SCSS aspects in this context; ● List the potential stakeholders (identified in the literature) as examples.
Consent Page	Illustrates how to anonymise the data	<ul style="list-style-type: none"> ● Changed “every step will be taken to anonymise data” into “All responses are completely confidential”.
Delphi Method clarification	The use of Delphi method might lead to uncontrollable results from the participants.	<ul style="list-style-type: none"> ● Explained the Delphi method in the first page and the approaching emails – the aim of using the Delphi method is to reach a group consensus. This round encourages experts to openly express their opinions.
Clarity of Context	Not clear about the AVs in the supply chain – what do they look like?	<ul style="list-style-type: none"> ● Gave clear illustrations and examples of the AVs in this context; ● Attached a table of automation levels from peer-reviewed papers for clarification; ● Added three pictures for illustrating the context – UAVs for parcel delivery, AMRs for ground product delivery, driverless trucks for long-haul freight transport; ● Added a figure showing the relationship among the terms to visualise the intended logic of the study.

Time to finish	15-20minutes	●	20 minutes as time to finish presented;
Presenting	Progress bar to be added	●	Add a progress bar for the questionnaire, for multiple sections included.
		●	Place the demographic part in front of the terminology section.
	Font size too small in terms	●	Larger font size for the terminologies.
	Separating the internal and external stakeholders	●	Set the internal and external stakeholders as two distinct questions.

The pilot testers extensively mentioned the needs in improving the clarity of terminologies and the context. The first round of the Delphi study mainly aimed to cover social impacts, social sustainability, stakeholders, and autonomous vehicles adoption in supply chains. It is crucial to provide clear instructions and definitions of the key terms involved in the study to ensure the preciseness of the answers the participants provide. Therefore, the definitions of SCSS and SCSS indicators were gathered and refined from existing seminal studies in SCSS studies (Ahi and Searcy, 2015; 2013; Carter and Rogers, 2008). The definitions for stakeholders and social impacts followed the logic and were presented with refined expressions (Freeman, 1984; Becker et al., 2001). A series of examples were presented to embody the key concepts involved in this study.

Similar clarifications were realised for the context section as well. For this study emphasises on AVs inclusively, Rai et al (2022) defines the AVs deployed in supply chains include drones, AMRs, and self-driving trucks. For the ground vehicles with at least Level 3 of automation are regarded as autonomous ground vehicles, following the SAE standards. Therefore, three representative figures were selected as examples in this study context. The detailed SAE standards were also attached in this page. At the end of the page, an illustrative figure mapped the basic logic to the participants that links the key elements covered in this study. All these efforts significantly improve the clarity of the terms on this page that they were not challenged by the participants in the actual studies of this round and the following rounds.

As multiple pilot testers recommended to add the definitions at each question bar, this suggestion was not adopted after careful consideration – it made the question

pages over-clumsy. Hence, the definition page was moved after the demographic question pages. This benefited the participants with fresher impression of the meanings of the terms.

Finally, the presenting style of the questionnaire was refined, on the basis of the recommendations regarding progress bar, font size, and logic flows. Some of the wordings were also changed to improve clarity.

B.3 Round 2

The second round aims to evaluate the results from the previous round. Therefore, the style of the questionnaire altered significantly, which means that it requires careful design and pilot tests to ensure the participants in the actual study to understand the aim and objectives of the study. This round of pilot study follows the format that was used in the previous round.

B.3.1 Participants

Half of the pilot testers (the two Cranfield University professors) in this round contributed to the first round of the pilot test. Similar to the first round, the pilot tests for this round also invited the experts to comment the overall questionnaire design, flow, and clarity. Table B-4 presents the pilot testers for this round.

Table B-4 Pilot testers Round 2

Expert	Role	Expertise
Expert 1	Lecturer Cranfield School of Management	SCM, Sustainability
Expert 2	Professor Cranfield School of Management	SCM, Sustainability
Expert 3	Professor Cranfield School of Management	SCM, Sustainability, Delphi method.
Expert 4	Research Fellow Cranfield School of Management	SCM, Sustainability, Humanitarian logistics.

B.3.2 Feedback

Table B-5 summarises the feedback from the pilot testers. Three pilot testers provided detailed verbal feedback, while expert 4 did not comment the questionnaire.

Table B-5 Pilot test feedback Round 2

	Feedback
Expert 1	<ul style="list-style-type: none"> ● Title: it is not very informative – what is the “social sustainability of autonomous vehicle adoption in the supply chain”? <ul style="list-style-type: none"> ○ You could rephrase it to be more direct and related to the point ○ You could also add a short explanation of what do you mean by “social impacts” and “social sustainability” in this survey <ul style="list-style-type: none"> ▪ If this is what you want to explore (and thus you don’t have a definition/explanation, rephrase the title accordingly) ● Aim: again, it is not very clear <ul style="list-style-type: none"> ○ You could write something like “This study is based on a Delphi approach. This 2nd round aims to elaborate the responses and feedback collected during the 1st round, to achieve a consensus about the key stakeholders (involved? To be considered?), the social impacts (what do you mean here?), and a set of suggested action categories”. ○ If you investigate autonomous vehicles adoption, this must be reflected in the aim as well... ● Initial model: I understand they already participated to the first round, but you use many acronyms and terms which are coming out of the blue <ul style="list-style-type: none"> ○ “AV adoption” is not defined, if it’s about autonomous vehicles you can use the full name or introduce/repeat the acronym ○ What are SCSS indicators? ○ Again, how do you define a positive or negative impact? ○ You know in advance who are the stakeholders, or is it an outcome of the process? ● Stakeholders: what you mention in the page “Stakeholders group” could actually be anticipated, highlighting what is the difference between AFFECTING and AFFECTED (in this survey, as this might be subjective) ● The introduction of IDT after the stakeholder groups is fine ● SCSS and SCSS indicators: you explain them later. I believe it could be helpful if you define all the terms of the initial model earlier, because otherwise it is difficult to interpret the chart (which indeed can be very helpful to visually explain what you are going to do). ● Motivators and barriers could come first (as in the model they are the first element) <p>Overall, you could anticipate the definition of the terms in the model and also anticipate that the different sections of the study will concern each part of the model separately – you pre-create the structure of the investigation and support understanding.</p>
Expert 2	<ul style="list-style-type: none"> ● I can understand the abbreviations in the model may not be immediately clear to any participant who did not participate in the first round. ● You are saying that stakeholders are affecting AV adoption, but your figure does not show an arrow from stakeholders to AV adoption. ● What is missing for me in the below question is who makes the decision to adopt AV and whether impact is on the stakeholders’ day-to-day operations (this is my assumption) or something else? It would be helpful if you gave an indication of what we should understand from your levels (slight impact, moderate impact, considerable impact, strong impact). My responses are mere guesses. ● In the below question, not sure whether you can have the same level of affected and affecting, but I do not have anything else to make a distinction.

	<ul style="list-style-type: none"> ● I was not able to recall what “GRC measures” meant. Try not to have abbreviations in your questions. ● This question was too long and the questions are not competing. I fear all of them may be somewhere between agree to strongly agree. ● For the research direction suggestions, I could not differentiate the importance of concepts in many instances. Maybe you ask the participants to rank them which will lead to a degree of importance.
Expert 3	<ul style="list-style-type: none"> ● Introduction to the model. You say the following, please see my comments in red: “A series of social motivators and barriers are motivating/preventing AV adoption [on the model there is no connecting arrow between barriers and AV adoption yet you’re saying the barriers may prevent adoption and so have a negative effect], followed by social positive and negative impacts that affect the related stakeholders. These impacts have relations with supply chain social sustainability (SCSS) via the SCSS indicators. In order to ensure social sustainability performance, a series of feedback actions are enacted in addressing the impacts. This questionnaire seeks to assess this initial model rather than these blocks and their potential connections. ● In quite a few of the questions you say: “... the adoption of AVs and the actions in the supply chain?” What do you mean by “actions in the supply chain”? This should be made clearer.

B.3.3 Synthesis of feedback

On the basis of the existing feedback, Table B-6 explains the feedback as well as the changes to address the feedback.

Table B-6 Synthesised pilot test feedback Round 2

Synthesised Feedback	Description	Change implemented
Clarity of “affecting” and “being affected”	The targets of “affecting” stakeholders are confusing	<ul style="list-style-type: none"> ● The targets of “affecting” stakeholders are intended to be the suggested actions that address the SCSS implications. ● The intended elements that impact the stakeholders are also the “adoption of AVs in supply chains” and the suggested actions. ● Kept the “affecting stakeholders” from the AV adoption block for holding the scope of the research not to focus on the “factors influencing AV adoption”, but to emphasise on the outcomes of AV adoption.
Clarity of the suggested actions for SCSS	Actions in the supply chain is confusing.	<ul style="list-style-type: none"> ● Added clarification of “actions” to clarify that they are to address the social impacts and improve SCSS performance.
Future Research direction	The importance of future research directions cannot be differentiated.	<ul style="list-style-type: none"> ● Changed the importance rating into multiple choices to ask the participants to choose the most important research directions, rather than rating the importance.
Presenting	Use of Abbreviation	<ul style="list-style-type: none"> ● Introduced the full name of the terms at the first time of their appearance with the abbreviation.

The model at each part	<ul style="list-style-type: none"> ● Added an arrow that lined the barriers to the AV adoption block; ● Provided a brief introduction of the overall model at the introduction page; ● Highlighted the part of the model to be evaluated at each round, leaving other parts in a grey colour.
Expression clarity	<ul style="list-style-type: none"> ● Moved the definitions of the terms and gathered them together after the demographic page (the same format as the previous round); ● Reworded the title and aim – emphasised the social impacts, stakeholders, suggested actions in the AV adoption context; ● Reworded the questions and shortened the length of each question.

Clarity of the questions is still a major issue raised by the pilot testers. Essentially, the clarity concerns fell into the two influential dimensions of the stakeholders. The first round only identified the key stakeholder groups, this round aimed to evaluate the degrees of the identified stakeholders' influences in this context. The extents of two dimensions – “being affected” and “affecting” were to be assessed. In order to clarify the dimensions, the questionnaire reworded the instructions at the “stakeholder” block to explain that stakeholders are affected by the AV adoption, as well as affecting the AV adoption. The affected stakeholders were linked with social impacts in the model, for the AV adoption in supply chains brings social impacts on the corresponding stakeholders. On the other hand, the affecting stakeholders were linked with suggested actions, for they were designed as the groups to enact actions to improve SCSS performance. The stakeholders potentially impact the AV adoption in supply chains, while in this study, this direction was not emphasised, for preventing confusions of participants about the scope of this study.

The suggested actions also received considerable comments. Since this study includes two streams: social impacts and social sustainability; and the suggested actions that address the social impacts, the instructions for the actions were refined as: the actions to improve the positive impacts, and to mitigate or prevent the negative impacts.

Regarding the future research directions, pilot testers concerned that following the same style of importance rating as the social impacts and actions would lower

the applicability of the answers – participants potentially select “extremely important” for all of the items. While this study does not seek to present the importance rank of the research directions, this study attempts to recognise the directions that the participants suggest to focus on for the future research. Therefore, the future research directions would be evaluated through multiple choices to fulfil this requirement.

B.4 Round 3

The third round is a re-evaluation process of the items that have not yet reached a consensus in the second round. Hence, the overall flow and design was similar to the second round.

B.4.1 Participants

All of the pilot testers in this round contributed to the previous round’s pilot test. This follows the participant selection criteria in the actual study that, only those who participated in the second round Delphi study were invited to participate in the third round. Due to the similar content and design as well as the limited availability of the experts, only two testers provided feedback on the pilot test. Table B-7 presents the pilot testers in Round 3.

Table B-7 Pilot testers Round 3

Expert	Role	Expertise
Expert 1	Lecturer Cranfield School of Management	SCM, Sustainability
Expert 2	Professor Cranfield School of Management	SCM, Sustainability, Delphi method.

B.4.2 Feedback

Table B-8 Pilot test feedback Round 3

	Feedback
Expert 1	<p>Purpose: Do you think the survey will elicit what we hope it will? Are the questions framed/phrased in an appropriate fashion? <i>You can improve the wording and the presentation – currently it is a bit hidden</i></p> <p>Understanding: Do you see any issues with the way it is designed or the explanations? <i>No issues with design, explanations are fine but, in some parts, could be improved (see later)</i></p> <p>Ease of use: Any problems in using the website or the questionnaire? <i>A bit, reading is difficult and there is a lot of condensed text</i></p>

Time: How long did it take you?

Not 25 minutes! I think it requires between 40 and 60 minutes

Any important details that you think are **missing** and should be included

Any **additional** comments

Some suggestions for specific areas

Stakeholder group

- To what extent are these MANAGERIAL level groups AFFECTING the suggested actions? Clarify WHAT ACTIONS?
- To what extent are these OPERATIONAL level groups AFFECTING? Reformulate this question – affecting on what?
- To what extent are these SUPPORT FUNCTIONS groups AFFECTED? Clarify “affected by what”
- Only 1 question about OPERATIONAL?

Overall, you need to explain better the “impact on” and the “affected by what”

Also, the text is pretty dense, making the reading hard and not supporting reflection – alternatives to present the questions and the alternatives?

Positive Impacts and SCSS indicators

This section is clearer and more understandable, although you should separate the sub-sections (e.g., health and safety, stakeholder satisfaction, diversity and equality). If there is no alternative, maybe create separate questions...

The model is great, but text is small and reading + understanding takes some time!

Expert 2

- Purpose: Do you think the survey will elicit what we hope it will? Are the questions framed/phrased in an appropriate fashion? Yes, but be aware of my comments below
 - Understanding: Do you see any issues with the way it is designed or the explanations?
 - The display of the Mean and Standard Deviation results from the last round should be more prominent (e.g., in bold) to be sure they are not ignored. Plus, might be good to put M and SD in full perhaps in smaller font
 - Ensure numbers (1, 2, 3, 4, 5) are showing on the Likert on every question because this relates to the M and SD feedback
 - At the top of each page provide the full description of AFFECTED and AFFECTING to remind the respondent
 - It would probably also be better if all the AFFECTED questions are grouped together (and likewise the AFFECTING questions) because these are essentially the same question and its easier for the respondents.
 - In some lists (e.g., Positive Impacts and SCSS indicators) you have headers like Health and Safety. These should be highlighted (e.g., bold)
 - Plus, sometimes the lists are so long that the Likert Scale disappears off the top of the page. Maybe put the Likert scale in more often
 - For the Research Directions, the ranking from the previous round should be highlighted (e.g., in bold).
 - Ease of use: Any problems in using the website or the questionnaire? It was easy to use. It does depend on a good Internet connection but there's nothing you can do about that
 - Time: How long did it take you? It took me about 40 minutes but I was considering improvements. Still think 30 minutes is a tight timeframe given the number of questions, if someone is really thinking about their responses
 - Any important details that you think are missing and should be included. No
 - Any additional comments None
-

B.4.3 Synthesis of feedback

Table B-9 Synthesised pilot feedback Round 3

Synthesised feedback	Description	Changes implemented
Clarity of the questions	Some questions in the instructions are confusing.	Clarified the suggested actions into to groups in the model; Further clarified the “affecting” and “being affected” stakeholders in the context; Added an illustration of the model shown in each of the section. Highlighted the aim of this round. Added the instructions of this round: only be presented with the questions that have not reached a consensus.
Presentation	Highlighting the key information.	Presented the numbers and the rating categories for all of the questions; Highlighted the mean and standard deviation values from the previous round; Adjusted the page width to fit all the selecting categories in; Highlighted the category titles in bold.

Table B-9 presents the refinement of the third round Delphi study on the basis of the feedback presented in Table B-8. Although the questions listed the targets of the affecting stakeholders in the questions, the illustration of the blocks in the model was still not clear to the participants. Hence, a paragraph of the overall illustrations regarding the social impacts, stakeholders, and actions were presented under the model, together with the definition of the terminologies.

Regarding the presentation of the overall questionnaire, all the key information were highlighted – mean and SD values were presented in red colour, titles for each category were bold, and numbers of each category were presented for each question.

The time to complete was set as 30 minutes. Although setting it at more than 40 minutes seems more realistic, I believed that 30-minute-time encourages participants to be more willing to complete the study. In addition, the expected time to finish was 35 minutes for round 2. Due to a reduced number of questions, 30-minute is a reasonable time.

B.5 Reference to Appendix B

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Appendix C Delphi questionnaires and invitations

This appendix provides the detailed questionnaires and invitations for the three rounds that serve Chapters 3 and 4. These questionnaires are attached to this document. Double click the documents to access them. In case they cannot be opened through the links, spare copies of these questionnaires are attached independently.

C.1 Delphi Round 1

2023/8/25 16:42

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Start page

Start Page.

Research Topic:

Social impacts and social sustainability of autonomous vehicle adoption in the supply chain.

Research Aim:

This Delphi study aims to explore the social impacts and social sustainability of autonomous vehicle adoption in the supply chain. This research has two objectives:

1. Development of a conceptual framework which connects supply chain social sustainability, social impacts and stakeholders;
2. Establishing a roadmap for supply chain organisations to improve social sustainability performance when adopting autonomous vehicles.

Instructions of this study:

Delphi method aims to solve a complex problem by gathering insights from a group of experts with diverse

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C.2 Creating captions in appendices

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Start page

Survey Topic:

Social impacts and social sustainability of Autonomous Vehicle (AV) adoption in the supply chain - Round 2

Survey Aim:

This round aims to assess the responses and feedback from the 1st round and to achieve a consensus on the detailed items involved in the following main themes of AV adoption in the supply chain: the key stakeholders, social impacts, and the suggested feedback action categories. The potential relations between these themes with supply chain social sustainability are also to be evaluated in this round.

We much appreciate all the initial responses and your contributions from the previous round.

Expected Time to Finish:

35 minutes

Chengzhen GU

Ph.D. Researcher Cranfield University

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C.3 Delphi Round 3

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Start page

Survey Topic:

Social impacts and social sustainability of Autonomous Vehicle (AV) adoption in the supply chain - Round 3

Survey Aim:

This Delphi study aims to explore the SOCIAL impacts and SOCIAL sustainability of AV adoption in the supply chain. This round aims to re-evaluate the responses and feedback from the 2nd round and to achieve a CONSENSUS across the study.

Instructions for the rating processes:

Re-rating of items in the third round of this Delphi study.

This round is shorter than the previous round since several questions achieved consensus across respondents.

You will only be presented with questions that have not reached a consensus yet and a few additional questions in this round, based on respondents' comments.

Answering this questionnaire

In order to make an informed decision you will also be presented with the second round results. i.e. the Mean Rating and the Standard Deviation of each evaluated item.
Please take these values into consideration when answering.

Mean Rating (M): This value indicates how the respondents rated the item on average on the given scale.

Standard Deviation (SD): This value indicates how much the responses fluctuated around the mean.

We much appreciate all the responses and your contributions from the previous rounds.

Expected Time to Finish:

30 minutes

Chengzhen GU

Ph.D. Researcher

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C.4 Delphi invitation emails/LinkedIn messages

C.4.1 Delphi invitation emails/messages for Round 1

Dear XXX (Participant),

Hope you are doing alright and this email finds you well.

I am Chengzhen GU, a doctoral student at Cranfield School of management supervised by Dr. Hendrik Reefke and Dr. Nicky Yates (cc'd). My panel chair Heather and I are approaching you to invite you, or suitable colleagues, to participate in my research which is about the **social impacts and social sustainability of autonomous vehicle adoption in the supply chain**. This research uses the Delphi method, which involves responding to a short questionnaire over a couple of rounds. We would greatly appreciate it if you both could participate in this research. The 1st round questionnaire will take you around 20 minutes at this link:

If you know any other experts who might be interested, please feel free to let me know and forward this questionnaire to them. Thank you so much!

If you have any questions, please do not hesitate to contact me. Your support means a lot and I appreciate it very much!

Kind Regards,

Chengzhen

C.4.2 Delphi invitation emails/messages for Round 2

Dear XXX (Participant),

Hope you are doing all right and this email finds you well.

Followed with the previous round, I am currently carrying out the second round of the Delphi research (My apologies that it took quite a while to get to this stage from the previous round). We much appreciate your insights for the previous round and we would love to involve you in the second round of this research as well. The questionnaire will take you around 35 minutes and the link has been attached below: Please check, thank you!

If you know any other experts who might be interested, please feel free to let me know and forward this questionnaire to them. Thank you so much!

If you have any questions, please do not hesitate to contact me. Your support means a lot and I appreciate it very much!

Kind Regards,

Chengzhen

C.4.3 Delphi invitation emails for Round 3

Dear XXX (Participant),

Thanks again for your valuable input to the second round of my Delphi study.

I am now carrying out the third round of this Delphi and would highly appreciate your involvement. The success of this study depends on your expert input and continued support.

Please read the following instructions before completing this third-round questionnaire:

Re-rating of items in the third round of the Delphi study

This round is shorter than the previous round since several questions achieved a sufficient consensus across respondents. You will only be presented with questions that have not reached a consensus yet and a few additional items based on respondents' comments.

Answering this questionnaire

In order to make an informed decision, you will be presented with the second-round results, i.e., the *Mean Rating* and the *Standard Deviation*. Please take these values into consideration when answering.

Mean Rating (M): This value indicates how the respondents rated items on average on the given scale;

Standard Deviation (SD): This value indicates how much the responses fluctuated around the mean value.

Please check the attached questionnaire:

I would much appreciate it if you could complete the questionnaire by 28th February. Your support means a lot!

If you have any questions, please do not hesitate to contact me. Thank you so much!

Kind Regards,
Chengzhen

Appendix D Round 1 Delphi data analysis description

This appendix section provides detailed descriptions of Delphi Round 1 analysis for Chapters 3 and 4 respectively.

D.1 Delphi Round 1 finding for Chapter 3

D.1.1 Stakeholders

Compared to social impacts that the literature has provided considerable evidence, the specific stakeholder groups received much less attention. Although the literature implicitly mentioned such stakeholder groups as “customers/recipients, traffic users, government, local communities” as external groups; “truck drivers, logistics managers” as internal groups, the question “who really matters” was still untouched. Therefore, the open-questions for stakeholders attempted to collect as detailed groups as possible (i.e., the specific levels in the organisations, and the specific supplier types). Hence, the “employees” in the answers were grouped into “operational level employees”. Likewise, the “suppliers” were further refined into “logistics service providers”, “technology suppliers”, and “maintenance service suppliers” which are the key supplier types in this context. This research expects additional stakeholders to be advised at the end of the second round in order to enrich the content. The internal and external stakeholder groups after noise reduction are presented in Tables D-1 and D-2. These items are later synthesised to be presented in the following rounds.

The last group “external research centres” was not directly mentioned by the participants. However, according to one expert’s comment, this is added as one external entity that includes research centres and institutions, and universities.

“Supply chain academics would do well to partner with behavioural economists to understand the consequences of fundamentally transforming how we move products across the supply chain. (DR1-25-P)

Although not explicitly mentioned the research entity, this comment implied the important roles of academics and researchers in this area.

Table D-1 Internal stakeholders extracted from Round 1

Category	Group	Detail
Mid-level managers	Logistics and supply chain managers (10)	Floor managers (1)
		Warehouse manager (1)
		Operational manager (2)
		Supervisory (1)
		Logistics planning manager (3)
		Supply chain manager (2)
Operational and shop-floor employees	Operational employees (33)	Staff/workers/operational level employees (18)
		Fulfilment colleagues/material handling personnel (2)
		Warehouse worker/forklift driver (5)
		Logistics/Transportation personnel (4)
		Employees undertaking manual driving tasks (2)
	Those who work with AVs (3)	Colleagues of AVs (1)
		AV operators (1)
		The employees on the floor who interact with the systems (1)
	Technology maintenance (11)	IT/Engineering (5)
		Technical support individuals (1)
		Continuous improvement and technology teams (2)
		Maintenance crews (4)
Senior managers	Senior decision makers (8)	Corporate governance & management, C-level executives (2)
		Senior logistics managers (1)
		Decision makers (2)
		Senior directors (1)
		COO (1)
		CFO (1)
Board	Employers (2)	Employers (1)
		Shareholders (1)
Support functions and administration	Sustainability department (1)	Health, safety and environment colleagues (1)
	Human resource (HR) and Change management (3)	Teams who directly deal with employee complaints or concerns (1)
		Risk management - risk profile will change as a result of changing labour for robots (1)
		Everybody affected by change processes (HR, Project management) (1)
	Finance & Accounting (3)	Finance & Accounting (3)
	Procurement (1)	Procurement (1)

Table D-2 External stakeholders extracted from Round 1

Group	Detail
Competitors (3)	Competitors (3)
Customers (25)	Customers and consignees (26)
Government and legal experts (12)	Local/national authorities/governments (5)
	Air traffic control professionals (2)
	Legal experts/Regulators (5)
	Administration, public entities (1)
Logistics service providers (10)	3PL, 4PL, consignors (6)
	Local services retail, transport provision (1)
	Delivery truck drivers (2)
	Vendor-Managed Inventory (VMI) suppliers (1)
Other traffic users (4)	The road users (1)
	Users of shared infrastructure (3)
Technology providers (9)	Software and IT suppliers (2)
	Maintenance service providers (1)
	AV manufacturers and suppliers (7)
Other entities (10)	Insurance service providers (2)
	Local communities who exposed to AVs (7)
	Health and safety experts (1)
	External Research centres (1)

D.1.2 Social impacts

After noise reduction (e.g., economic perspectives: cost reduction, efficiency, productivity; environmental aspects: fewer emissions, land and resource usage); the positive social impacts that are most relevant to the social perspectives are listed in table D-3. These positive impacts are later synthesised and merged with the findings in the literature review to be evaluated in the following rounds.

Similar to the positive impacts, there is also a noise reduction (e.g., economic perspectives: costs, Return on Investment - ROI; environment perspectives: noise, resource misuse) and synthesis process for the negative impacts (shown in Table D-4). The following rounds evaluate the impacts that are extracted from both the literature review and the first round of the Delphi study. While some items such as attitudes identified as social barriers that are resulted from these negative impacts that hinder the wider adoption of AVs in supply chains.

Table D-3 Positive impacts extracted from Round 1

SCSS Indicator	Category	Detail
Health and Safety	Health and Safety (16)	Fewer human errors and increased safety (10)
		Workforce physical health and safety in safer working places (4)
		Workforce mental health and less stress (2)
		Improved safety in pandemics (1)
Stakeholder satisfaction	Fast delivery (5)	Faster process (1)
		Better delivery services (1)
		Faster delivery speed (3)
	Response in emergency (2)	Emergency services (2)
	Better services (5)	Increased flexibility (1)
		Offer better services in the long term (1)
		Accuracy of services (1)
		More reliable supply to customers and consumers (2)
	Customer satisfaction (4)	Customer experience and satisfaction improvement (4)
Employment	Reduce inefficient jobs (7)	Improved working environment (1)
		Worker satisfaction (2)
		More "pleasant" work (1)
	New job creation (4)	Worker satisfaction due to new and more qualified jobs (1)
		Fewer poorly paid, repetitive and boring jobs (5)
		Fewer human labour needed (1)
Transparency Diversity and Equality	Data integration (1)	New job opportunities creation (2)
	Better accessibility (2)	Demand for high skilled staff increased (2)
		Data integration (1)
Welfare	Reduce crowding and congestion (4)	Accessibility for remote areas being better served (2)
		Better use of road space (1)
		Reduced traffic congestion due to scheduling (2)
	Work-life balance (3)	Less traffic due to optimised routing (1)
		Life-work balance (1)
Not specified	New image (3)	Potential increase in leisure time (1)
		Improved living standards (1)
		Modern image as "innovation" (1)
		Use of Avs as a part of marketing and branding (1)
		New market economy based around Avs (1)

Table D-4 Negative impacts extracted from Round 1

SCSS indicator	Category	Detail
Health and Safety	Health & safety (5)	Safety accidents because of the risks of crashes and system failures (3) Psychological and physical strain of the people who are confronted by new technology adoption (2)
Employment	Unemployment (27)	Initial loss of jobs (poorly-paid job; low-skilled) in some of the supply chain processes (16) Short-term structural unemployment (10) Fewer jobs available in some regions - reduced prosperity (1)
Transparency	Privacy & cybersecurity (3)	Loss of control over the system (1) Privacy concerns for those who don't understand the society uses of drones (2)
Diversity and Equality	Equality & equity (1)	Cannot ensure participatory development with diverse users (1)
Welfare	Human contacts (3)	Alienation of workers from the operation (1) Loss of human touch (1) Isolation of people and communities (1)
	Congestion (1)	Increased congestion (1)
Not specified	Change management (1)	Lack of change management (1)
	Peer pressure (1)	Being forced into adopting AVs because competitors have done so (1)
	Technology dependence (1)	Too dependent on technology (1)

D.1.3 Social motivators and barriers

Social motivators and barriers are not the focal issues in this research. However, this study still attempted to identify some of the motivators and barriers that are tightly related to the prementioned social impacts. The key motivators raised by the participants include cost saving, labour shortage, performance improvement, gaining competitive advantages (especially in technology leadership), and better sustainability performance (environmental, safety). Table D-5 lists the main social motivators.

Likewise, the analysis of the barriers is similar to the motivators. Most of the participants mentioned the barriers falling into high costs and ROI, lack of expertise and unfamiliarity, immature technology and infrastructure, lack of regulations and legislative guides, negative attitudes, and complexity and incompatibility. The main social barriers are listed in Table D-6.

Table D-5 Social motivators extracted from Round 1

Category	Detail
Labour shortage (10)	Shortage of skilled employees (1)
	Shortage of lower-skilled labour (drivers) (7)
	Shortage of staff for health issues (COVID) and work limitations (24/7) (2)
Potential to gain social sustainability (1)	For safety purposes (1)
Promotion (2)	public relations and brand image - image for future-oriented (2)

Table D-6 Social barriers extracted from Round 1

Category	Detail
Health and Safety (2)	Health and safety concerns (2)
Lack of expertise and unfamiliarity (11)	Lack of skill set and technical expertise for the IT capabilities (8)
	Unfamiliarity with the concept and lack of design and implement knowledge (2)
	Lack of awareness and education (2)
Regulation or law limitations (7)	Extreme restrictions for airspace for UAVs (2)
	Lack or inefficient legal framework and guidelines (5)
Negative attitudes (13)	Inertia, lack of willingness to change, resistance and protests from stakeholders and unacceptance (9)
	Fear of technology (2)
	Lack of innovativeness within the company (1)
	External pressures about the potential negative impacts (1)

D.2 Round 1 finding for Chapter 4

The Delphi study identified two lists of the actions that were suggested to address the social impacts to gain wide social approval of adopting AVs in supply chains (abbreviated as “two lists” below): Actions to improve/maintain positive impacts, and Actions to mitigate/prevent negative impacts. The actions for the two list are presented in Tables D-7 and D-8 respectively.

D.2.1 Refined action categories from the first round for evaluation

After further synthesising the individual actions, 9 main categories were formed for both addressing the social implications in both positive and negative aspects. Hence, although there are minor differences among the actions in the two lists,

the 9 categories are commonly-applied for both lists. The 9 categories are: Communications; Continuous Improvement; CSR focus; Employment; Planning; Promotion; Regulation Improvement; Real-world Experiments; and Stakeholder Involvement. During the refining process, individual items with similar meanings in this context are synthesised as one integrated and inclusive item. For example, “improved and broadened interactivity with other OEM’s systems” was combined with “Community integration” into an item “Integrate with stakeholders and communities” for improved inclusiveness. OEMs stand for “Original Equipment Manufacturers” that are the suppliers for the equipment and facilities for further manufacturing or providing the products or services (Wu, 2013). In this context, they are the AV manufacturers or hardware suppliers for the organisations which adopt AVs in their operations. Both items call for active and wide collaborations with external stakeholders (upstream and downstream respectively). This also helps shorten the overall length of the questionnaire for improved participants’ experience.

Meanwhile, some items were initially mentioned in only one list, while it was considered to potentially address both positive and negative impacts. For example, “Better end-to-end transparency of AV lifecycle from manufacturing to end of life decommissioning linking to operational service benefits” was only mentioned to address positive impacts. While based on the author’s understanding, some negative impacts such as the safety accidents caused by breakdown of the AVs (especially UAVs). The lack of AV lifecycle status transparency of AV users potentially leads to these accidents in that they are not informed with timely health conditions of the machines, so that they fail to provide repairing works prior to the breakdowns. With this concern, the importance of these actions is to be evaluated and compared for addressing both positive and negative implications. Detailed categories of the actions are presented as the following sections.

Table D-7 Actions addressing positive impacts from Round 1

Category	Group	Detail
Better technology	Better technology (3)	Deployments of advancing AV systems (2) Constantly look at the technology and improve energy consumption and results (1)
	Further technology research (2)	Enhance the research and development of relevant technologies, e.g., self-driving and automatic sorting technologies (2)
Communication	Clear communications (2)	Clear communications through the supply chain. Appropriate messages to all stakeholders (2).
Continuous Improvement	Working environment improving (1)	Build processes around co-bots that improve ergonomics for existing workers to highlight the importance of the roles of human (1)
	Change management (1)	Active change management (1)
Data integration	Data integration and transparency (3)	Data and information integration (2)
		Better end-to-end transparency of AV lifecycle from manufacturing to end of life decommissioning (1)
Employment	Upskilling and training (3)	Upskilling and trainings as there would be changes in process and staff (2)
		Cooperation with training centres and universities (1)
	Financial supports (2)	Subsidies (1) Pay drone pilots more to attract more attention to the field (1)
Planning	Strategic planning (6)	Solid planning to integrate drone services into supply chain processes to ensure system performance (3)
		Appropriate GRC measures to be adopted, balanced scorecard designed (1)
		High quality initial design and data analysis capabilities (1)
		Provide appropriate business environment (1)
	Route planning (4)	For UAVs, careful flight planning (1) Flexibility in design and operational configurations to optimise load space, minimise empty and partial running and avoid non-essential use (2) AV activities can be optimised as a fleet for efficiency (1)
Promotion	Promotion to external stakeholders (6)	Publicise results in media, offer trials to public with free samples of useful products (1) Consistent brand and promotion of AV introduction to raise awareness of the benefits – explain how this will affect the overall business (3)

		Smooth deployment and transition by promising social impacts prevail: safety and reliability improvement and opportunities created (2)
	Quantify benefits (1)	Better to quantify benefits (1)
	Promotion to internal stakeholders (2)	Education about system capability and interconnectivities with other systems (1)
		Explain and internal promotion of contemporary processes (1)
Real-world experiments	Real-world labs to prove concepts (4)	Start trials of AVs and include average individual to participate (1)
		Pilots and prove on concepts to prove benefits (2)
		Use living lab approach (1)
Regulation improvement	Clear regulations and restrictions (3)	Clear regulations on approving each type of technologies for use in different situations, locations (2)
		Reasonable restrictions or regulations when needed (1)
Social impact check	Check (1)	Security check (1)
	Safety assurance (2)	Ensure safety and reduced risk to drivers/operators isn't negated by increased risk to others (2)
Stakeholder involvement	Stakeholder participation and involvement for development, planning, implementation for success (5)	A user-centric development, better participatory (1)
		Engagement of stakeholders to better implement services and benefits (2)
		Involvement of employees in planning and implementation (1)
		Ensure communication aligns the success factors for the technology, corporate success, and stakeholder participation (1)

Table D-8 Actions addressing negative impacts from Round 1

Category	Group	Detail
Better technology	Better technologies (1)	Improved (more silent) drones (1)
Communications	Information sharing (2)	Provisions of information on the parts of companies and dialog with employees (2)
	Expectation setting (1)	Communication and setting expectations (1)
Continuous improvement	Feedback loops (1)	Residential feedback loops implemented and learning from experience (1)
	Change management (2)	Active change management (2)
	Continuous innovation (1)	Continuous Innovation (1)
CSR focus	Strategic (1)	Business needs to be responsible on their actions. Mainly the CSR activities should boost remarkably to compensate any social negative impacts (1)
	Operational (1)	Security checks (1)

Employment	Job creation (3)	More jobs and opportunities created to prevent job loss (3)
	Upskilling and training (15)	Retrain and upskill the employees to requalify the higher-skilled positions (15)
	Other supports (2)	Psychological support (1)
		Subsidies (1)
Planning	Strategic (3)	Redesign operations for better technology integration with existing operations and practices (1)
		Nearshoring manufacturing of robots (1)
		Appropriate GRC measures to be adopted, balanced scorecard designed (1)
	Route planning (1)	Careful flight planning for UAVs (1)
Promotion	To employees (2)	Directly showcase technology to employees (1)
		Education about system capability and interconnectivities with other systems (1)
	To external stakeholders, awareness (5)	Increase average person's understanding and awareness of the technology e.g., via business cases (5)
	To external stakeholders, the benefits (5)	Dissemination of advantageous and benefits of automation technologies to the public (5)
Real World Experiments	Real-life experiments (3)	Use living lab approach (1)
		Pilots and prove on concepts to prove benefits (1)
		Running proof of concepts with employees to check technologies (1)
Regulation improvement	Regulations for unemployment (1)	Society-wide policies to deal with job lost to automation (1)
	Regulations for healthy and security (2)	Ensuring data protection and privacy and cybersecurity are addressed (1)
	Reset regulations (2)	Clear regulation of safety (1)
		Government should recreate UAV rules in each country by consulting to the drone pilots (1)
Stakeholder Involvement	Journey mapping (1)	Regulations e.g., time of the day can operate, congestion charging (2)
	Internal stakeholder involvement (2)	Customer journey mapping, and do the "affected stakeholder journey mapping" for social changes (1).
		Continuous team meetings with operational team, briefings (1)
	External stakeholder involvement (2)	Involvement of employees and functional managers (1)
		Improved and broadened interactivity with other OEM's systems (1)
		Community integration (1)

D.2.2 Communications

Actions under this category appeal for clear communications among the supply chain stakeholders for information sharing and expectation clarifying. Multiple supply chain processes and relevant stakeholders are to be covered when implementing communications. Despite the generic and broadly inclusive actions, they are essential for long-term benefits and sustainability performance (Venkatesh et al., 2020). Table D-9 present the actions involved in the communication category.

Table D-9 Communication category

List	Detailed actions
Communications to address positive implications	● Clear communication through the whole supply chain among stakeholders
Communications to address negative implications	● Provide information and set expectations among supply chain processes

D.2.3 Continuous Improvement

Continuous improvement calls for the constant development of the technologies and the research into the technologies, as well as consistent improvement in services and working environments. In supply chain management, continuous improvement is generally presented by “KAIZEN” framework that includes Just-in-time (JIT), Zero defects, effectiveness, Total Quality Management (TQM), etc. (Singh and Singh, 2013). That means “change for better consistently” for continuous improvement. Given the specifications of change management in continuous renewing the organisations’ direction, structure, and capabilities for satisfying stakeholders’ needs (By, 2005), change management is considered as one aspect of continuous improvement. The actions involved in this category therefore embody the logic of constant changing, and constant improving. Table D-10 highlights the actions under continuous improvement category to address positive and negative social implications respectively.

Table D-10 Continuous improvement category

List	Detailed actions
Continuous improvement to address positive implications	<ul style="list-style-type: none"> ● Constant development and research of AV technologies; ● Active change management; ● Constant development of a working environment for existing employees; ● AV lifecycle status transparency for better services.
Continuous improvement to address negative implications	<ul style="list-style-type: none"> ● Constant development and research of AV technologies; ● Active change management; ● Constant improvement via feedback loops; ● AV lifecycle status transparency for better services.

D.2.4 CSR focus

CSR focus calls for a holistic considerations and implementations of CSR in supply chains in the AV adoption context. This includes two aspects: the considerations and being responsible for the activities from starting point of being socially responsible; and the regular check at the operational levels for risk mitigations and safety assurance. The actions raised by the participants cannot be merged into other categories yet. Therefore, they were listed as an independent category. Table D-11 presents these two aspects of CSR focus.

Table D-11 CSR focus category

List	Detailed actions
CSR focus to address positive implications	<ul style="list-style-type: none"> ● Regular security and safety check for reduced stakeholders' risks
CSR focus to address negative implications	<ul style="list-style-type: none"> ● Regular security and safety check and ensure reduced stakeholders' risks; ● Business to be responsible for their actions and focus on CSR.

D.2.5 Human Resource management

The human resource management category includes actions concerning the upskilling, reskilling, training, and supporting of the existing employees, the recruitment of new, high-skilled and experienced employees, and new job creation. All these aspects are to make the employees and the supply chain organisation to be ready for the AV adoption and to qualify the jobs. These actions seek to improve employees' awareness, knowledge, and skills to compete in the industry. The detailed actions are listed in Tables D-12.

Table D-12 Human resource management category

List	Detailed actions
Human Resource management to address positive implications	<ul style="list-style-type: none"> ● Financial subsidies for AV operators and AV adopters; ● Internal upskilling and training programmes; ● Cooperation with external training institutions.
Human Resource management to address negative implications	<ul style="list-style-type: none"> ● Employee psychological support; ● Financial subsidies to the AV adopters; ● Retrain and upskill the employees to requalify the higher-skilled positions; ● Create new job positions to prevent positions' loss due to AV adoption.

D.2.6 Planning

The planning actions aim at mapping and analysing how AVs to serve the supply chain and stakeholders before adoption and implementation. This would cover long-term, supply chain-wide mechanisms for integration of AVs in the supply chain, as well as the short-term, floor-level scheduling for operations with AVs. These two streams are defined as “strategic” and “operational” planning (Robinson et al., 1985). In addition, creating an appropriate business environment is also considered as a planning action. Business environment is essential for organisations to survive, for it controls the resources (human, material, information etc.) that the organisations demand (Dess and Beard, 1984). The organisations operating in an appropriate business environment would require accompanied operating and management skills to utilise the resources they have and create values (Christopher and Towill, 2002). In the AV adoption context, critical resources such as reliable vehicles to adopt, skilled workforce to operate and maintain, key legal provisions to support the deployment are all essential for the decision-makers to consider when planning. Therefore, creating an appropriate business environment is a crucial planning action in this context. Table D-13 presents the planning actions in this context.

Table D-13 Planning category

List	Detailed actions
Planning to address positive implications	<ul style="list-style-type: none"> ● Route planning; ● Appropriate GRC measures, balanced scorecard, and data analysis capabilities; ● Designing and integrating new technologies into supply chain processes;

	<ul style="list-style-type: none"> ● Appropriate business environment creation; ● Data and information integration.
Planning to address negative implications	<ul style="list-style-type: none"> ● Route planning; ● Appropriate GRC measures, balanced scorecard, and data analysis capabilities; ● Designing and integrating new technologies into supply chain processes.

D.2.7 Promotion

The actions for promotion emphasise awareness and knowledge improvement of AVs among the various stakeholders (mainly external stakeholders – communities, customers, etc.). Promotion is a key step to raise public familiarity, which is identified as one of the key determinants for acceptance (Aydin, 2019; Eißfeldt et al., 2020). Table D-14 presents the promoting actions for the two lists.

Table D-14 Promotion category

List	Detailed actions
Promotion to address positive implications	<ul style="list-style-type: none"> ● Promote to the employees for the system capabilities and interconnectivity; ● Promote and introduce the AVs to the communities about the trial samples, the benefits and improvement; ● Quantify the benefits compared to the past.
Promotion to address negative implications	<ul style="list-style-type: none"> ● Promote to the employees for the system capabilities and interconnectivity; ● Inform the communities of the advantages and applications of AVs via business cases; ● Quantify the benefits compared to the past.

D.2.8 Regulation Improvement

This category covers the actions suggested by the participants to refine the existing regulatory frameworks to address safety, employment, privacy issues, and to regulate the usage of AVs in various scenarios based on the AV type and specifications. These suggestions aim to loosen the extant restrictions for a broader AV adoption in supply chains (Rao et al., 2016). Table D-15 presents the actions for improving regulations in addressing positive and negative implications respectively.

Table D-15 Regulation improvement category

List	Detailed actions
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Regulation improvement to address positive implications	<ul style="list-style-type: none"> ● Clear regulations on approving each type of technology in different scenarios.
Regulation improvement to address negative implications	<ul style="list-style-type: none"> ● Regulations detailing about the AV operation zones, time, and social issues; ● Social-wide policies to deal with job loss to automation.

D.2.9 Real-world Experiments

Real-world experiments involve the actions that appealing to test the reliability of the technologies and prove the concepts in the real-world scenarios. Holistic tests should be conducted for safety assurance and risk preventions (Poljak and Šterbenc, 2020; Kellermann et al., 2020). While the actions raised in the Delphi study are generic and minor differences existed between the two lists. Table D-16 concludes the actions under the Real-world experiment category.

Table D-16 Real-world experiments category

List	Detailed actions
Real-world experiments to address positive implications	<ul style="list-style-type: none"> ● Trials of AVs to prove the concepts and the benefits
Real-world experiments to address negative implications	<ul style="list-style-type: none"> ● Trials of AVs to prove the concepts and the benefits

D.2.10 Stakeholder Involvement

Stakeholder involvement calls for the active engagement with the stakeholders along the supply chains – internal and external, to collectively improve the group knowledge and awareness of the AVs' specifications in supply chains. This also benefits resistance and miscommunication mitigation among the diverse stakeholders (Ding, 2018; Vlachos et al., 2021). Hence, a series of actions are proposed to involve various stakeholder groups under different scenarios. Table D-17 summarises the actions proposed for stakeholder involvement.

Table D-17 Stakeholder involvement category

List	Detailed actions
Stakeholder involvement to address positive implications	<ul style="list-style-type: none"> ● Stakeholder involvement and engagement in developing, planning, and implementation.
Stakeholder involvement to address negative implications	<ul style="list-style-type: none"> ● Continuous team meetings with different levels of employees; ● Integrating with stakeholders and communities; ● Stakeholder journey mapping to check social changes.

D.3 Reference to Appendix D

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Appendix E Delphi study evolves between Rounds 2 and 3

This appendix section describes the changes from Round 2 to Round 3 of the Delphi study. Key evolutions have been covered in the main text, while this part serves as a supplementary for the main text.

E.1 Changes for Chapter 3

E.1.1 Consensus reached items in Round 2

After the second round, 12 items in stakeholders and social impacts reached a consensus following the “51-80 rule”. These items will no longer be evaluated in the third round.

Stakeholders

Internal stakeholders

In terms of the degree of being affected by the AV adoption, the mid-level managers, operational employees, and operational technology maintenance crew are the groups that received high-level consensus on the high degree of being affected. Around 90% of participants believed these stakeholders are highly (considerably and extremely) affected by the AV adoption in the supply chain. These people are the frontline employees that deal with operations daily. The adoption of AVs directly changes the working mode and operations of these groups. The operational employees change their working style from manual to automatic and are required to manage to interact with these machines. While mid-level managers are affected through enhanced data visibility for immediate decision-making (Sellevold et al., 2020). The maintenance crew are also required to master the skills of conducting routinised maintenance work for the AVs and coding the tailored programmes for the AVs that suit the operations in the specific organisations. One participant placed a comment to prove this:

“We observe their (AVs’) influence on decision-making and the introduction of AV from both strategic and operational perspectives.” (DR2-34-P)

On the other hand, the senior level managers, according to the respondents, highly impact the AV adoption and the actions to take to address the social sustainability implications. Almost all of the participants (95%) believed the degree is high (considerably and extremely affecting). It is not surprising that these executives take strategic actions for the organisations that have a significant impact on the AV adoption decisions and the actions to address the SCSS. According to one comment,

“C-suite is the decision maker so their main driving parameter is always high-level vision towards technology advancement and unlocking business opportunities”. (DR2-22-P)

This is supported by another comment:

“The senior stakeholder groups are strategically affecting the design and roll-out of autonomous vehicles with the intention of improving productivity and service. Therefore, the other management groups will be affected by design”. (DR2-24-P)

External stakeholders

The participants reached a consensus on the three external stakeholder groups that are highly affected by AV adoption: logistics service providers, software suppliers and AV manufacturers. They are the groups that are directly confronted with AV technology – either they are the direct adopters or the creators. The trend of AV adoption on the one hand impacts the service providers in the technology know-how regarding the new mode of services they can deliver. The AVs are the new techniques for business operations. On the other hand, the trend and the technology maturity impact software and hardware providers of AVs through an increasing number of demands from their downstream business customers – an organisation decides to adopt AVs in the warehouse, the software and hardware suppliers receive orders from the organisation to provide tailored AV systems. That is not surprising to see why these stakeholders receive a consensus in a high-level degree of “being affected”.

The AV hardware suppliers also play an extremely important role in affecting the AV adoption in the supply chain, concerned by nearly three-quarters of the

participants. If the AVs provided by the manufacturers are highly reliable (e.g., health and safety issues) (Perussi et al., 2019), and provide significant competitive advantages compared to the existing conventional vehicles in the logistics so that the AVs gained wide social approval (Kurniawan et al., 2021), the organisations indeed adopt AVs in supply chains at a broader scale. The products they provide lead the innovation trends in AV technology. Surprisingly, two respondents selected low-affecting degree categories, while the rest considered AV manufacturers with at least a moderate degree of affecting. It can be possible that the small and medium-scale AV suppliers have a relatively low capability in affecting the general AV adoption trend, compared to the giants. Rogers (2003) generated that the larger organisations are, the more innovative they are. This implies that the larger technology providers potentially have more capabilities and resources in developing superior AVs. Therefore, it is not absolute that AV manufacturers are in a high degree of affecting. Rather, the size of the manufacturer is a critical variable in this scenario. In the meantime, competitors are regarded as a group of high-degree affecting stakeholders that affect AV adoption in the supply chain. It relates to one of the later impacts that the organisation is “being forced to adopt AVs under competitors’ pressure”. The organisations will have to determine whether to adopt AVs in their operations if their direct competitors have done so. Although that negative impact only received a 2.95 average importance rate and was later deleted from the list of “social impact”, the competitors proved to be the “affecting” stakeholders in this context.

Social impacts

All three impacts that reached a consensus were categorised in the “health and safety” indicator. Fast response for emergencies and workforce physical health and safety received agreements in “extremely important” among more than half of the experts. Most of the participants believed that AVs benefit life-saving and workforce health and safety in workplaces as at least moderately important impacts. Likewise, 84% of experts considered road traffic safety as a considerably or extremely important positive impact. This proves that the automation of freight transport vehicles indeed mitigates human-error accidents

and potentially improves overall road traffic safety for all traffic users (Gružauskas et al., 2018). Surprisingly, one participant considered fast response for life-saving as an impact that is not important at all. The importance of fast response of AVs can be undermined if the fast-response system for first-aid or emergencies is already sound by using existing delivery vehicles such as helicopters. In addition, the unavailability of wireless communications and navigation signals at disaster sites significantly limits the usage of unmanned transport vehicles. Under these circumstances, the advantages of the fast response of AVs are not competitive and less critical. While the answers for the other two impacts generally showed a convergence effect towards high-level importance.

E.1.2 New stakeholder groups suggested

As one comment suggested to consider some external stakeholders such as industrial associations or lobby groups and media, these were considered to be added to the design of the third round. Regarding the lobby groups, however, the comment did not explicitly mention who the lobby groups specifically represent. The lobby groups are concluded as the organisations that influence the decisions or legislations enacted by the policy makers or high-level decision-makers to achieve their interests or purposes (Browne et al., 2000; Ovaere et al., 2013). These lobby groups are sometimes classified as one type of non-governmental organisations (NGOs), namely, business-organised NGOs (Rogers and Marres, 2000). In this context, the main lobby groups can be the organisations that promote the adoption of AVs in the supply chain, and represent the AV manufacturers' interests. On the other hand, the groups that represent operational employees' interests to exert pressure on senior decision-makers are described as labour unions (Farber, 1986). In this context, these unions are the organisations in the industry that present the operational employees in the logistics sectors whose occupations are potentially replaced by the adoption of AVs. With such considerations, they are also one external stakeholder group. Hence, two potential lobby groups were proposed – the lobby groups represent the AV providers; and the unions that represent the operational employees in the logistics sectors. Apart from the lobby groups, the media is also suggested as an external stakeholder group. Mass media content has significant potential in

changing individuals' preferences over time (Soroka, 2003). In this research, media can play a role in enhancing the public's awareness of AVs and their implementations in the supply chain. Likewise, the media can be influenced by the incremental maturity of the AV technology that updates their ideas to promote. As a result, the media was added as an external stakeholder group.

By adding the individual questions to ask "affecting" and "being affected" to all three groups, there are six additional items for evaluation in the third round of the Delphi study.

E.1.3 Items adjusted

Customer satisfaction

After the first round, one of the experts mentioned improved workforce satisfaction due to the improved working environment as one of the positive impacts. In order to categorise the satisfaction issues from multiple stakeholders, the category "customer satisfaction" was expanded to "stakeholder satisfaction" and involved employee satisfaction in this category. This design was published to the Delphi participants for evaluation in the second round. The participants did not unveil a disagreement, however, "stakeholder satisfaction" does not exist in the identified existing seminal supply chain social sustainability publications as an independent indicator. By definition, "employee satisfaction" is included in the "employment" indicator (Ahi and Searcy, 2015; To and Lee, 2017). It is wise not to change the definitions that are widely recognised in academia. Therefore, "improved employee satisfaction" was relocated to be categorised into the "employment" indicator, and the "stakeholder satisfaction" category was amended back to "customer satisfaction", following the initial model proposed in the literature review.

Transparency

Based on the comments about the privacy impact, this item was adjusted to "privacy and cybersecurity concerns".

"Maybe security issues to be considered. They can be tracked or hijacked. You covered privacy but we could emphasise security as well." (DR2-12-A)

This is not only to make this impact more inclusive but also to align with the initial model proposed in the literature review.

Health and Safety

Although the impact “safety accidents due to crashes and failures” did not receive any comments from the participants, this item was adjusted to “safety incidents due to crashes, failures, and attacks” to be more inclusive.

E.2 Changes for Chapter 4

E.2.1 Items reached a consensus at Round 2

After the evaluation process in the second round, four items in the action list and the agreement rating for the model reached a consensus following the “51-80 rule”. The four actions will not be shown for assessing in the third round. However, a series of comments on the model suggested a further improvement is necessary, even if most of the participants expressed their agreement of the model. Hence, the model was amended for further evaluation in the third round.

Actions to improve positive impacts

There are four items in the list of “actions to improve social impacts” that reached a consensus concerning their importance at the end of Round 2 (shown in Table E-1). Under the “planning” category, there are two actions reached a consensus among the respondents: Data and information integration; and designing, and integration technologies into supply chain processes. Both of them were rated higher than 4 in importance rating, meaning that most of the participants dropped their selections of these two items between “considerably important” and “extremely important”, and no one selected the choice that represent unimportant. Further integrating data and information in supply chains reinforces the positive impact of real-time data visibility in the transparency category of SCSS in this context (Gružauskas et al., 2018). While designing and integrating the AVs in multiple supply chain processes is general. This action calls for a reasonable design of the supply chain processes that integrate the AVs prior to the real adoption. Although not closely relating to specific impacts, the integration

of technologies in operations benefits the overall supply chains in improved efficiency and productivity (economic perspective) (Vlachos et al., 2021).

The action “clear communications through the whole supply chain among stakeholders” also received concrete agreement for its considerable importance in improving social impacts. Clear communications indeed mitigate information differences among the various stakeholder groups positioned in each node, for a unified vision in the supply chain, which is essential for socially sustainable supply chains (Sen et al., 2020). On the one hand, the communications among the internal stakeholder groups enable the employees in each level and position of the organisation understand AVs’ protocol in safe operations, as well as the benefits and drawbacks. On the other hand, the communications between internal and external stakeholders also benefit the organisations by understanding the demands from the external stakeholders. This provides a foundation for the organisations to provide further actions in satisfying the stakeholders’ enquiries in the AV adoption context. This individual action serves as a general standpoint that includes other detailed actions including stakeholder engagement and participatory (Vlachos et al., 2021), and gaining feedbacks from local communities (Kurniawan et al., 2021).

Although AVs potentially replace a number of lower-skilled employees and make them redundant, human workforce still exists in the supply chain. Hence, more than half (54%) of the participants believe the constant development of a decent working environment for the employees a considerably important action. Although the mean value was dragged down to 3.82 by 20% participants who selected “considerably important”, they did not undermine the importance of this action for continuous improvement. Afterall, this action closely relates to the “improved working environment and employee satisfaction” in the positive social impact list of AV adoption.

Table E-1 Actions reached a consensus at Round 2

Category	Actions	R2 M	R2 SD
Planning	Data and information integration.	4.21	0.91
	Designing, and integrating technologies into supply chain processes.	4.18	0.78

Communication	Clear communications through the whole supply chain among stakeholders	4.13	0.69
Continuous Improvement	Constant development of a working environment for existing employees	3.82	0.81

E.2.2 Model evaluation in the Delphi study

Clarifying the research unit: organisational level.

The DOI theory includes both individual and organisational levels innovation process. The proposed alignment of the actions with the individual-level in Round 2 seeks to explore that, targeting at distinct stakeholders at each level of their innovation decision process, what actions can be taken to enhance their acceptance of AVs. Meanwhile, the alignment of the action categories with the organisational level represents that, the organisations in each of the stage of innovation adoption are suggested to take the respective categories of actions to mitigate negative social implications. This research evaluates how the organisations react to address the social implications in the AV adoption context, which indicates a holistic view of the action categories to take targeting at various stakeholders at present. It is not realistic to explore the how the action categories affect distinct stakeholder during each stage of the decision process in detail in this study. The acceptance and preferences of the distinct stakeholders (especially, customers and local communities) are influenced by the perceived social impacts of AVs, according to the theoretical frameworks (UTAUT – Unified Theory of Acceptance and Use of Technology, UTAUT2 – extended UTAUT etc.) (Kapser and Abdelrahman, 2020; Pani et al., 2020), as also recommended by one participant:

“You might also want to check out Technology Acceptance Model, UTAUT, UTAUT2, etc.” (DR2-10-A)

However, there is a lack of existing theoretical underpinning in relating the SCSS concepts to the individual level technology acceptance variables. It is also not the objective to explore how to enhance the stakeholders’ acceptance of the technology. Furthermore, the focus of this research falls into the organisations – the broad views in “internal” and “external” stakeholders identified in Chapter 3 are referred to the organisations, rather than the distinct stakeholder. Therefore,

this research sticks with the research unit as the organisations in supply chains, and the action categories are only aligned with organisational level innovation decision process under the scope of this research.

Model evaluation

Table E-2 Agreement evaluation for the model

Applicability Agreement	M	SD	% in highest category	% in two adjacent categories
Round 2	4.31	0.62	53%	92%
Round 3	4.31	0.71	52%	93%

Table E-2 presents the agreement of the applicability of the model among the participants. The outcome barely changes between the two rounds, even if the model changed significantly. The majority of the respondents selected “somewhat agree”, and the percentage of choice in “strongly agree” increased by 2% from 39% in the second round to 41%, even though there is a decrease in the overall number of the participants. This outcome presents an increase in overall agreement of the model among the Delphi participants. The participant who questioned about the sequence of the actions in the previous round commented on the new model:

“I think this model fits. It affects different organisations/entities at different stages of the adoption curve though.” (DR3-24-P)

This comment approved the efforts of this model in fitting the actions in the adopters in various stages. However, apart from the positive feedback, there are some comments asking for further clarification and illustration of the model:

“Not sure, maybe we need to discuss later on so that I can better understand what you are trying to achieve.” (DR3-11-A)

“I am not sure I understand this model and/or how I need to follow this through. In any case, I cannot see the strategy and the tactics being employed which are always part of the decision making (to my experience obvs).” (DR3-7-A)

With the exists of these comments, this model was discussed further in the follow-up interviews for further refinement. Those who made such comments were

invited and participated in the interviews. The model is to be refined on the basis of the interviews with them.

E.3 Reference to Appendix E

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Appendix F Low Agreement items in the Delphi study

This section in the appendix presents the items with low agreements – either lower than 40% of agreement in one category of the rating scale, or lower than 70% of the two adjacent categories of the scale are analysed in this section. These items still receive low agreement among the participants even after two rounds of evaluation (except the newly added items). Figure F-1 shows the items with low agreements.

No.	3	20	24	27	32	33	34	41	118
Question	To what extent are these MANAGERIAL level groups IMPACTED BY the AV adoption and the actions to address the social impacts for a socially sustainable supply chain? (Following questions will only show "IMPACTED") - Shareholders/Owners. M=3.18, SD=1.25	To what extent are the Logistics service providers IMPACTING? - Vendor-managed inventory suppliers. M=3.54, SD=1.14	To what extent are the Government and legislative authorities IMPACTING? - Air traffic control professionals. M=3.74, SD=1.27	To what extent are the Technology providers IMPACTING? - The external maintenance team. M=3.46, SD=1.33	To what extent are the Other external entities IMPACTED? - Research and training centres. M=3.37, SD=1.11	To what extent are the Other external entities IMPACTED? - Lobby groups representing the technology providers. (Newly added)	To what extent are the Other external entities IMPACTING? - Media. (Newly added)	To what extent are the Other external entities IMPACTING? - Media. (Newly added)	How important are these motivators for motivating the AV adoption in the supply chain? - Shortage of employees due to health issues and work limitations. M=3.45, SD=1.02
M Value	3.13	3.62	3.79	3.67	3.20	2.62	3.21	3.13	3.70
SD Value	1.14	0.94	1.05	0.96	0.96	1.01	0.83	1.14	0.84
1 category	33.33%	41.38%	41.38%	36.67%	36.67%	41.38%	39.29%	41.38%	36.67%
2 categories	56.67%	68.97%	68.97%	73.33%	70.00%	68.97%	75.00%	68.97%	70.00%

Figure F-1 Low agreement items

F.1 Low agreements regarding stakeholders

The divergence mainly occurs in the stakeholder section – 8 out of 9 items are in the stakeholder section of questions. Apart from the newly added items, the low agreements exist among the stakeholder groups result from the generic context of the research. The participants held diverse opinions about the stakeholders depending on the AV application contexts from their perspectives.

“The relative importance of the factors will vary by sector and how much the AVs are focused on internal vs. external environments”. (DR3-24-P)

Vendor-managed Inventory (VMI) suppliers and air-traffic control personnels received the same consensus in affecting ratings. These two stakeholders are affecting the AV adoption, while the applicability varies by contexts. It is not realistic to ask air traffic control personnels to affect significantly in the warehouses where AMRs are broadly deployed, and vice versa. While the VMI suppliers' role in this context remains vague, resulting to the major selections

from the participants fall into the neutral category. This is similar to the role ratings of technology providers and research/education institutions. Respondents were not confident in one rating category and a large portion of them preferred neutral range of the choices.

Among all of the low agreement items, the degree of being affected among shareholders/owners receives the most disputes. The distribution of the answers almost formed a bell shape curve (shown in Figure F-2). Shareholders' roles and status vary by the contexts. Hence, the participants stayed neutral with the opinion of "it depends". On the other hand, even at a specific context, it remains vague showing how they can be affected. The shareholders and owners are potentially benefited from AVs via the high transparency and visibility so that they can adjust their strategic decisions for investment portfolios (Arunmozhi et al., 2022). However, other aspects of the AV adoption to the shareholders and owners as well as the degree of the impacts remain to be explored further in the future.

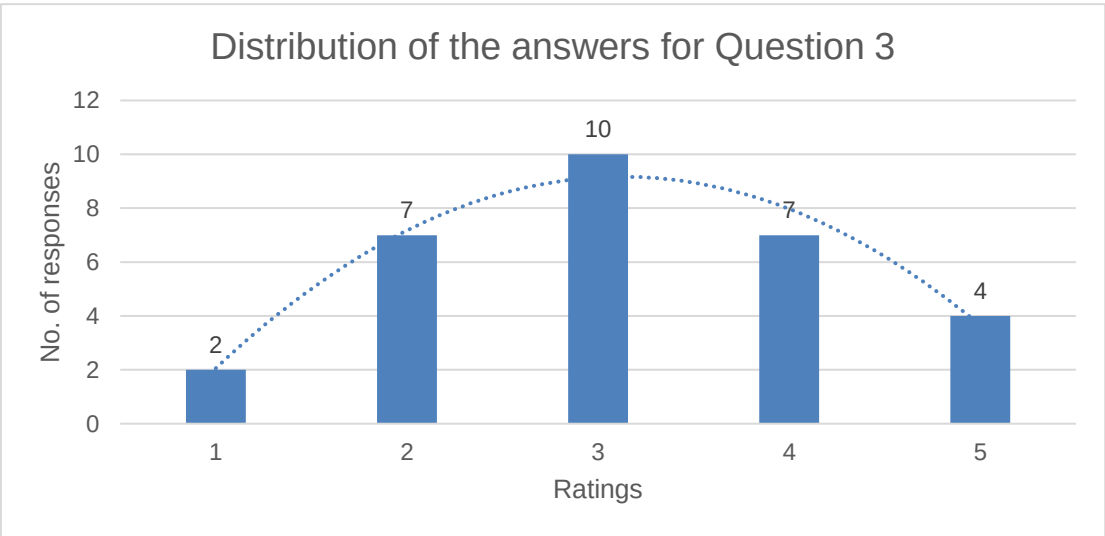


Figure F-2 Answer distribution for Q3

In addition, low agreements exist among the items that are newly added in Round 3, i.e., Media (both being affected and affecting), and the Lobby groups (being affected) that represent the technology providers. Since these items were raised by only few respondents in the second round, it is normal that other participants did not recognise, approve or even realise these items. In addition, these items

have not experienced the iterative evaluation process of the Delphi, it is not surprising to see these items receive a low agreement at present. Lobby groups received 75% responses concerned as highly “being affected”. The incremental maturity of the technologies and public awareness potentially fosters the groups’ confidence in promoting the technologies to the industry and policy-makers. In comparison, the lobby groups are believed to impact the AV adoption by half of the participants. Since “the emergence of lobby groups who are trying to influence outcomes”, they tend to be allocated at an “affecting” position.

F.2 Low agreements in one social motivator

The final divergence exists in the importance of “shortage of employees due to health issues and work limitations” almost evenly spreads into three categories – from slight, moderate to considerable. It is surprising to the author that only one participant considered this item as an extremely important motivator to adopt AVs in the supply chain, even after the pandemic of COVID-19. The incremental labour shortage in the global supply chain due to illness is one of the main consequences of this contagious disease (Nagurney, 2021). Some of the studies discussed the accelerated adoption of robotics and AVs in the supply chain to reduce labour uncertainty (especially the shortage because of being infected) during and post-pandemic (Sodhi and Tang, 2021; Murphy et al., 2022). It remains controversial whether labour availability is one of the essential social motivators to adopt AVs in the supply chain.

F.3 Reference to Appendix F.

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Appendix G Delphi study panel profile

On the basis of the participant selection criteria, Tables G-1 to G-9 present the detailed information of the participants for each round. All of the “years of experience” represent the years of experience of the participant at the period when filling the concurrent questionnaire.

Table G-1 Delphi Participant Round 1

Participant	Category	Field/Affiliation	Job title	Years
1	Academia (n=22)	Sustainability	Reader	20+
2		Humanitarian Logistics	Adjunct Professor	15
3		Both	Head of Institute	35
4		Both	Director of Education	27
5		AVs	Assistant Professor	7
6		Both	Associate Professor	7
7		Sustainability	Professor	10
8		Both	Professor	14
9		Both	Professor	18
10		Both	Professor	20+
11		Both	Professor	20+
12		AVs	Associate Professor	22
13		Both	Professor	28
14		Both	Professor	37
15		Sustainability	Professor	5
16		Both	Associate Professor	8
17		AVs	Associate Professor	22
18		Sustainability	Various	25
19		Both	Associate Professor	6
20		AVs	Researcher	5
21		AVs	Head of the Group	15
22		Logistics	Professor	34
23	Industry (n=14)	Industry Consultant	Consultant MHE	28
24		B2B Distributer	VP Supply Chain	15
25		Distribution	COO	30
26		Industry Consultant	Global Head Supply Chain Financing	10
27		Industry Consultant	Senior Consultant	5
28		Technology Provider	CCO	7
29		Technology Provider	Business Development Lead	5
30		Food and Drink	Project manager	20+
31		Industry Consultant	Associate Director	20+
32		Logistics service provider	Transport manager	6
33		Investor	Fellow	10
34		Logistics service provider	VP Innovation EU and Trend Research	10

35	Logistics service provider	Managing Director	10
36	Industrial Manufacturing	Pre-sale Manager	3
37	Gov (n=1)	Division Head	30+

Table G-2 Academic participant information - Round 1

Academics Job Title	No.	Field of Expertise			Years of Experience		
		AVs	SCM	Sustainability	3 - 9	10 - 19	>=20
Reader	DR1-1		√	√			√
Adjunct Professor	DR1-2		√			√	
Head of Institute	DR1-3	√	√	√			√
Director of Education	DR1-4	√	√	√			√
Assistant Professor	DR1-5	√	√		√		
Associate Professor	DR1-6	√	√	√	√		
Professor	DR1-7		√	√		√	
Professor	DR1-8	√	√	√		√	
Professor	DR1-9	√	√	√		√	
Professor	DR1-10	√	√	√			√
Professor	DR1-11	√	√	√			√
Associate Professor	DR1-12	√	√				√
Professor	DR1-13	√	√	√			√
Professor	DR1-14	√	√	√			√
Professor	DR1-15		√	√	√		
Associate Professor	DR1-16	√	√	√	√		
Associate Professor	DR1-17	√	√				√
Various	DR1-18		√	√			√
Associate Professor	DR1-19	√	√	√	√		
Researcher	DR1-20	√	√		√		
Head of the Group	DR1-21	√	√			√	
Professor	DR1-22		√				√

Table G-3 Delphi Participant Round 2

Participant	Category	Field/Affiliation	Job title	Years
1	Academia (n=17)	Sustainability	Reader	20+
2		Both	Director of Education	27
3		AVs	Assistant Professor	7
4		Both	Associate Professor	7
5		Sustainability	Professor	10
6		Both	Professor	14
7		Both	Professor	18
8		AVs	Associate Professor	22
9		Both	Professor	28
10		Both	Professor	37
11		Sustainability	Professor	5
12		Both	Associate Professor	8
13		AVs	Associate Professor	22
14		Sustainability	Various	25
15		Both	Associate Professor	6
16		AVs	Researcher	5
17		Logistics	Professor	34

18	Industry (n=12)	Industry Consultant	Consultant MHE	28
19		Distribution	COO	30
20		Industry Consultant	Global Head Supply Chain Financing	10
21		Technology Provider	CCO	7
22		Technology Provider	Business Development Lead	5
23		Food and Drink	Logistics Transformation Project manager	20+
24		Industry Consultant	Associate Director	20+
25		Logistics service provider	Transport manager	6
26		Investor	Fellow	10
27		Logistics service provider	VP Innovation EU and Trend Research	10
28		Logistics service provider	Managing Director	10
29		Industrial Manufacturing	Pre-sale Manager	3
New Participants				
30	Academia (n=5)	AVs	Senior Lecturer	22
31		Industry 4.0	Associate Professor	5
32		Sustainability	Senior Lecturer	25
33		Sustainability	Senior Lecturer	21
34	Industry (n=5)	Sustainability	Research Director	20
35		Technology provider	Researcher	7
36		Industrial Manufacturing	Supply Chain Executive	30
37		Industry Consultant	CEO	10
38		Logistics service provider	Senior Manager	20
39		Logistics service provider	VP Global Innovation	23

Table G-4 Academic participant information - Round 2

Academics Job Title	No.	Field of Expertise			Years of Experience		
		AVs	SCM	Sustainability	3 - 9	10 - 19	>=20
Reader	DR2-1		√	√			√
Director of Education	DR2-2	√	√	√			√
Assistant Professor	DR2-3	√	√		√		
Associate Professor	DR2-4	√	√	√	√		
Professor	DR2-5		√	√		√	
Professor	DR2-6	√	√	√		√	
Professor	DR2-7	√	√	√		√	
Associate Professor	DR2-8	√	√				√
Professor	DR2-9	√	√	√			√
Professor	DR2-10	√	√	√			√
Professor	DR2-11		√	√	√		
Associate Professor	DR2-12	√	√	√	√		
Associate Professor	DR2-13	√	√				√
Various	DR2-14		√	√			√
Associate Professor	DR2-15	√	√	√	√		
Researcher	DR2-16	√	√		√		
Professor	DR2-17		√				√
Senior Lecturer*	DR2-18	√	√				√
Associate Professor*	DR2-19	√	√		√		

Senior Lecturer*	DR2-20	√	√	√
Senior Lecturer*	DR2-21	√	√	√
Research Director*	DR2-22	√	√	√

Due to the attrition effects, the second round invited new experts to participate in the study. Most of the new participants were identified in the events and conferences the researcher attended at the design period of Round 2.

In spite of the attrition effects, the distribution of the experts in academia and industry remained balanced. All of the experts in round 3 participated the previous round of the Delphi study. These two aspects guaranteed the validity and consistency of the Delphi results. In the main text, the citations of the Delphi participants' comments are shown as "DR2-2-A" representing the comment comes from the academic Delph participant No.2 in Round 2. For the comment raised in Round 3 by a practitioner marked as No. 19, then that citation is marked as "DR3-19-P".

Table G-5 Delphi Participant Round 3

Participant	Category	Field/Affiliation	Job title	Years
1	Academia (n=18)	Sustainability	Reader	20+
2		Both	Director of Education	27
3		Both	Associate Professor	7
4		Sustainability	Professor	10
5		Both	Professor	14
6		Both	Professor	18
7		AVs	Associate Professor	22
8		Both	Professor	28
9		Both	Professor	37
10		Sustainability	Professor	5
11		Both	Associate Professor	8
12		AVs	Associate Professor	22
13		Sustainability	Various	25
14		AVs	Researcher	5
15		Logistics	Professor	34
16		Industry 4.0	Associate Professor	5
17		Sustainability	Senior Lecturer	21
18		Sustainability	Research Director	20
19	Industry (n=12)	Industry Consultant	Consultant MHE	28
20		Distribution	COO	30
21		Industry Consultant	Global Head Supply Chain Financing	10

22	Technology Provider	Business Development Lead	5
23	Food and Drink	Logistics Transformation Project manager	20+
24	Industry Consultant	Associate Director	20+
25	Logistics service provider	Transport manager	6
26	Logistics service provider	Managing Director	10
27	Industrial Manufacturing	Pre-sale Manager	3
28	Technology provider	Researcher	7
29	Industry Consultant	CEO	10
30	Logistics service provider	Senior Manager	20

Table G-6 Academic participant information – Round 3

Academics Job Title	No.	Field of Expertise			Years of Experience		
		AVs	SCM	Sustainability	3 - 9	10 - 19	>=20
Reader	DR3-1		√	√			√
Director of Education	DR3-2	√	√	√			√
Associate Professor	DR3-3	√	√	√	√		
Professor	DR3-4		√	√		√	
Professor	DR3-5	√	√	√		√	
Professor	DR3-6	√	√	√		√	
Associate Professor	DR3-7	√	√				√
Professor	DR3-8	√	√	√			√
Professor	DR3-9	√	√	√			√
Professor	DR3-10		√	√	√		
Associate Professor	DR3-11	√	√	√	√		
Associate Professor	DR3-12	√	√				√
Various	DR3-13		√	√			√
Researcher	DR3-14	√	√		√		
Professor	DR3-15		√				√
Associate Professor	DR3-16	√	√		√		
Senior Lecturer	DR3-17		√	√			√
Research Director	DR3-18		√	√			√

Table G-7 Practitioner information - Round 1

Practitioners Job Titles	No.	Field of Expertise			Roles	Years of Experience		
		AVs	SCM	Sustainability		3 - 9	10 - 19	>=20
Consultant MHE	DR1-23	√	√	√	Consultant			√
VP Supply Chain	DR1-24	√	√		Logistics service provider		√	
COO	DR1-25		√		Logistics service provider			√
Global Head Supply Chain Finance	DR1-26	√	√		Consultant		√	
Senior Consultant	DR1-27	√	√		Consultant	√		
COO	DR1-28	√	√		Technology Provider	√		
Business Development Lead	DR1-29	√	√		Technology Provider	√		
Project Manager	DR1-30	√	√		Manufacturer			√
Associate Director	DR1-31	√	√	√	Consultant			√
Transport Manager	DR1-32		√		Logistics service provider	√		
Fellow	DR1-33	√	√		Investor		√	
VP Innovation EU	DR1-34	√	√	√	Logistics service provider		√	
Managing Director	DR1-35	√	√		Logistics service provider		√	
Pre-sale Manager	DR1-36	√	√		Manufacturer			
Head of Division (Gov)	DR1-37	√	√	√	Government			√

Table G-8 Practitioner information - Round 2

Practitioners Job Titles	No.	Field of Expertise			Roles	Years of Experience		
		AVs	SCM	Sustainability		3 - 9	10 - 19	>=20
Consultant MHE	DR2-23	√	√	√	Consultant			√
COO	DR2-24		√		Logistics service provider			√
Global Head Supply Chain Finance	DR2-25	√	√		Consultant		√	

COO	DR2-26	√	√		Technology Provider	√		
Business Development Lead	DR2-27	√	√		Technology Provider	√		
Project Manager	DR2-28	√	√		Manufacturer			√
Associate Director	DR2-29	√	√	√	Consultant			√
Transport Manager	DR2-30		√		Logistics service provider	√		
Fellow	DR2-31	√	√		Investor		√	
VP Innovation	DR2-32	√	√	√	Logistics service provider		√	
Managing Director	DR2-33	√	√		Logistics service provider		√	
Pre-sale Manager	DR2-34	√	√		Manufacturer	√		
Researcher*	DR2-35	√	√		Technology Provider	√		
Supply Chain Executive*	DR2-36	√	√		Manufacturer			√
CEO*	DR2-37	√	√	√	Consultant		√	
Senior Manager*	DR2-38		√	√	Logistics service provider			√
VP Global Innovation*	DR2-39	√	√	√	Logistics service provider			√

Table G-9 Practitioner information - Round 3

Practitioners Job Titles	No.	Field of Expertise			Roles	Years of Experience		
		AVs	SCM	Sustainability		3 - 9	10 - 19	>=20
Consultant MHE	DR3-19	√	√	√	Consultant			√
COO	DR3-20		√		Logistics service provider			√
Global Head Supply Chain Finance	DR3-21	√	√		Consultant		√	
Business Development Lead	DR3-22	√	√		Technology Provider	√		
Project Manager	DR3-23	√	√		Manufacturer			√
Associate Director	DR3-24	√	√	√	Consultant			√
Transport Manager	DR3-25		√		Logistics service provider	√		
Managing Director	DR3-26	√	√		Logistics service provider		√	
Pre-sale Manager	DR3-27	√	√		Manufacturer	√		
Researcher	DR3-28	√	√		Technology Provider	√		
CEO	DR3-29	√	√	√	Consultant		√	
Senior Manager	DR3-30		√	√	Logistics service provider			√

Appendix H Interview Protocol

H.1 Warm-up questions

- What is your professional experience/life experience of AV adoption in supply chains/using the AVs for delivery services? (Example)
- What are your thoughts about SCSS? How important would you suggest the SCSS in the AV adoption context? (Opinions)
- Do you have any comments about the overall links between the social impacts and SCSS indicators? Any additions, adjustments, or deletion? (Suggestions)

H.2 Main questions

H.2.1 Part 1 – Validating the actions and action categories

Objectives: understand what social sustainability aspects do the actions address

- Which SCSS indicators and aspects are these actions generally aligned with/addressing, primarily? (Opinions)

H.2.2 Part 2 – structuring the actions

Objectives: allocate the actions into hierarchical decision-making framework

- Are these actions strategic, tactical, or operational level oriented? (Opinions)

Parts 1 and 2 were asked combined during the evaluation of each of the 8 action categories. Figures H2 to H9 present the images presented to the interviewees during the interviews.

H.2.3 Part 3 – structuring the action categories

Objectives: align the action categories into each stage of Innovation Decision Process model.

- What action categories (shown in Table H-1) would you suggest that can be aligned with each stage/period of the innovation decision process, and in this context, the process of AV adoption (presented in Figure H-1)? (Opinions/Suggestions)

Table H-1 Eight action categories for evaluation

Communications and Stakeholder Involvement	Continuous Improvement	CSR focus	Employment
Planning	Promotion	Regulation Improvement	Real-world experiments

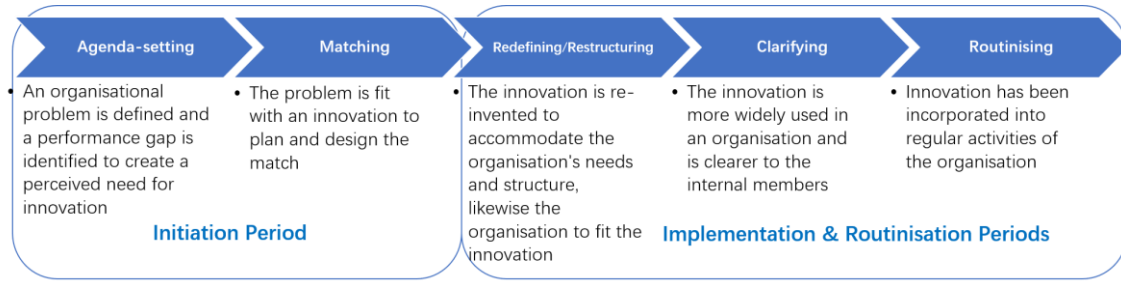


Figure H-1 Organisational IP to be presented

H.2.4 Part 4 – contributions and impacts

Objectives: understand the usage of the outcomes from this study.

- How can academics and practitioners use these models? (Suggestions)
- Would you suggest any extra mechanisms/tools/techniques to consider SCSS in this context? (Suggestions)

H.2.5 Presented pages

Figures H-2 to H-9 present the pages shown to the interviewees during the interviews.

Communications and Stakeholder Involvement		
<ol style="list-style-type: none"> Which SCSS indicators are these actions generally aligned with, primarily? Are these actions strategic, tactical or operational level oriented? <ul style="list-style-type: none"> Clear communications through the whole supply chain among stakeholders; Integrating with stakeholders and communities; Stakeholder journey mapping to check the social changes; Stakeholder involvement, engagement, and participation in developing, planning, and implementation for resistance mitigation; Providing information and setting expectations among supply chain processes; Continuous team meetings with different levels of employees. 	Health and Safety	<ul style="list-style-type: none"> Health and safety of various stakeholder groups such as employees, end-users, communities etc.
	Customer Satisfaction	<ul style="list-style-type: none"> Customer thoughts, preferences, expectations in terms of the products or services provided.
	Employment	<ul style="list-style-type: none"> Labour input and output, productivity, employee satisfaction, unemployment, child/forced labour etc.
	Diversity and Equality	<ul style="list-style-type: none"> Gender equality, diversity, disabled people inclusion, minority development etc.
	Transparency	<ul style="list-style-type: none"> Information sharing, monitoring for supply chain visibility; cybersecurity, and privacy.
	Reputation	<ul style="list-style-type: none"> The image of an organization which represents public sentiment
	Welfare	<ul style="list-style-type: none"> Road traffic congestions and Human interactions in this context.

Figure H-2 CSI for evaluation

Continuous improvement

<ol style="list-style-type: none"> 1. Which SCSS indicators are these actions generally aligned with, primarily? 2. Are these actions strategic, tactical or operational level oriented? <ul style="list-style-type: none"> • Constant development of the technologies and the research of AVs; • Development of working environment for the existing employees; • Change management; • Constant improvement via feedback loops and behaviour measures after the technologies are fully available in the communities; • AV lifecycle status transparency for improved services. 	Health and Safety	• Health and safety of various stakeholder groups such as employees, end-users, communities etc.
	Customer Satisfaction	• Customer thoughts, preferences, expectations in terms of the products or services provided.
	Employment	• Labour input and output, productivity, employee satisfaction, unemployment, child/forced labour etc.
	Diversity and Equality	• Gender equality, diversity, disabled people inclusion, minority development etc.
	Transparency	• Information sharing, monitoring for supply chain visibility, cybersecurity, and privacy.
	Reputation	• The image of an organization which represents public sentiment
	Welfare	• Road traffic congestions and Human interactions in this context.

Figure H-3 CI for evaluation

CSR focus

<ol style="list-style-type: none"> 1. Which SCSS indicators are these actions generally aligned with, primarily? 2. Are these actions strategic, tactical or operational level oriented? <ul style="list-style-type: none"> • Business to be responsible for their actions and focus on CSR; • Regular security and safety checks for reduced stakeholders' risks. 	Health and Safety	• Health and safety of various stakeholder groups such as employees, end-users, communities etc.
	Customer Satisfaction	• Customer thoughts, preferences, expectations in terms of the products or services provided.
	Employment	• Labour input and output, productivity, employee satisfaction, unemployment, child/forced labour etc.
	Diversity and Equality	• Gender equality, diversity, disabled people inclusion, minority development etc.
	Transparency	• Information sharing, monitoring for supply chain visibility, cybersecurity, and privacy.
	Reputation	• The image of an organization which represents public sentiment
	Welfare	• Road traffic congestions and Human interactions in this context.

Figure H-4 CSR focus for evaluation

HR Management

<ol style="list-style-type: none"> 1. Are these actions/decisions strategic, tactical or operational level oriented? 2. Which SCSS indicators are these actions generally aligned with, primarily? <ul style="list-style-type: none"> • Internal organisational upskilling and training programmes for employees to requalify the high-skilled positions; • Cooperation with external training institutions; • New job positions creating; • Recruiting more highly trained and experienced workforce; • Developing reskill strategies for less-educated and lower-skilled employees; • Employee psychological support. 	Health and Safety	• Health and safety of various stakeholder groups such as employees, end-users, communities etc.
	Customer Satisfaction	• Customer thoughts, preferences, expectations in terms of the products or services provided.
	Employment	• Labour input and output, productivity, employee satisfaction, unemployment, child/forced labour etc.
	Diversity and Equality	• Gender equality, diversity, disabled people inclusion, minority development etc.
	Transparency	• Information sharing, monitoring for supply chain visibility, cybersecurity, and privacy.
	Reputation	• The image of an organization which represents public sentiment
	Welfare	• Road traffic congestions and Human interactions in this context.

Figure H-5 HRM for evaluation

Planning

<ol style="list-style-type: none"> 1. Which SCSS indicators are these actions generally aligned with, primarily? 2. Are these actions strategic, tactical or operational level oriented? <ul style="list-style-type: none"> • Design and integrating technologies into supply chain processes; • Integrating Avs into smart cities and collaborate with other technologies; • Appropriate business environment; • Data and information integration; • Appropriate GRC measures, balanced scorecard, and data analysis capabilities; • Route planning. 	Health and Safety	• Health and safety of various stakeholder groups such as employees, end-users, communities etc.
	Customer Satisfaction	• Customer thoughts, preferences, expectations in terms of the products or services provided.
	Employment	• Labour input and output, productivity, employee satisfaction, unemployment, child/forced labour etc.
	Diversity and Equality	• Gender equality, diversity, disabled people inclusion, minority development etc.
	Transparency	• Information sharing, monitoring for supply chain visibility, cybersecurity, and privacy.
	Reputation	• The image of an organization which represents public sentiment
	Welfare	• Road traffic congestions and Human interactions in this context.

Figure H-6 PL for evaluation

Promotion

<ol style="list-style-type: none"> Which SCSS indicators are these actions generally aligned with, primarily? Are these actions strategic, tactical or operational level oriented? <ul style="list-style-type: none"> Promote and introduce the Avs to the communities about the trial results benefits, advantages, and improvement; Promote Avs to the communities risk mitigation methods; Quantifying the benefits compared to the past; Promote the employees for the system's capabilities and interconnectivity. 	Health and Safety	• Health and safety of various stakeholder groups such as employees, end-users, communities etc.
	Customer Satisfaction	• Customer thoughts, preferences, expectations in terms of the products or services provided.
	Employment	• Labour input and output, productivity, employee satisfaction, unemployment, child/forced labour etc.
	Diversity and Equality	• Gender equality, diversity, disabled people inclusion, minority development etc.
	Transparency	• Information sharing, monitoring for supply chain visibility, cybersecurity, and privacy.
	Reputation	• The image of an organization which represents public sentiment
	Welfare	• Road traffic congestions and Human interactions in this context.

Figure H-7 PRM for evaluation

Real-world experiments

<ol style="list-style-type: none"> Which SCSS indicators are these actions generally aligned with, primarily? Are these actions strategic, tactical or operational level oriented? <ul style="list-style-type: none"> Trial of AVs to prove concepts and benefits in small-scale place preliminary; Preventative measures for drone designs; Tests the integration of airspaces. 	Health and Safety	• Health and safety of various stakeholder groups such as employees, end-users, communities etc.
	Customer Satisfaction	• Customer thoughts, preferences, expectations in terms of the products or services provided.
	Employment	• Labour input and output, productivity, employee satisfaction, unemployment, child/forced labour etc.
	Diversity and Equality	• Gender equality, diversity, disabled people inclusion, minority development etc.
	Transparency	• Information sharing, monitoring for supply chain visibility, cybersecurity, and privacy.
	Reputation	• The image of an organization which represents public sentiment
	Welfare	• Road traffic congestions and Human interactions in this context.

Figure H-8 RWE for evaluation

Regulation improvement

<ol style="list-style-type: none"> Which SCSS indicators are these actions generally aligned with, primarily? Are these actions strategic, tactical or operational level oriented? <ul style="list-style-type: none"> Regulatory Measures for safety, accountability, and privacy; No fly zones; Data collection and operations protocol; Transnational legislative approval; Regulations and legal guides, frameworks for approving each type of technology in different scenarios; Financial subsidising the delivery solutions; Social-wide regulations to mitigate the outcomes of unemployment due to automation; Federal guidance for adoption and certifications. 	Health and Safety	<ul style="list-style-type: none"> Health and safety of various stakeholder groups such as employees, end-users, communities etc.
	Customer Satisfaction	<ul style="list-style-type: none"> Customer thoughts, preferences, expectations in terms of the products or services provided.
	Employment	<ul style="list-style-type: none"> Labour input and output, productivity, employee satisfaction, unemployment, child/forced labour etc.
	Diversity and Equality	<ul style="list-style-type: none"> Gender equality, diversity, disabled people inclusion, minority development etc.
	Transparency	<ul style="list-style-type: none"> Information sharing, monitoring for supply chain visibility, cybersecurity, and privacy.
	Reputation	<ul style="list-style-type: none"> The image of an organization which represents public sentiment
	Welfare	<ul style="list-style-type: none"> Road traffic congestions and Human interactions in this context.

Figure H-9 RI for evaluation

Appendix I Evidence from interviews

This section of appendix provides evidence examples from the interviews regarding the SCSS indicators being addressed by action categories through the following nine tables.

Table I-1 CSI evidence

Content	SCSS Indicators	Sample Quotes
CSI	Health and Safety	<p>“So, a lot of these communications with stakeholders and providing information and so on, a lot of them are either to make sure of the health and safety, but more important maybe to communicate to stakeholders that they are safe is I think that's really the stage we are in right now.” (In3-A)</p> <p>“Health and safety for the various stakeholder groups, communities in users. It's you know that that's a biggie. Health and safety is a biggie, if these AVs have risks, particularly to the community, then I do think it's going to be a problem.” (In4-A)</p>
	Employment	<p>“And continuous team meetings and different levels of employees. Because that's we had the classic implementation monitoring and control that would very much be the control side of it. And of course, the continuous team meetings at different levels of employees, that would be maybe. Employment, obviously.” (In4-A)</p> <p>“We just cannot get enough people to do the jobs. And we are not desperate. So, these AV has not seen as being technologies now not seen as taking jobs. It's actually losing people to do jobs. Yeah, so. And I think that when you talk about social changes, it doesn't necessarily have to have a negative connotation at the moment. It would be a very positive connotation.” (In4-A)</p>
	Transparency	<p>“I think transparency is certainly the most, the most important for me. And in terms of because I think it has an operational risk as well which is if you don't have transparency, you're generally not get trust and if you don't get trust, you'll struggle with change management and the implementation of these transformational changes within an organisation.” (In2-P)</p> <p>“Communication definitely addresses transparency. I think transparency is just is a key here. Because in any you know particularly this this type of adoption where you, I think everybody wants to be more sustainable, right. But I think the you know we hear things about like green washing we hit people because it's quite an invasive technology in the sense of all the negative things that you talked about. I think people want to trust; they want to be able to trust the</p>

		<p>communications. And that comes from transparency. I think transparency is absolutely critical in in this particular one for the communication.” (In4-A)</p> <p>“Because the whole, communicating, providing information, integrating, and also the meetings. So, transparency to me is the one at the highest level here.” (In5-A)</p> <p>“Transparency is something that the way that you go about all those issues from clear communications through the continuous team meetings.” (In6-A)</p> <p>“Should be about transparency, I think. About information sharing, yeah, because when we communicate, we should share information among stakeholders. So, this is why where I would put it. And visibility maybe. It's, of course, about transparency, providing information and setting expectations among supply chain processes. When you have expectations are, you'll have to monitor so it will fall on the transparency.” (In9-A)</p> <p>“Clear communication means like a real-time communication sharing is more about transparency” (In12-P)</p>
	Reputation	<p>“We need people to trust them. I don't feel that there's, I don't think society has a full trust on these of AVs yet so I think that's definitely one of the key indicators, they're sort of related people are not you as often you see negative articles in the media and people aren't you know they heard that there was an accident with Google Car or something you know people. So, I think a lot of the communication and stakeholder work is to try to deal with these types of transparency and reputation at the moment.” (In3-A)</p>
	Diversity and Equality	<p>“I think it's just a matter of communication and education. And for elder community, I think we'll get on board very quickly if we give them the right amount of support and didn't and intervention.” (In7-A)</p> <p>“Stakeholder and involvement, engagement and participation, developing planning and implementation for resistance mitigation. This has been around. It's very, very important. And it has been around. You are doing urban mobility initiatives; you need the stakeholder involvement. Actually, most of the tools out there in that respect require a lengthy involvement of the stakeholders and participation, so a number of participatory events and so on.” (In13-A)</p>
	Customer Satisfaction	<p>“I would go to customer satisfaction. So, we are meeting the journey. The solids they could become more satisfied, but check the social changes.” (In9-A)</p> <p>“Communication is very important for transparency and improving customer satisfaction at the end.” (In14-A)</p>

Table I-2 CI evidence

Content	SCSS Indicators	Sample Quotes
Continuous Improvement	Health and Safety	<p>“That might be a health and safety one. You might be recording potential hazards or near misses, hopefully not accidents. So that probably is linked to whether the working environment is actually providing the benefit.” (In1-A)</p> <p>“There's a health and safety element of any continuous improvement and making sure that it's adequately tested, making sure that it's been proven safe in new environments, particularly when you're doing things that involve working at height or with heavy machinery or involving new energy technology.” (In2-P)</p>
	Customer Satisfaction	<p>“I think customer satisfaction is absolutely crucial there in terms of the way that you're developing technologies and research. I think it's probably going to be your biggest focus there. Yeah, that that customer satisfaction is going to be crucial.” (In6-A)</p>
	Employment	<p>“Change management is interesting, because you need to start working on the processes and the procedures that you have with the company. And this is one of the most difficult things to do at the moment, from like, changing mindsets and cultures down to changing the way that you are approaching things, E.G. Now, how do you do it? We have a truck that comes in. One example, comes into the warehouse, sort of like those the park, goes to the gate, and then you can load and unload things. You have a UAV. And if that UAV is sort of on the surface, it might be a similar case. But if it's an air-based UAV, then this is a lot more difficult for people to, like, pay attention to everything.” (In13-A)</p>
	Reputation	<p>“And you know, and as with any continuous improvement and there's a reputation issue that needs to be considered, you know, to use the technologies and there needs to be considered with any changes that you make because it can be a positive or a negative.” (In2-P)</p> <p>“In terms of reputations for companies, every company will make them have a problem. That's how they address those problems and what issues they have. Whereas if they just do nothing. Then the reputation is not good.” (In4-A)</p>

		<p>“Constant development of the technologies and the research of AVs. It might be about reputation because you see you showed the value that you pay to those technologies to that development. So, I would put it on the reputation.” (In9-A)</p>
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Table I-3 CSR focus evidence

Content	SCSS Indicators	Sample Quotes
CSR focus	Health and Safety	<p>“there's health and safety impact and when it comes to being responsible” (In2-P)</p> <p>“I would say in terms of the security and safety checks, definitely it's in the. Health and safety.” (In5-A)</p>
	Customer Satisfaction	<p>“Considering the impact CSR has I think particularly in this day and age the importance of being a responsible organization and is imperative and will be imperative to your customers. And therefore, I think you're going to see more consumer choice move away from organisations that don't show strong CSR governance.” (In2-P)</p> <p>“Also, customer satisfaction, you are not going to if the AV is interacting with the customers, you don't want that to be affected negatively.” (In5-A)</p>
	Transparency	<p>“I think you need to be transparent to prove that and demonstrate that. And I think that transparency probably to me aligns with the word integrity. And I think that any, any organisation that has CSR and you know that is that is genuinely responsible and ethical and sustainable and environmentally conscious must be transparent in the way in which they govern. And as we would want any organisation that governs us to be.” (In2-P)</p> <p>“Think of CSR's. Any major supply chain management infrastructure company, their annual reports. And then all say the exactly the same thing. What it does is it gives you the quantification to say all right then this is not just the yearly figure. This is the figure by region. And this is the figure by category and this is the figure by type. So, we can start to identify areas where there are opportunities for improvement. Because the last thing we want to do with any of this is push it into the ground” (In7-A)</p>
	Reputation	<p>“How CSR set up within the organization's reputation will also be crucial then. Because typically things the directors are looking for, they're looking not only for the company to be responsible, but to be seen to be responsible. So, reputation is going to be important.” (In6-A)</p>
	Employment	<p>“But you'd be measuring specifically I suspect around your impact on employee welfare, you might have a whole raft of things that you're measuring at this point.” (In1-A)</p>

Table I-4 HRM evidence

Content	SCSS Indicators	Sample Quotes
HR Management	Health and Safety	<p>"It would be an interesting point, yeah. Or do you need a different driver's license? On the other hand, the non-interference with the physical environment and have everything just through cameras and so on. But I guess it is doable. We look at the monitors for hours anyway. Yeah, and even such autonomous vehicle, maybe you can hand it over to a colleague for a 5-minute break or something like this or you slow it down to, I don't know, 60 km/h then you let it drive it on its own for the next straight kilometres on the motorway." (In10-A)</p> <p>"Psychological support I think really health and safety." (In12-P)</p>
	Customer Satisfaction	<p>"Being able to take use this data to drive evidence-led decisions, and those evidence-led decisions could be the ones that I particularly think are going to be useful are in doing better planned preventive maintenance of the vehicles. I do some plan preventive maintenance on it rather than it to break down halfway through the cycle of operation. Nevertheless, it's a very, very integral part of the network, so. If that fails, it has a ripple effect and it's only got a failure for 10 or 15 minutes and then it will have a significant ripple effect throughout that shift." (In7-A)</p> <p>"Corporation with external training institutions. This will be relevant to the customer satisfaction" (In12-P)</p>
	Diversity and Equality	<p>"And coming into the industry and diversity, so at the moment what we have is you know in, in the in the material handling storage industry is 97% of leadership roles are fulfilled by white, male. And that doesn't equate to having, an employment structure of the future, it inhibits innovation and it prevents education and you know, education and widening of the horizons that we need to be able to actually transform the organization." (In2-P)</p> <p>"Because women may not have been involved in certain sectors before. But now because of AV. I also can become a part of this system. So that it applies to new job positions being created. And reskilling strategies, both male and female. So, diversity and equality as well" (In5-A)</p>
	Employment	<p>"Skilling could be a significant amount of retraining and realignment within the organization or it could be a relatively low amount of upskilling where part of the network is going to be broadly similar to the networks</p>

		<p>that it's been evolved from, but they're still there, has to be upskilling in terms of date or access.” (In7-A)</p> <p>“It's all about How does the skills mix change? you've got a certain type of job which effectively ramps down and then you've got another type of role which ramps up. And you need to really plan the transition as you move from one to the other. And you know the idea that, well, you just take some of your drivers and you, sort of reskill them and, programmers and things probably doesn't work. You might find one or two of them actually can make that transition, but actually a lot of them won't be able to. And actually, a lot of them won't want to do it either. So, when you get to the operating model thinking in terms of this upskilling and training, the first thing to identify is what capabilities you actually need. Because by identifying the capabilities that you understand that either things like you have to maintain the robots so, you know, a maintenance capability has to be developed now is that maintenance capability different to the maintenance capabilities you've already have or is it essentially the same skills?” (In11-P)</p>
	Reputation	<p>“So, the social impact will vary according to the job density in that environment. Yeah, you could close a warehouse in in Milton Keynes, and people would find work fairly quickly. Yeah. If you close the warehouse in a more rural location, and it's the main employer for many miles around. That's more difficult. So again, that could be vocational. The opportunities for those laid off would be different. And the reputational damage is different.” (In1-A)</p> <p>“Having a culture of growing your employees, the employees are important. And one could argue sometimes too, that that's customers satisfaction as well because you know yourself that with particularly in fashion now. A lot of people are saying if it's been so and then one of these sweat factories, they won't buy it. But that's maybe more reputation. Setting the culture that you know we do not fire people. We are one into sustainability that means we're considered the welfare of our staff. And it's not a matter of just hire and fire when we need people. So that definitely happened. That's a culture.” (In4-A)</p> <p>“It depends on cooperation with what training institutions, but it will definitely help you to improve employment, and reputation” (In14-A)</p>

Table I-5 PL evidence

Content	SCSS Indicators	Sample Quotes
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Planning	Health and Safety	<p>“So, they might be looking at, potentially will there be any accidents? What will be the severity of those from past experience? They might be looking at that. Yeah. If you try and look at all of those blue boxes on the right-hand side. I guess the issues for a lot of AVs if you looked at in cities, in smart cities.” (In1-A)</p> <p>“And if from my perspective and clearly health and safety should be a number one priority in any plan and to ensure that people are safe. And I think when you're talking about planning at a governmental level or a Council level such as in the environments of smart cities.” (In2-P)</p>
	Customer Satisfaction	<p>“That's so crucial issue there I think relates to customer satisfaction because if I look at the way that you've structured those, those six bullet points, it's very much about being able to execute the developing your plans and being able to execute on your plans. The primary purpose of those plans is to run the supply chain. Customer satisfaction is going to be crucial,” (In6-A)</p> <p>“The customers, those who have increased mobility needs, they will be able to get better services. Now, with drones, if we had like cabs like that, we could do it more easily, right? Or more widespread, because you don't have a small cab like going to pick them up.” (In13-A)</p>
	Employment	<p>“Appropriate business environments. It's about, Employments,” (In9-A)</p> <p>“GRC, balanced scorecard, Employment” (In12-P)</p>
	Transparency	<p>“What I think people mistrust is a lack of understanding of the vision and the holistic impact of that vision. And I think that if planning is not, you know, if plans are to an appropriate level transparent. And then I think what you do is you lose people along the way and what you garner and what you create is mistrust, mistrust in technology that actually undermines itself and it undermines all the positive impacts of it. So, I think that transparency is important”. (In2-P)</p> <p>“Data and information integration. It is about transparency. You share information, data, gather it, share it, use it. So, it's about transparency to me” (In9-A)</p>
	Diversity and Equality	<p>“And there that we gain the consideration of diversity and equality there and making sure that this technology doesn't work just for those who are able or able to afford it. And I think that's key. I think that's key.” (In2-P)</p>
	Welfare	<p>“You know that we are taking it from a planning perspective that's probably one of the most important aspects and is considering the welfare of the society in which that serves.” (In2-P)</p>

		<p>“Welfare there, traffic congestion. And so, if that whole thing of data management and smart cities is will relate to that.” (In3-A)</p> <p>“Route planning definitely about welfare because of the congestion.” (In9-A)</p>
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Table I-6 PRM evidence

Content	SCSS Indicators	Sample Quotes
Promotion	Health and Safety	<p>“So that's where the promotion and introduction of AVs into communities to customers in a good way improves the health and safety. There are all kinds of mechanisms there to prevent you from hurting yourself.” (In5-A)</p> <p>“Health and safety is certainly will constitute some of the benefits, advantages and improvements. But there are presumably a whole bunch of other benefits, advantages, advantages and improvements, so I wouldn't look at health and safety as necessarily a primary link thing. If, however, the majority of those benefits are health and safety, then definitely that's the case.” (In6-A)</p>
	Customer Satisfaction	<p>“So, satisfaction may actually increase with customers. Because they start seeing OK, there are significant benefits cycle time reduction, you know, quality improvement, less damage goods, accurate delivery, you know and quick delivery. So, yeah, I think customer satisfaction definitely huge.” (In5-A)</p> <p>“And you had seen the networks, which were planned to become widespread across Dunstable or Luton. Yeah, entirely different communities. You'd have to approach each one of those communities differently.” (In7-A)</p> <p>“And it is about again the customer satisfaction because you improved your numbers, you are you are you have you increased your throughput; you are selling more with less cost let's say. So, which might be the reason to reduce your price as well. So, it's all customer satisfaction in my opinion.” (In9-A)</p>
	Transparency	<p>“It's getting that community at a very early stage through. None of these will come as a surprise to them. They'll see this as a natural development over time. So, this could be even things like, as you're starting to develop your network and what the network looks like. Then you can start promoting that network through civic interactions with external stakeholders.” (In7-A)</p> <p>“Quantifying the benefits compared to the past transparency.” (In8-A)</p>
	Employment	<p>“And then also, obviously the employment side because you're dealing with in this block, you also dealing with</p>

		<p>the employees as well. So that's your other primary stakeholder here." (In6-A)</p> <p>"The truck driver shortage alone will be enough promotion. Everybody will be happy so to say because if either the driver gets a better job or once more, we get a better capacity utilization needing less trucks, having less CO2 emissions and more smooth delivery in these kinds of things, that should be all good." (In10-A)</p>
	Diversity and Equality	<p>"I think, trying to establish the benefits that the AVS could bring. So, a good example if you had remote home delivery processes then that could be very beneficial to disabled or more elderly people. it could improve access." (In1-A)</p> <p>"We need to promote this and you know these types of technologies and the capability and the interest in coming into these industries to the to a diverse audience of people to ensure that we get the best chance of innovation and the best and we ensure that it works for them all and not just the majority and which is something that I don't think we've done very well in the past and necessarily so I would choose diversity and equality as being the most important." (In2-P)</p>
	Reputation	<p>"I mean it's all related to reputation, but it's all of those things. Convince people that they're safe. Convince people that you're going to share the information and you're not. It's not just a way for some an evil software company to take all their information." (In3-A)</p>

Table I-7 RWE evidence

Content	SCSS Indicators	Sample Quotes
Real-World Experiments	Health and Safety	<p>"I would say would be health and safety and any form of experiment comes with a risk that needs to be managed. health and safety is probably the most important one in the any form of experimentation and particularly when I can see the word airspaces and drones on the side there because clearly I am bit concerned about this, about the facts that they're, you know, we might soon have payloads of half a ton waving around their heads with no one driving it and that would be concern to me." (In2-P)</p> <p>"So first of all, you want to check there is actually safe on the roads to be able to do it, and then the second thing you want to trial is how useful is it for moving goods around or whatever it is you're trying to do." (In11-P)</p> <p>"It's what aspects they're going to be tested. And because back to the promotion, how you will be promoting, because the proof of concept is there, we have already done it, there are a lot of benefits. But the thing is, how you train the users? In the state called this in accepting</p>

		those, e.g., the buzzing? I mean, a lot of people are quite negative on the noises that the drones are making, or producing. So, I think that, these actions, go to be a health and safety and I try to prove that it's a healthy and safe operation." (In13-A)
	Customer Satisfaction	<p>"Trial of AV to prove concepts. Customer satisfaction." (In8-A)</p> <p>"AV to prove concept and the benefit in small scale place. This will be customer satisfaction." (In12-P)</p>
	Transparency	<p>"Could be the benefits would be particular. Maybe information sharing, monitoring of visibility, cyberspace and privacy that would be testing" (In4-A)</p> <p>"There's just not enough evidence to suggest that smart motorways because of the lack of maturity are more dangerous than standard motorways, or just as dangerous as smart as standard motorways. Because what will undoubtedly find is they are going to be much safer." (In7-A)</p>
	Welfare	<p>"In terms of if you extend welfare from Rd. traffic congestion. Human interactions. Yeah. Here we're talking air. Potential air-Human interaction. So, if I'm understanding correctly, the welfare is getting in. In terms of the integration of airspaces." (In6-A)</p> <p>"And also, the welfare, of course. So that you make sure you won't have congestions. So, you try those concepts and see the benefits or the challenges that it brings." (In9-A)</p>
	Reputation	<p>"You're the authorities are going to be more lenient in terms of allowing stuff happening, if you've got a good reputation." (In6-A)</p> <p>"This is the terrible thing of that with social media as well. We see a relatively few amounts of people, families whose family member has died because of the smart motorway, between rescue islands. You don't see people saying, 5-10 five years ago my husband told me wife died in the motorway crush. Let's not have any more motorways so they'll accept motorways and the accept the inherent danger of a motorway. But the not accept smart motorways, even though they're going to be a lot safer." (In7-A)</p> <p>"You show people that you're doing this and double check this, then they will feel you have done the job you should do. Otherwise, the people might be in doubt like about how you did it. It's the reputation perceived by people and government and other stakeholders. If you test the integration of air spaces, you improve your reputation in front of other stakeholders." (In14-A)</p>

Table I-8 RI evidence

Content	SCSS Indicators	Sample Quotes
Regulation Improvement	Health and Safety	<p>"Most important for regulation, health and safety, isn't it? And I think that has to be the number one priority and is probably making sure that people are safe. we have to make sure that first and foremost, people need to be safe and this technology, you know, the decisions we make need to be and for the benefit of people." (In2-P)</p> <p>"The regulator doesn't care so much if you don't make any money or you it turns out to not be a good strategy from a business perspective, but they care about if there's one accident, if there's if an AV kills one person, it's a disaster." (In3-A)</p>
	Customer Satisfaction	<p>"Financial subsidies that deliver solutions. Customer satisfaction? For example, like EV, EV subsidiaries, right? So, customers really satisfy for that kind of product solutions? You can adopt it easily, so that's relevant to the customer satisfaction." (In12-P)</p> <p>"Customers need to know how the organisations operate with activity, the way they with the data. I guess it will affect their satisfaction" (In14-A)</p>
	Transparency	"Data collection and operational protocol. These would be transparency. Measures for safety, accountability and the privacy. Transparency." (In12-P)
	Employment	"Mitigating unemployment outcomes would also could be part of the regulations that you have to include these people." (In4-A)
	Diversity and Equality	<p>"We need to make sure that we take everyone with us." (In2-P)</p> <p>"Financial subsidizing for delivery solutions typically this is an issue in the countryside. This is always the argument that you will also have in the UK as long as you are in Berlin, Frankfurt or London, it's not an issue. Then you have Amazon is willing to deliver you three times a day. Yeah. But if you are in some rural places in South Wales. Yeah. Or if you are in Cornville, in the village. What will you get when?" (In10-A)</p>
	Reputation	"So early adopters would get an advantage, later adopters don't. And to me the subsidy that the money is using subsidy be better creating the infrastructure which will enable the adoption of AVs to be simpler. Yes. So, the fact for instance, that

		government has recently removed some of the subsidy from electric cars, to invest in infrastructure for charging, to make it easier to have an electric car makes a lot more sense to me. My view is subsidies that is generally picked up by the bigger companies because they know how the process works. And therefore, they're probably the people that could afford to make the investment anyway, but they're the ones who get subsidised and the medium and smaller companies who don't have people that know how it works, often don't pick up on the subsidies and therefore they now can't compete." (In2-P)
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Table I-9 IP alignment evidence

IP stage	Added action category	Sample Quotes
Agenda-setting	CSR focus	<p>"I wonder whether CSR focus does not also have a component in terms of agenda setting. Because it goes into how we do things around here within the organization. I still think that is. That needs to be higher up the earlier if you like in the decision-making process." (In6-A)</p> <p>"CSR focus in agenda setting." (In13-A)</p>
Matching	CSR focus	"CSR focus - And I think that there needs to be a CSR focus at matching because you need to be matching technology that aligns with your CSR needs, and so I don't think that you can move that away." (In2-P)
	Promotion & Employment	<p>"Regulation improvement, CSR focus, employment" (In3-A)</p> <p>"Matching is more about planning, and promotion;" (In13-A)</p>
	Regulation Improvement	"In fact, you might end up stopping here because regular regulations need to improve. So close real-world experiments and new for drones. But the legislation hasn't allowed the operation yet. Regulation improvement is required. So that there's a there's probably a stop check. Why even bother planning to do it if you can't do it. Well, if we don't do it, and we don't show experiments, how are we going to put the pressure on legislators to change the legislation? We've got to prove that it's technically feasible, that there are benefits and therefore we can put pressure on to make change. So, I don't think that's the last step in this process." (In1-A)

		<p>"We cannot integrate it into the internal organisation if there is no regulation improvement. How can we use it in organisations if there is no regulation improvement?" (In14-A)</p>
Redefining/Restructuring	Employment	<p>"Employment – they might need to know if earlier that they are going to have these technologies adopted by the company." (In9-A)</p>
Clarifying & Routinising	CSR focus	<p>"I would have here is the CSR focus when you're clarifying is different CSR focus you have when your routinising because for me that's been about measurement. That would be more around measurement at this point. So, if you think what your CSR impacts are likely to be but here in routinising you'd be measuring it it's not just a focus because it's much more than that. It's about measurement specific. Because that they are slightly different as you move from that." (In1-A)</p>
Implementation stages	Continuous Improvement	<p>"I think it's around continuous improvement, but I do think there's a cyclical map with when it comes to planning, so it's not so much planning as it is being aware of the alternative options, but I think that probably is covered with continuous improvement and to some degree." (In2-P)</p> <p>"Well, when I saw this, I was immediately put in mind of Demmings continuous improvement cycle. Basically, this is it. It's planning, doing, checking, acknowledging. That acknowledgment comes in the routinising and operationalization. So, I actually think you flows are very good and it's fit for purpose in this as it stands as a framework. I think it's a very, very good framework. It's a very well-developed framework." (In7-A)</p> <p>"When you're saying innovation, it's not like one cycle, then we're done with it. Go away. It's like a Deming cycle. Hmm. You are familiar with the Deming cycle. Deming cycle. That pretty much like the PDCA. It's like that. So, you have like a continuous cycle there. So, you do the innovation, you sort of come up with, uh, sort of an assessment of what was okay, what went wrong. And so on. You take this feedback into your design redesign loop again and again and again. And because we are quite happy with this process with, especially with the drones, we are not quite sure what works and what doesn't work." (In13-A)</p>

Appendix J Interviewee profiles

Table J-1 Interviewee profiles

Interviewee	Category	Job title	Years
1	Academic (A)	Professor	34
2	Practitioner (P)	Managing Director	10
3	Academic (A)	Professor	14
4	Academic (A)	Senior Lecturer	21
5	Academic (A)	Professor	37
6	Academic (A)	Visting lecturer	25
7	Academic (A)	Director of Education	27
8	Academic (A)	Professor	5
9	Academic (A)	Researcher	5
10	Academic (A)	Professor	18
11	Practitioner (P)	Associate Director	20+
12	Practitioner (P)	CEO	10
13*	Academic (A)	Associate Professor	22
14*	Academic (A)	Associate Professor	8

Table J-1 provides an overview of the interviewee profiles. The interviewees marked with “*” are pilot testers. In the main text, academic interviewees are marked as “In1-A”, whereas the practitioners are marked as “In2-P”.