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DEPARTMENT OF
SCIENCE & TECHNOLOGY

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

INDIAN AUTOMOTIVE SECTORIAL SYSTEM OF INNOVATION (IASSI)

United Nations Industrial Development Organization (UNIDO) &
Department of Science & Technology, Government of India

March 2023

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INDIAN AUTOMOTIVE SECTORIAL SYSTEM OF INNOVATION (IASSI) – MEASUREMENT, ANALYSIS AND POLICY RECOMMENDATIONS

UNIDO-DST Survey Report

March 2023 Vienna, Austria

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डॉ. जितेन्द्र सिंह
राज्य मंत्री (स्वतंत्र प्रभार)
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राज्य मंत्री, प्रधान मंत्री कार्यालय;
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राज्य मंत्री परमाणु ऊर्जा विभाग तथा
राज्य मंत्री अंतरिक्ष विभाग
भारत सरकार

सत्यमेव जयते

Dr. JITENDRA SINGH
Minister of State (Independent Charge)
of the Ministry of Science and Technology;
Minister of State (Independent Charge)
of the Ministry of Earth Sciences;
Minister of State in the Prime Minister's Office;
Minister of State in the Ministry of Personnel,
Public Grievances and Pensions;
Minister of State in the Department of Atomic Energy and
Minister of State in the Department of Space
Government of India

MESSAGE

I am pleased to extend my warmest congratulations to the Department of Science and Technology (DST) and the United Nations Industrial Development Organization (UNIDO) on the successful completion of the National Manufacturing Innovation Survey (NMIS) 2021-22. The results of the survey provide significant insight into the state of innovation in India's manufacturing sector. The Government of India has been steadfast in its commitment in promoting the competitiveness of Indian manufacturing and increasing its contribution to the GDP. In the past decade, key policies and programmes have been implemented to stimulate innovation, entrepreneurship and the adoption of new technologies. Additionally, large-scale incentive schemes have been introduced to foster growth and innovation in the manufacturing sector, positioning India as a global manufacturing hub.

The findings of the NMIS 2021-22 can add significant value to the Make in India programme objective, and, the more recent Production Linked Incentive (PLI) scheme. These initiatives aim to enhance manufacturing in various sectors, including electronics, pharmaceuticals, and automobiles, and have already demonstrated positive outcomes. The study's recommendations will undoubtedly strengthen our efforts to address the challenges and opportunities in manufacturing that require immediate attention.

I would once again like to applaud DST and UNIDO for their fruitful collaboration in bringing out NMIS reports and offering recommendations for continued growth and success of the Indian manufacturing sector.

(**Dr. Jitendra Singh**)
MBBS (Stanley, Chennai)
MD Medicine, Fellowship (AIIMS, NDL)
MNAMS Diabetes & Endocrinology

Anusandhan Bhawan, 2, Rafi Marg
New Delhi - 110001
Tel. : 011-23316766, 23714230,
Fax. : 011-23316745

South Block, New Delhi – 110011
Tel. : 011-23010191 Fax : 022-23017931
North Block, New Delhi – 110001
Tel. : 011-23092475 Fax : 011-23092716

सचिव
भारत सरकार
विज्ञान एवं प्रौद्योगिकी मंत्रालय
विज्ञान एवं प्रौद्योगिकी विभाग

डॉ. एस. चंद्रशेखर
Dr. S. Chandrasekhar

Secretary
Government of India
Ministry of Science and Technology
Department of Science and Technology

FOREWORD

I am pleased to present the National Manufacturing Innovation Survey (NMIS) 2021-22 report on behalf of the Department of Science and Technology (DST), Government of India. The significance of this study lies in the government's prioritization of the manufacturing sector as a critical driver of economic growth and job creation in India, and the launch of several initiatives to catalyse innovation across the industry.

NMIS 2021-22, a follow up of first Indian innovation survey in 2011, is a focused effort to evaluate the state of innovation in India's manufacturing sector. In collaboration with the United Nations Industrial Development Organization (UNIDO), this survey provides a comprehensive understanding of the Indian manufacturing innovation landscape.

The NMIS 2021-22 findings offer valuable insights into the enabling characteristics and barriers to innovation faced by firms, and closely evaluated the performance of states and sectors in terms of producing new products and services. The detailed analysis of the survey results provides valuable insights into the innovation ecosystem in India. I anticipate this report to be of great interest to policymakers, researchers, and practitioners in the field of innovation and economic development.

Furthermore, the findings and recommendations of NMIS offer strong insights for strengthening the scope of the 5th National Science, Technology and Innovation Policy (STIP) (draft), to enable a holistic ecosystem for science, technology, and innovation that includes academia, industry, government, and civil society, with a stronger vision for manufacturing innovation to bolster the Make in India agenda.

I am confident that these reports will serve as an essential resource for all those interested in the state of innovation in India, providing valuable information that can contribute to the development of policies and initiatives that can foster a more innovative and dynamic manufacturing sector in the country.

(S. Chandrasekhar)

Technology Bhavan, New Mehrauli Road, New Delhi - 110016
Tel: 0091 11 26511439 / 26510068 | Fax: 00 91 11 26863847 | e-mail: dstsec@nic.in | website: www.dst.gov.in

Preface by Mr. Ciyong Zou, UNIDO Deputy to the Director General and Managing Director for publication of "the National Manufacturing Innovation Survey 2021-2022"

It is with great pleasure that I introduce the National Manufacturing Innovation Survey (NMIS) 2021-2022 report. Jointly conducted by the Department of Science and Technology (DST) of the Ministry of Science and Technology of India and the United Nations Industrial Development Organization (UNIDO), this report aims at comprehensively assessing the state of manufacturing innovation in India towards the achievement of the 2030 Agenda for Sustainable Development, especially Goal 9, and beyond.

As the only specialized agency of the United Nations mandated to promoting inclusive and sustainable industrial development, UNIDO recognizes the critical role that innovation plays in driving economic growth and job creation in the manufacturing sector. We are proud to partner with the DST in this endeavour to assess the state of innovation in India's manufacturing sector.

The NMIS 2021-2022 is a comprehensive study that provides a detailed understanding of the innovation landscape in India's manufacturing sector through a firm-level and systems analysis of innovation. The firm-level component of the survey examines the performance of firms across states, sectors, and firm sizes in terms of innovation processes, outputs, and barriers, and evaluates the innovation ecosystem that affects the innovation outcomes. The sectorial systems of innovation component provide insights into the collaborative processes between innovation stakeholders in specific industrial sectors, such as automotive, pharmaceutical, textiles, food and beverages, and information and communication technologies (ICT).

The findings of the NMIS 2021-2022 serve as a valuable resource to policymakers, researchers, and practitioners in the field of manufacturing, innovation, and economic development. The report highlights the enabling factors and barriers to innovation in the manufacturing sector and provides valuable insights for strengthening the ecosystem for science, technology, and innovation in India. The recommendations contained in this report will not only contribute to the development of national policies and initiatives but can also guide other countries in the region on ways to foster a more innovative and dynamic manufacturing sector.

I would like to express my sincere appreciation to the DST and the technical advisory committee for their valuable contributions to the NMIS 2021-2022. I also extend my gratitude to all the survey respondents who provided their insights and valuable information for this study serving as a public good. UNIDO is eager to continuing the long-standing collaboration with the Government of India in promoting inclusive and sustainable industrial development.

Ciyong Zou
Deputy to the Director General and Managing Director,
Directorate of Technical Cooperation and Sustainable Industrial Development,
United Nations Industrial Development Organization (UNIDO)

वरिष्ठ सलाहकार एवं प्रमुख
नीति समन्वय एवं कार्यक्रम प्रबंधन प्रभाग
विज्ञान और प्रौद्योगिकी विभाग
विज्ञान और प्रौद्योगिकी मंत्रालय
भारत सरकार

डॉ. अखिलेश गुप्ता
Dr. Akhilesh Gupta

Senior Adviser & Head
Policy Coordination & Programme
Management Division
Department of Science and Technology
Ministry of Science and Technology
Government of India

PREFACE

The National Manufacturing Innovation Survey (NMIS) 2021-22 is a significant step towards assessing manufacturing innovation in India. The objective of the survey was to evaluate the performance of states, sectors, and firm sizes in terms of innovation processes, outcomes, and barriers, as well as the innovation ecosystem that affects innovation outcomes. The NMIS 2021-22 offers a comprehensive understanding of manufacturing innovation in India from all perspectives.

The Department of Science and Technology (DST), in collaboration with the United Nations Industrial Development Organization (UNIDO), has developed the first Indian Manufacturing Innovation Index (IMII) for guiding decision-making in innovation policy with respect to manufacturing and related services. The significant difference in the IMII score captures the variations in manufacturing across the states.

The “Assessment of Firm-Level Innovation in Indian Manufacturing” report provides a comprehensive and in-depth analysis of innovation activities, outcomes, and barriers in manufacturing firms. Additionally, the NMIS 2021-22 survey produced five reports studying the sectorial systems of innovation within manufacturing sectors, namely, Automotive, Pharmaceutical, Textiles, Food & Beverages, and Information & Communication Technologies (ICT). These reports examine the collaborative processes between innovation stakeholders and the innovation systems available to specific industrial sectors.

The key findings from the study demonstrate that innovation is highly beneficial to manufacturing firms. Over a quarter of manufacturing firms in the country are innovative, and about eighty percent of these firms have used innovations successfully to increase turnover, open new market opportunities, and respond to market and cost pressures. However, the study also reveals that firms face a wide array of barriers to innovation, and innovation activities require perseverance and long-term commitment. Manufacturing firms demonstrate high risk-aversion and lack of entrepreneurial appetite to engage with innovation. Instead of competing for new products that are necessary to compete in the future, firms are still addressing the predominant and immediate demands in the market. These findings call for concerted efforts in strengthening manufacturing policies and bring attention to the need for an innovation strategy for the country, with particular attention to manufacturing.

I would like to express my sincere appreciation to all those who contributed to the creation of this report, including the UNIDO team and the technical advisory committee from DST. We sincerely hope that this report will be of great value as valuable resource and reference note.

(Akhilesh Gupta)

Technology Bhawan, New Mehrauli Road, New Delhi - 110016
Phone: +91-11-26862512 Email: akhilesh.g@nic.in, gakhilesh2008@gmail.com, Website: www.dst.gov.in

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Acronyms

4IR	Fourth Industrial Revolution
AAT	Advanced Automotive Technology
ACC	Advanced Chemistry Cell
ACES	Autonomous Vehicles, Connectivity, Electrification of Vehicles and Shared Mobility
ACMA	Automotive Component Manufacturers Association of India
ACoE	ACMA Centre of Excellence
ADAS	Advanced Driver Assistance Systems
ADP	Advanced Digital Production
AFCS	Asset Finance Companies
AI	Artificial Intelligence
AIM	Atal Innovation Mission
AISC	Automotive Industry Standards Committee
AMP	Automotive Mission Plan
ARAI	Automotive Research Association of India
ARB	Arbitrageur
ASDC	Automotive Skill Development Council
ASI	Annual Survey of Industries
ASPIRE	Automotive Solutions Portal for Industry Research & Education
ATI	Advanced Training Institute
BHEL	Bharat Heavy Electricals Limited
BIS	Bureau of Indian Standards
BTS	Bartlett's Test of Sphericity
BMZ	Federal Ministry of Economic Cooperation and Development
BNVSAP	Bharat New Vehicle Safety Assessment Programme
BS IV/V/VI	Bharat Stage IV/V/V
C4I4	Centre for Industry 4.0
CAGR	Compound Annual Growth Rate
CAP	Creator Accelerator Programme
CART	Centre for Automotive Research and Tribology
CASE	Connectivity, Autonomous, Sharing/Subscription and Electrification
CEO	Chief Executive Officer
CGSC	Capital Goods Skill Council
CII	Confederation of Indian Industry
CMIE	Centre for Monitoring Indian Economy
CMTI	Central Manufacturing Technology Institute
CMVR	Central Motor Vehicles Rules
CNC	Computerized Numerical Control
COVID - 19	Coronavirus Disease 2019
CPI	Consumer Price Index

CPS	Cyber-Physical Systems
CRC	Collaborative Research Centres
CSIR	Council of Scientific and Industrial Research
CVC	Corporate Venture Capital
DASI	Data Acquisition Survey Instrument
DASI - V4	Data Acquisition Survey Instrument Version 4
DBT	Department of Biotechnology
DCAAI	Development Council for Automobiles and Allied Industries
DESE	Department of Energy Science and Engineering
DHI	Department of Heavy Industries
DISK	Data Information Statistics and Knowledge
DME	Dimethyl Ether
DoTE	Directorate of Technical Education
DPIIT	Department for Promotion of Industry and Internal Trade
DSEU	Delhi Skill and Entrepreneurship University
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
DTSI	Digital Twin Spark Ignition
DUI	Doing, Using and Interacting
EIC	Enterprise Incubation Centre
ELV	End-of-Life Vehicles
EMPEA	Emerging Market Private Equity Association
EV	Electric Vehicles
EY	Ernst and Young
FADA	Federation of Automobile Dealers Associations
FAIR	Findable, Accessible, Interoperable and Reusable
FAME	Faster Adoption and Manufacturing of Hybrid & Electric Vehicles
FAPCCI	Federation of Andhra Pradesh Chambers of Commerce and Industry
FDI	Foreign Direct Investment
FI	Financial Institutions
FIC - ISID	Facility for International Cooperation for Inclusive & Sustainable Industrial Development
FICCI	Federation of Indian Chambers of Commerce and Industry
FITT	Foundation for Innovation and Technology Transfer
FOSS	Free Open-Source Software
FRT	Fault Ride-Through
FTCCI	Federation of Telangana Chambers of Commerce and Industry
GARC	Global Automotive Research Centre
GDP	Gross Domestic Product
GEM	Government e Marketplace
GFR	General Financial Rules
GITA	Global Innovation & Technology Alliance
GmBH	Gesellschaft mit beschrankter Haftung (Company with limited liability)
GoI	Government of India
GOV	Government
GST	Goods and Services Tax

GTR	Global Technical Regulations
GVA	Gross Value Added
GVC	Global Value Chain
HDFC	Housing Development Finance Corporation Limited
HERC	Higher Education Research Centres
HFC	Housing Finance Companies
HMI	Human-Machine Interaction
IASSI	Indian Automotive Sectorial System of Innovation
ICAT	International Centre for Automotive Technology
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
IDBI	Industrial Development Bank of India
IFC	Infrastructure Finance Companies
IFCI	Industrial Finance Corporation of India
IIM	Indian Institute of Management
IIoT	Industrial Internet of Things
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IMDS	International Material Data System
IND	Industry
INDSTA	Indian Science and Technology Archive of Research
INR	Indian Rupees
INT	Intermediary
IOC	Indian Oil Corporation
IoT	Internet of Things
IPO	International Purchase Office
IPR	Intellectual Property Right
IQ	Intelligent Quotient
IRCTC	Indian Railway Catering and Tourism Corporation
IRRD	Industry Relevant Research and Development
ISBA	Indian Science and Technology Entrepreneurs Parks and Business Incubator Association
ISO	International Organization for Standardization
ISTC	Institutions Supporting Technical Change
IT	Information Technology
ITI	Industrial Training Institute
IVCA	Indian Private Equity & Venture Capital Association
KBI	Knowledge-based Institutions
K - DISC	Kerala Development Innovation Strategic Council
KMO	Kaiser-Meyer-Olkin
LIC	Life Insurance Corporation
MCCI	Madras Chamber of Commerce and Industry
MDA	Model Dealer Agreement
MEITY	Ministry of Electronics and Information Technology
MHI	Ministry of Heavy Industries

MNRE	Ministry of New and Renewable Energy
MoRTH&S	Ministry of Road Transport, Highways and Shipping
MoU	Memorandum of Understanding
MoUD	Ministry of Urban Development
MPNG	Ministry of Petroleum and Natural Gas
MSME	Micro, Small and Medium Enterprises
MTR	Mini Tool Rooms
NAAC	National Assessment and Accreditation Council
NABCB	National Accreditation Board for Certification Bodies
NAC	National Automotive Council
NAP	National Automotive Policy
NASSCOM	National Association of Software and Service Companies
NATRAX	National Automotive Test Tracks
NATRiP	National Automotive Testing and R&D Infrastructure Project
NBFC	Non-Banking Financial Company
NCR	National Capital Region
NCVRS	National Centre for Vehicle Research & Safety
NDA	Non-Disclosure Agreement
NEMMP	National Electric Mobility Mission Plan
NIAIMT	National Institute of Automotive Inspection, Maintenance & Training
NIC	National Industrial Classification
NIRF	National Institutional Ranking Framework
NIScPR	National Institute of Science Communication and Policy Research
NIT	National Institute of Technology
NITI	National Institution for Transforming India
NLP	National Logistics Policy
NMEM	National Mission for Electric Mobility
NMIS	National Manufacturing Innovation Survey
NMIT	National Institute for Manufacturing Technologies
NPBF	National Policy on BioFuels
NSDC	National Skill Development Corporation
NSQF	National Skills Qualification Framework
NUTP	National Urban Transport Policy
OECD	Organization for Economic Co-Operation and Development
OEE	Overall Equipment Efficiency
OEM	Original Equipment Manufacturer
OSF	Open Science Framework
PCB	Pollution Control Board
PE	Private Equity
PEM	Proton Exchange Membrane
PG	Post-Graduation
PHDCCI	Progress, Harmony and Development Chamber of Commerce and Industry
PISC	Project Implementation and Sanctioning Committee
PLI	Production Linked Incentive
PMGSY	Pradhan Mantri Gram Sadak Yojana
PMKVY	Pradhan Mantri Kaushal Vikas Yojna

PMP	Phased Manufacturing Programme
PPE	Personal Protection Equipment
PPP	Public-Private Partnership
PSU	Public Sector Undertaking
QP	Qualification Pack
R&D	Research and Development
RBIH	Reserve Bank of India Innovation Hub
RI	Research Institution
RPL	Recognition of Prior Learning
RVTI	Regional Vocational Training Institute
S&T	Science and Technology
SAMARTH	Smart Advanced Manufacturing and Rapid Transformation Hub
SCOE	Standing Committee on Implementation of Emission Legislation
SERB	Science and Engineering Research Board
SEZ	Special Economic Zone
SI	System of Innovation
SIAM	Society of Indian Automobile Manufacturers
SIDBI	Small Industries Development Bank of India
SME	Small and Micro Enterprises
SPPU	Savitribai Phule Pune University
SSI	Sectorial System of Innovation
STEM	Science, Technology, Engineering and Mathematics
STEP	Science & Technology Entrepreneurship Park
STI	Science, Technology and Innovation
STIP	Science and Technology Innovation Policy
TAGMA	Tool And Gauge Manufacturers Association
TCI	Technical Centre India
TH	Triple Helix
TIEMA	Thirumudivakkam Industrial Estate Manufacturers Association
TIFAC	Technology Information Forecasting and Assessment Council
TKM	Toyota Kirloskar Motor
TLC	Teaching-Learning Centre
TPEM	Technology Platform for Electric Mobility
TRIZ	Theory of Inventive Problem Solving
TSC	Technical Standing Committee
T-TEP	Toyota Technical Education Program
TVE	Total Variance Explained
UCL	University College London
UN	United Nations
UNCITRAL	United Nations Commission on International Trade Law
UNIDO	United Nations Industrial Development Organization
USA	United States of America
USD	United States Dollar

VC	Venture Capital
VDA	Verband der Automobilindustrie (German Association of the Automotive Industry)
VRDE	Vehicle Research & Development Establishment
WRI	World Resources Institute

Conversion factor

1 Crore = 10 millions

1 Lakh = 100,000

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The data analysis presented in this report has been performed by Dr. Ritin Koria, Project Specialist for Innovation, UNIDO, Ms. Christi Thomas, Project Associate, UNIDO, and Mr. Pratik Dake, Project Assistant, UNIDO.

Technical chapters of the report have been authored by Dr K Chandra Shekar Consultant Kerala Development Innovation Strategic Council (K-DISC) Government of Kerala; Prof. Husain Kanchwala and Mr. Abhimanyu Pratap Singh, Indian Institute of Technology, Delhi; and Dr. Ritin Koria, Ms. Sirjjan Preet, Ms. Christi Thomas and Ms. Reshmi Vasudevan, UNIDO.

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DST and UNIDO are also incredibly grateful to all the respondents: government policymakers, chief executives of business enterprises, leaders in knowledge-based institutions, directors of financial institutions, venture capital, and knowledge brokering firms for participating in the survey.

Preface

The goal of crafting a US$ 5 trillion economy by 2026-27 will require reinventing Indian manufacturing and innovation. India's aspiration to become a global economic powerhouse will be based on the foundation of a robust industrial sector and its innovative performance. To deliver rapid and sustained industrial growth over the next few decades, the Government of India (GoI) needs to strategically focus on building a next generation intelligent manufacturing base with domestic manufacturing companies becoming an integral part of global supply chains. To become a global manufacturing superpower a manufacturing revolution needs to be catalysed. India must harness its soft power advantages and leverage its strong Information Technology (IT) sector and drive supply chain efficiencies and productivity growth through use of IT deployed at scale.

Creating an industrial revolution of this scale would require the Indian government to formulate a comprehensive vision for industrial development and execute it through the implementation of coherent and effective industrial policy. The unprecedented disruptions of societies and economies caused by the COVID-19 pandemic have emphasised the need to take immediate action. In recent years, the Government of India (GoI) has launched special initiatives like Production Linked Incentive (PLI) schemes to shore up India's industrial capabilities and technological innovation in 14 key sectors, while creating and nurturing global champions capable of producing for the world. The PLI scheme is a time bound initiative with a clear mandate of focusing on critical sectors such as automotives that can attract maximum investments and scale rapidly to provide the maximum returns in terms of higher productivity, employment and exports. This scheme is also designed to identify and support the adoption of the Fourth Industrial Revolution (4IR) technologies that are opening new avenues of opportunity for advancing economic competitiveness, creating shared prosperity, safeguarding the environment, and strengthening knowledge and institutions.

With knowledge emerging as a critical resource, its better management and flow among people, enterprises and institutions is key to the innovative process. A System of Innovation (SI) represents the strength and quality of the systematically organised interactions and linkages between the stakeholders of the ecosystem; namely government, knowledge-based institutions, industry, intermediaries (institutions supporting technical change, industry associations and incubators), and arbitrageurs (venture capital, angel investors, and financial institutions). The mapping and visualisation of the dynamics of an innovation system are crucial to formulating evidence-based policy for the effective use of resources.

The growth of the Indian automotive sector depends on the utilisation of the 4IR technologies, innovation and knowledge production, the availability of a skilled workforce, and on the need for timely and reasonable policy and regulatory support for the sector as it doggedly takes to robotics and automation. It needs clear and targeted policy, enabling effective allocation of resources to ensure that India ranks among the top three countries globally for engineering, manufacturing, and the export of automotives and auto components by 2026. UNIDO acknowledges the importance of evidence in optimally deploying policy instruments and targeting available resources (economic incentives and institutions) so that the Indian automotive sector can achieve a competitive advantage. The development of a well-functioning SI works as a driver for long-term socio-economic development.

The "Indian Automotive Sectorial System of Innovation (IASSI) Report" maps and analyses the challenges, potential, and opportunities arising from the innovation system. The analysis is based on data gathered as part of the "National Manufacturing Innovation Survey" conducted by UNIDO in 2021-22. The measurement through this survey enables the provision of evidence to guide policy. Hence, the IASSI Report is a source of policy insight for supporting the GoI to elaborate an evidence-based industrial policy that articulates the role of science, technology, and innovation throughout the economy. Moreover, the policy analysis, implications arising from the analysis and the policy recommendations presented in the report offer a range of evidence-based policy choices to facilitate policy decisions related to the role of sectorial system actors in the draft "National Automotive Policy 2018". The mandate of UNIDO – as one of the specialised agencies of the United Nations system – to provide its member states with capacity-building and policy advisory services is manifest in this report.

The chapters in this report are the result of UNIDO's services in capacity-building, policy analysis, and empirical research on the Indian automotive sector. It aims to enhance the understanding of the role of the core actors and their interactions and perspectives, thus providing a solid basis for strategic planning, policy, and the management of policy actions to achieve national targets and goals effectively.

Executive Summary

This report, titled the "Indian Automotive Sectorial System of Innovation (IASSI) – Measurement, Analysis, and Policy Recommendations" surveys innovation and innovativeness in the automotive sector in India and maps the functioning of innovation and the associated collaborative processes between innovation stakeholders. The survey and analysis were undertaken within the framework of the "National Manufacturing Innovation Survey 2021-22" (NMIS 2021), co-designed with and funded by the Department of Science and Technology, Government of India, (GoI).

The report has been compiled for the GoI to inform innovation policy and improve innovation practices within the sector. Furthermore, it aims to facilitate coherent delivery of innovation policy and the establishment of a long-term policy monitoring and management capability for the sector.

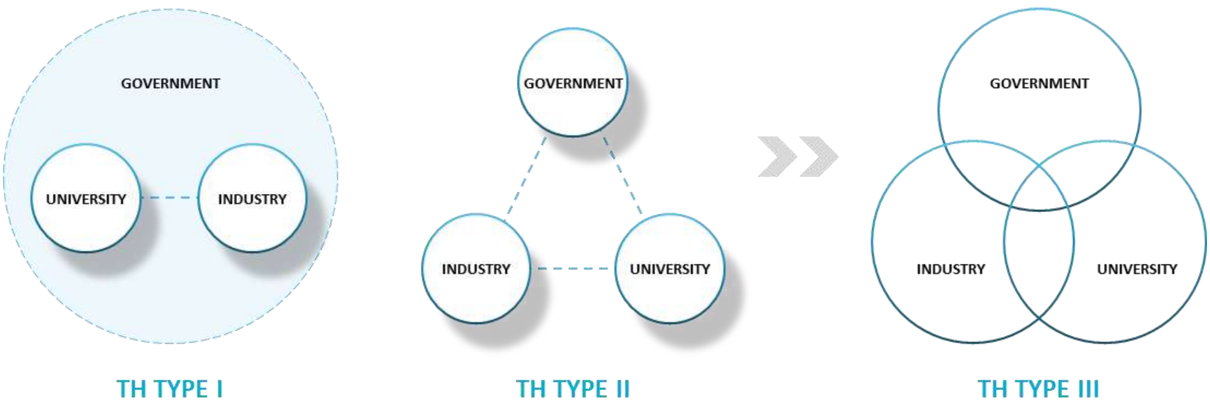
Although there are many significant challenges identified, the implications arising from the analyses, and the policy recommendations to address these implications provide an unprecedented menu of evidence-based development priorities and policy choices to address the challenges. The approach outlined in this report is comprehensive and holistic for mapping and measuring the Indian Automotive Sectorial System of Innovation (IASSI). It provides an accurate visualisation of the connectivity between the core actors of the IASSI, the significant barriers to innovation and innovativeness, and the relative success of current policies in overcoming these barriers. After all, it is not the number of assets India has when considering innovation and innovativeness, but rather how well and coherently they are connected and managed and if they are achieving innovative products and business processes and subsequent economic value.

It is imperative that policymakers view the analysis, implications, and recommendations in light of India's economic performance in an emerging economy and in the context of the COVID-19 pandemic, which hit all sectors across the globe. The analysis of the GoI policy documents, the mapping and measurement of the IASSI in terms of analysing linkages between (and within) actor groups, barriers to innovation; and the success of policy instruments disclose the significant key policy analysis findings, the major implications from the analysis, and the recommendations that stem from them.

In the specific case of the automotive sector, our assessment is that the IASSI falls into the category of a Triple Helix (TH) Type II transitioning to Triple Helix Type III, as per the traditional framing of the TH model. TH-Type I can be considered to be statist, and the three spheres of the actors are strongly institutionally defined, however, work in isolation leading to the local technological knowledge also being kept isolated.

TH Type II refers to mechanisms of communication between the actors that are strongly influenced by the market and technological innovations. In this case, the point of control is at the interfaces and consequently new codes of communication are developed. However, in TH-Type III, the actors assume each other's roles in the institutional spheres as well as the performance of their traditional functions with the formation of a complex network of organizational ties, both formal and informal, among the overlapping spheres of operations. It could be said that the interactions between the actors of the system are more competitive rather than collaborative in nature.

FIGURE 1: Triple Helix types



Consequently, there is the need to foster linkages between crucial actors of the IASSI, particularly for the use and application of joint research, skills orientation and development, as well as access to finance.

Based on this observation, the inter and intra interactions that need attention are:

- Industry relations with KBIs in the form of 'Secondments' and 'Recruitment' need to be bolstered to foster tacit exchange of knowledge.
- Industry intra-linkages with other industry actors in terms of 'Joint research' is missing and needs to be promoted in order to reduce costs, minimise risk, promote knowledge and technology transfer and improve market access.
- Intra-linkages between KBIs in the form of 'Joint research' need to be strengthened as they can result in the bolstering of direct support to industry.
- Research collaborations between universities, and public and private research institutions require better management therefore generating firm-level benefits leading to innovative ideas and impulses and the provision of support for technological development.

Secondly, the analysis highlights that relationships between actors in the IASSI are imbalanced in that there is an unequal level of exchange between two actors hindering the flow of knowledge and information crucial to the innovation process. This is mainly due to a suboptimal understanding of each actor's role within an effective system of innovation and the terms and conditions unfavourable to meaningful participation. Consequently, 'Industry 4.0', 'Policy Function', 'Market' and 'Human Capital' emerge as the underlying barriers to innovation within the IASSI.

From the perspective of 'Industry 4.0', the associated variables are: 'Lack of access to I4.0 technologies', 'Lack of understanding of I4.0 technologies', 'Cost of I4.0 technologies' and 'Lack of infrastructure for I4.0'. Although there has been a marked improvement since the COVID-19 pandemic a lack of understanding of the value, goals and needs of 4IR technologies still exists among many firms, at the T2 or T3 and deeper into the components manufacturing value chain. Robust evaluation mechanisms and decision support tools can help manufacturing firms understand the impact of 4IR technologies and effectively implement them. A clear understanding of 4IR technologies, their benefits and impact can help firms develop an organization-wide 4IR strategy and set implementation targets. Educating the workforce on 4IR technologies and upskilling them is key to its effective implementation.

With respect to 'Policy Function', the associated variables are 'Lack of legal framework', 'Lack of clear national innovation strategy', 'Restrictive public/ govt regulations' and 'Lack of explicit policy support'. Actors find it complex to apprehend policy direction and targets which in turn are extremely pertinent as goal posts for innovation activity and thus bringing innovation actors together to address shared research priorities.

The 'Market' shows its importance in driving innovation through demanding customers and innovative customers, as well as distinct 'rules of the game'. The variables associated with this barrier are 'Lack of innovative customers' and 'Lack of demanding customers.

'Human Capital' as a perceived barrier underscores the question of how firms can effectively identify, mobilise, and deploy skilled, talented, and entrepreneurial human resources who can conceptualise and deliver innovation activities. This is a crucial issue particularly with the paradigm shift caused by digital transformation and the 4IR. Consequently, the emergent variables are the 'Lack of technically trained manpower' and 'Quality of technically trained manpower'.

Finally, with respect to policy success, policy instruments were analysed in terms of supply-side measures (services and financial) and demand-side measures. The study results indicate that in general policy instruments are successful, however the most unsuccessful policy instrument reported by all actors is 'Explicit firm innovation policy support', which is also reflective of the barriers previously reported under the policy function. This is reflective of the need to clearly articulate high-level goals and visions down to the level of industry, in particular T2 and T3 firms, with a reduction in the level of complexity.

In addition, each actor has a specific view on effective or ineffective policy instruments, which needs to be considered when selecting a policy mix. Policy selection should not be an arbitrary process. It should be based on evidence and reflect the needs of the actors in the system and be in line with India's overall strategic orientation. The major implications of the analysis outlined in the report are that there are very few externalities that emanate from the public goods of funding and support, and innovation inputs need to be better translated into innovation outputs.

As a result of the non-existent nexus of the knowledgebase and industry, research institutions remain weak in their entrepreneurial outlook and industries in their innovation outlook, in turn compromising the effectiveness and impact of their respective innovation activities. The lack of positive externalities magnifies the negative impact of the absent relationships relevant to innovation in the sector. The remoteness of actors causes them to be relatively independent of the policy-making process, especially in terms of wielding influence in configuring and calibrating policy to exploit knowledge and intermediating the flows of technical know-how. The present public infrastructure needs to be strengthened to create a fabric of vibrant linkages that supports innovation. What is required is a widely accepted conducive environment in which organizational rigidities are overcome.

The IASSI Report demonstrates the value of comprehensive survey and the critical importance of mapping and measurement to guide the discussion for evidence-based and collaborative policy making, execution, monitoring and impact evaluation. A periodic repeat of systematic mapping and measurement of the IASSI in two to three years is strongly advised and can help to ascertain the effects of policy choices, implementation, resource application, and hence innovation and innovativeness in the Indian economy.

1. Project Context

Project Context

The “National Manufacturing Innovation Survey (NMIS) 2021-22” is a follow-up to the Department of Science and Technology’s (DST) (GoI) first “National Innovation Survey” held in 2011. The 2011 survey results showed that most of the innovations in Indian firms were in the form of introducing new machines, or improvements to existing products and processes (DST, 2014). The study found these firms at par or ahead of their competitors regarding improved ranges of products (better quality and standards), besides improving production capacity and reducing environmental impacts. Such firms were largely privately owned small companies and relied on domestic financial institutions. While these innovative firms struggled with cost factor and availability of skilled manpower, more than 50% did not employ scientists or engineers but reported that access to knowledge and information was a critical barrier.

The decade that followed the 2011 National Innovation Survey saw the launch of key policy initiatives, especially the “Make in India”, “Startup India” and the “Aatmanirbhar Bharat Abhiyan”, among others, positioned to strengthen and boost the country’s manufacturing sector outputs where innovation and entrepreneurship programmes were prioritised. The scope of indigenous innovations and innovation ecosystems thus received greater impetus in this period. In 2019 the DST followed up with the planning of the second nationwide innovation survey and partnered with the United Nations Industrial Development Organization (UNIDO), with greater attention to manufacturing and associated services spread across large, medium, small and micro enterprises. It emphasised the role and separately studied the impact of this ecosystem and its actors on innovations in specific sectors.

1.1 The National Manufacturing Innovation Survey 2021-22

The National Manufacturing Innovation Survey (NMIS) 2021-22 was designed as a 2-pronged survey where the DST-UNIDO collaboration adopted a 360-degree approach to measuring innovation performance at the level of manufacturing firms, and assessing innovation processes, its barriers and support measures at the ecosystem level of industrial sectors. To this end, the survey was designed with two specific components – the Firm-Level Survey and the Sectorial System of Innovation (SSI) Survey.

The objective of the Firm-Level Survey was to capture insights regarding activities impacting innovations in a firm, across a broad spectrum of product and business process innovations and understand the various factors enabling and/or limiting innovation activities. On the other hand, the SSI Survey aimed to measure the innovation system available to specific industrial sectors to examine how manufacturing firms accessed information, knowledge, technologies, practices, and human and financial resources, and what linkages connect the innovating firm to other actors in the innovation system (laboratories, universities, policy departments, regulators, competitors, suppliers, and customers). Thus, with an overarching scope to strengthen, improve and diversify India’s manufacturing with targeted and evidence-based innovation policy, the NMIS 2021-22 Survey was launched in February 2021.

TABLE 1: Overview of Firm-level survey and SSI survey

The Firm-Level Survey assessed the following: *(Broad overview)*	**The SSI Survey assessed the following:** *(Broad overview)*

• Types of innovations in manufacturing firms
  ◦ Product innovation
  ◦ Business process innovations in (e.g., operation, product/business process development, marketing & sales, procurement, distribution & logistics, administration, and management)
• Innovation activities
• Sources of information, collaborations, resources
• Factors hampering innovation activities.
• Impacts of digitalisation, infrastructure, IP
• Impact of COVID-19 pandemic
	• Innovation actors (firms and non-firm actors) for their networks (density, distribution, directionality, symmetry of intra- and inter-linkages of actors)
	• The role and impact of actors and institutions on innovation activities in firms
	• Impact of policy instruments (fiscal, monetary, regulatory, standards and others)
	• Barriers to innovation

With a stratified random sample representing micro, small, medium and large manufacturing companies, the Firm-Level Survey targeted 10,139 firms across 58 manufacturing sectors (as per the national industrial classification 2008[1]) across the 36 states and union territories in the country. The SSI Survey targeted the innovation systems of 5 key manufacturing sectors critical to the Indian economy, prioritised by their gross value-added (GVA) and their presence across the country, impacting state-level and national policies and strategies. These 5 sectors are: Food and Beverages, Textiles and Apparel, Automotive, Pharmaceuticals, and Information and Communication Technologies (ICT). A stratified random sample close to 7,851 firms and 1,000 non-firm actors were targeted under the SSI Survey across India. The outcomes of the Firm-Level Survey are separately reported, while this report features the SSI Survey objectives and findings.

1.2 Significance of the Sectoral Systems of Innovation Survey

The SSI Survey postulates that for a firm to be effective in the innovation process, a conducive environment that consists of an effective support infrastructure of actors is critical. Connectivity between them that is fluid and dynamic will be pivotal in aiding access to the requisite, knowledge, skills, and resources. Hence, the survey aimed to map the innovation capability of manufacturing firms to such actors and institutions of sector-specific systems of innovation and also regional systems of innovation, and national systems of innovations. To this end, the interactions (or linkages) and the density of these linkages to various ecosystem actors were studied to achieve a clear understanding of these relationships in empirical terms to assess the flow of communications and information and assets between knowledge-based institutions, research and development agencies, industry bodies, government agencies, financial institutions, startup incubators, institutions supporting technical change, and arbitrageurs.

The survey particularly took cognisance of the innovation and manufacturing mandate of NITI Aayog, the apex policy advisory body to the GoI[2]. In its strategic recommendation for improving India's manufacturing sector outcomes, NITI Aayog strongly recommended the need for promoting latest technology advancements and predicted a defining role for Industry 4.0 intervention in shaping the sector and achieving an ambitious double-digit growth (NITI Aayog, 2018). Further, the agency has also been assessing the nation's priorities and strategies for consolidating and strengthening science and technology (S&T) initiatives to amplify technology development and commercialisation. Since the 1990s, the Government of India has deployed technology incubators as an important policy tool for S&T entrepreneurship (Surana et al., 2018). The DST has been at the forefront of designing and establishing science and technology entrepreneurship parks, incubation systems, and technology business incubators to build close linkages between universities, academia, R&D institutions and the industry, including MSMEs, and also to generate employment[3]. These initiatives led to strong technology-based entrepreneurship and startups in the country, and set motion to various policy frameworks and initiatives, such that most incubation programmes in the country today leverage support offered under various ministries, who also have a manufacturing stake. The public sector enterprise model for biotechnology-based startups by the Department for Biotechnology (DBT) has been highly successful in converting research into products and attracting investments and has impacted the pharma and life-sciences landscape in the country. Similarly, for strengthening IT and digital startup linkages with markets, the Ministry of Electronics and Information Technology (MeitY) has been offering risk capital and low-cost loans. With their broader mandate, the Ministry of MSME and the Department for Promotion of Industry and Internal Trade (DPIIT) have designed and implemented several startup programmes, and importantly brought SME collaborations to sector-specific incubators, thus offering a stronger market access to entrepreneurs.

India's technology and innovation agenda took a strong leap over the last decade when the Government of India launched a series of high-powered initiatives to amplify and catalyse the pace of innovation and entrepreneurship with greater emphasis on the startup ecosystem. The "Startup India" mission was put in place to tackle the complex, lengthy regulatory processes for startups and introduced tax incentives and high-risk funding to startups[4]. The "Atal Innovation Mission" brought sector-specific attention to the startup agenda for innovation and entrepreneurship incubation infrastructure across the country and widened

[1] National Industrial Classification (NIC) 2008 is an essential statistical standard for developing and maintaining a comparable database according to economic activities: https://www.ncs.gov.in/Documents/NIC_Sector.pdf

[2] About NITI Aayog: https://www.niti.gov.in/objectives-and-features

[3] Science & Technology Entrepreneurship Park (STEP): https://www.nstedb.com/institutional/step.htm

[4] The Startup India initiative (under DPIIT) was launched to improve the innovation ecosystem and handhold, fund and incentivise startups and improve industry-academia partnerships through incubation services: https://www.startupindia.gov.in/content/dam/invest-india/Templates/public/Action%20Plan.pdf

its scope to schools and other academic institutes[5]. Further, the "Invest India" programme was launched to catalyse investments in manufacturing, technologies, incentivising innovations and other areas of trade and commerce[6]. The increased access to risk capital in technologies in this period have played a key role, such that Bain (2022) reports that VC investments in India pegged at US$ 38.5 billion in 2021 and have positioned India as the third largest startup ecosystem in the world[7].

The SSI Survey was positioned to examine how such policy and institutional arrangements (innovation/incubation programmes established in various technology and higher education institutes) across the country have impacted the collaboration of firms with academia, startups and investors for commercialising innovations, thereby addressing various transaction-related problems endemic to lab-to-market journeys. Studies show that traditional R&D institutions in the country, however, continue to prioritise "blue-sky research" over "application-oriented research" and on the other hand, several recent studies have brought attention to the challenges faced by India's public-funded labs in commercialising their research outputs. While technology interventions have a direct impact on productivity, accessing capital in manufacturing technology-based projects continues to be a challenge, owing to the longer gestation period before they yield returns. As Nandagopal et al., (2013) point out, Indian firms continue to be traditionally risk-averse, and are inclined to invest in non-technology-based sectors like retail, banking, infrastructure, entertainment, among others. The SSI Survey made crucial inclusion of the role of arbitrageurs, such as the venture capitalists and knowledge brokers, as these actors have increasingly been decisive in the innovation process in bringing internal and external knowledge and high-risk investments that result in new business models and new types of companies.

1.3 Relevance of the 5 Manufacturing Sectors prioritised by the SSI Survey

With the goal of significantly increasing the manufacturing sector contribution to the GDP from 16.5%, the "Make in India" mission is a major policy initiative launched in 2014 aimed to make India a high-tech manufacturing hub[8]. The mission now targets 27 manufacturing sectors that have key significance to the economy and the 5 manufacturing sectors identified for the SSI Survey have significant priority in the Make in India mission.

India's food processing is globally one of the largest, with a significant number of registered factories across the country attributing to the direct employment of 1.9 million people, with 8.9% MVA (food and beverage along with tobacco) (UNIDO IAP, 2023). Despite being a major trader and exporter of agriculture products, India's export processed food is less than 10% owing to critical impediments across supply chain infrastructure, production and processing, inefficient capacity utilisation, quality and safety challenges, and slow product and technology interventions (RBI, 2020). Similarly, the other large sector in the survey, the textiles and apparel sector, has a prominent manufacturing presence in many states and provides direct employment to more than 45 million people and contributes close to 7% of MVA[9]. In 2021-22 the Indian textiles and apparel industry was valued at US$ 152 billion and accounted for a 4% share of the global textile markets. Yet the highly fragmented sector is also labour and raw material intensive and is mired with productivity challenges that tend to undermine value chains and their backward linkages. For instance, more than 80% of the 50 million spindles and 842,000 rotors deployed by textile mills are found to be outdated or inefficient[10].

The SSI Survey aimed to also gather learnings from actor collaborations, institutional best practices, challenges, technology leapfrogging trajectories and other aspects of systems of innovation in three high performing sectors, such as the automotive, pharmaceutical and ICT sectors. With a 20.1% contribution to the manufacturing GDP, the automotive sector is a top driver of macroeconomic growth and technological development in the country (UNIDO IAP, 2023). With robust performances, the ICT and pharmaceutical sectors are the world's key players. India's pharmaceutical sector is the third largest in volume, driven by export markets and the expansion of Indian healthcare that has resulted in innovative products, processes and services, thereby positioning India as the *pharmacy of the world*[11].

[5] The Atal Innovaiton Mission driven by NITI Aayog established numerous innovation and entrepreneurship centres in schools, universities, research institutions, private and MSME sectors: https://www.aim.gov.in/overview.php
[6] Invest India: Investment Promotion and Facilitation Agency.
[7] Economic Survey: India becomes third-largest startup ecosystem in the world. Mint: https://www.livemint.com
[8] The Make in India Mission: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1738170
[9] Textile Industry in India - Garment & Apparels Market in India: http://www.investindia.gov.in/sector/textiles-apparel
[10] India should continue investing in modern, efficient spinning technology to remain globally competitive: https://www.indiantextilemagazine.in/india-should-continue-investing-in-modern-efficient-spinning-technology-to-remain-globally-competitive/
[11] India has become pharmacy of the world: https://www.moneycontrol.com/news/india/india-recognised-as-pharmacy-of-the-world-fm-9759651.html

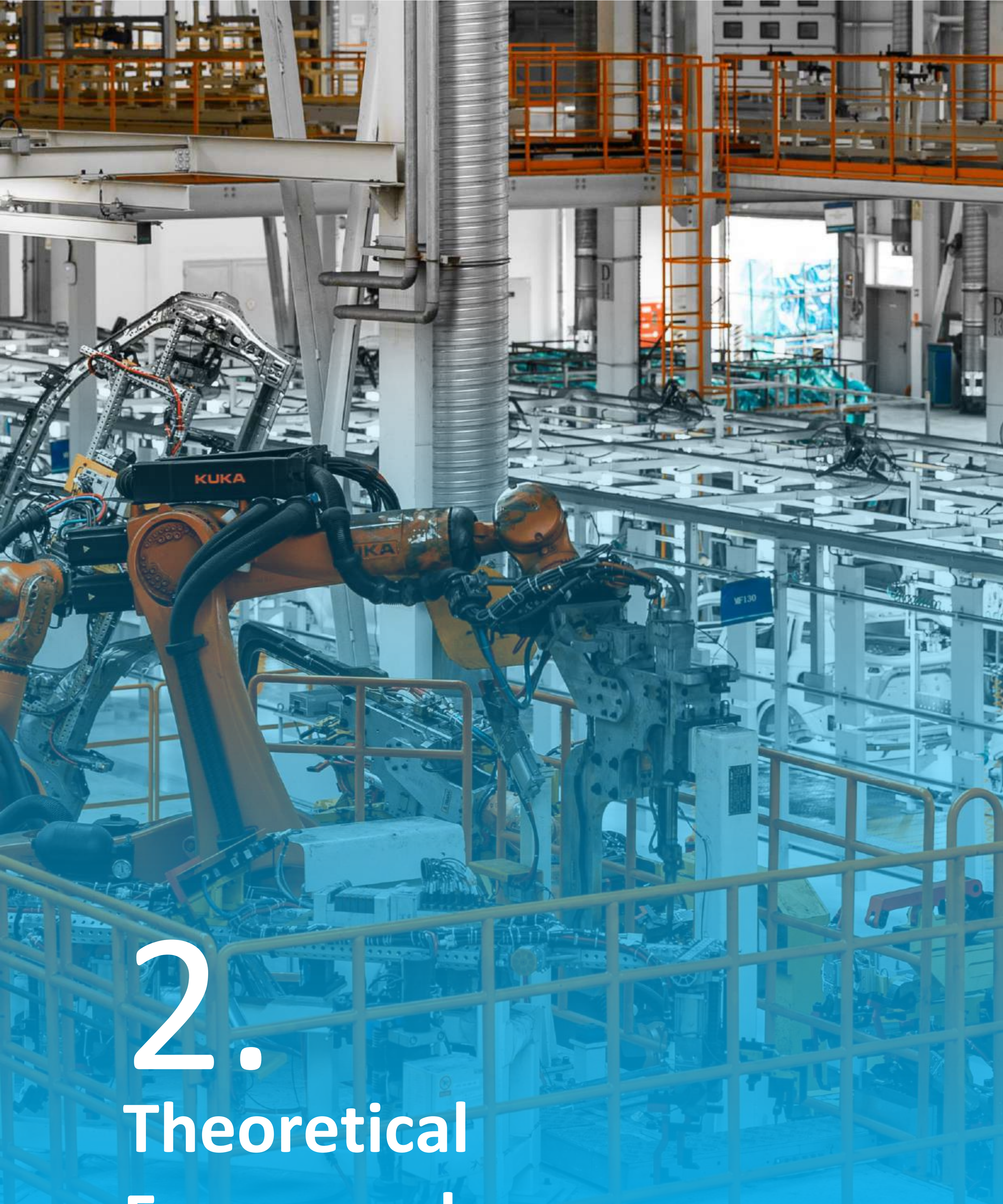
1.4 SSI Survey to Strengthen Manufacturing Innovation as a GoI Policy Imperative

The Make in India ambitions were further boosted in 2020-21 with the launch of the Production Linked Incentive (PLI) scheme across 14 key manufacturing sectors, to incentivise import substitution by domestic production in strategic growth sectors[12]. Invariably, the domestic manufacturing ecosystem and supply chains are critical to the success of the PLI scheme. Similarly, the "Gati Shakti" programme was launched in 2021 to improve infrastructure and connectivity for faster and more efficient movement of goods and services, and impact manufacturing and business operations at large[13]. Besides technological leapfrogging, world-class innovation capabilities, skills and investments, the Government of India's efforts in improving the investment environment has been critical. The country saw FDI inflow catch great momentum between 2014-22 and by 2019 India was recognised as one of the most attractive emerging markets for investments[14]. However, the FDI share in Indian industries seems to continue to largely benefit non-manufacturing sectors such as software businesses. Nevertheless, the hardware, pharma-biotech and electrical equipment sectors, among others, with strong product sophistication and better production capabilities, attract strong foreign direct investment (FDI) inflow, especially with their digital capabilities in manufacturing and product offerings[15]. The global shifts in advanced digital manufacturing with self-correcting intelligence has been a game changer since the pandemic and has reflected in investment interests as well.

The SSI Survey has attempted to capture the dynamics of communication, stocks and flows of knowledge and organization by introducing the notion of an intersection of exchange relations that feed back into institutional arrangements. The aim has been to understand how co-evolution between the layers of institutional arrangements and evolutionary functions can be conceptualised, in relation to the division of innovative labour among both institutions and functions. This is particularly important when crafting policy for the effective use of resources. Thus, by generating evidence of the barriers and challenges to technological learning, innovation and development, and technological up-gradation of Indian industries the survey findings shall be used for devising policies, programmes, and partnerships to strengthen innovation outcomes and benefits.

The project was supported by the UNIDO Facility for International Cooperation for Inclusive & Sustainable Industrial Development (FIC-ISID), a joint initiative of the DPIIT and UNIDO, with the aim to catalyse inclusivity and sustainability in manufacturing industry development. Five major business membership organizations, respectively the India SME Forum (ISF), the Federation of Telangana Chambers of Commerce and Industry (FTCCI), the Federation of Andhra Pradesh Chambers of Commerce and Industry (FAPCCI), the Madras Chamber of Commerce and Industry (MCCI), and the PHD Chamber of Commerce and Industry (PHDCCI) were key partners in data-collection across India's 28 states and 8 union territories. The survey completed the data collection in early May 2022.

[12] The PLI Scheme: https://www.investindia.gov.in/production-linked-incentives-schemes-india
[13] Gati Shakti: https://dpiit.gov.in/logistics-division
[14] Emerging Markets Private Equity Association 2019 Survey: https://www.globalprivatecapital.org/app/uploads/2019/05/2019-lp-survey-final-web.pdf
[15] FDI in India 2021: https://www.makeinindia.com/policy/foreign-direct-investment



2. Theoretical Framework

Theoretical Framework

Innovation is increasingly viewed as the salient ingredient in the sustainable growth of the modern economy. An economy must continuously absorb new knowledge and develop new skills and capabilities to avoid erosion of competitiveness and facilitate economic growth and diversification. Historically, countries that fostered innovation by developing interconnected innovation systems have proven to be more capable of generating new knowledge and translating it into business opportunities and thus wealth creation (Freeman, 1987; Nelson and Rosenberg, 1993; Lundvall, 1992, 2016; Chaminade et al., 2018). An innovation system refers to a set of institutions that contribute to the development, diffusion and application of scientific and technological knowledge (Dosi, 1988). Studies have shown that well-functioning innovation systems are essential to catch up with advanced economies (Kim, 1992, 1997; Kim and Nelson, 2000; Fagerberg and Srholec, 2008; Malerba and Nelson, 2013; Fagerberg et al., 2017; Shekar, K. C., & Joseph, K. J., 2022).

Innovation systems are framed at different scales, including national, sectoral and local/regional (Chaminade, 2018). The framing of an innovation system involves different types of network and interactions depending on the driving interest, practices, behaviours and the working environment in general. The considerations for building these networks may vary depending on the context and scale of the operations/activities happening among the actors. These networks will evolve based on the behaviour and routine among the actors and their organizational context (Hall, Mytelka, and Oyeyinka 1997; Jacob 2016). However, knowledge and learning remain the central points to the networks (Moschitz et al., 2015). The establishment of such networks for building a system involves breaking barriers and reconstructing channels for knowledge flow. This is done by setting interactive processes, sharing best practices and learning from prior experience, while overcoming failures and filling gaps. The form and the performance of learning approaches may vary from one sector to another, depending on different patterns such as the roles, habits, mode of operation, competencies, demand, among others (Mytelka and Smith, 2002). This suggests a systemic way of establishing a framework that allows interactions among the different groups and contributes to the use of knowledge for the collective/mutual interest of the actors.

Since innovation is a collective action that involves a multitude of actors who co-operate and compete in networks and who are stimulated and constrained by institutional settings in different sectors, we use the concept of 'Sectorial Innovation Systems'. The rationale for using this framework can be further justified on the ground that it encompasses all the relevant aspects that might possibly influence innovation and economic growth and is suitable to analyse the inter-related character of innovation processes. In this backdrop, this chapter presents the theoretical underpinnings for the approach used in mapping and measuring the Indian Textiles and Apparel Sectorial System of Innovation (ITASSI). It introduces the concept of the Sectorial System of Innovation (SSI), as well as reviews the elements that constitute its early conceptualisation, through a review of the evolution of seminal literature. Based on this, the chapter outlines the traditional Triple Helix Model of government-university-industry (Etzkowitz and Leydesdorff, 2000) interactions as well as its extension.

2.1 Underpinning Theoretical Framework

The Organization and development of innovation have gained much attention from different perspectives. The traditional notion of innovation as an end provides a narrow view of innovation and the potential it has on societal development in different dimensions. Whereas the consideration of innovation as a process that engages a chain of activities that can lead to different types of innovations that then have diverse socio-economic impacts is more prevalent today. An innovation system considers innovation as a process and considers how the actors interact among themselves to undertake innovation activities. They consider the inputs to innovations and the channels leading to the expected outputs. This does not mean the use of the linear model of input-output that has been used for some time as a way of linking science to innovation. Rather, it considers the complexity of the processes and the interactions among actors involving learning activities and the use and transfer of knowledge (Etzkowitz and Leydesdorff, 2000). The available literature on innovation capabilities in the Indian industrial sector is mostly based on STI indicators that focus more on R&D activities and the creation of access to codified knowledge (Basant, 1997; Basant and Fikkert; 1996; Kartak, 1985; Kumar and Siddharthan, 2013; Shekar, K. C., & Paily, G., 2019). For instance, Basant and Fikkert, (1996) examines the effects of domestic and foreign technology purchases as well as R&D activities in enhancing the productivity of firms in India. The study shows that between 1974-75 and

1981-82, domestic and international R&D spillovers and foreign technology purchases are highly statistically significant as compared to own R&D expenditures. Even though technological strategies greatly contribute to the productivity growth of Indian enterprises it is not directly reflected in export performance, which is also considered as an important indicator of a firm becoming more innovative (Lall and Kumar, 1981). It is highly evident in high technology sectors rather than medium and low technology sectors (Kumar and Siddharthan, 1994). A sector-specific study conducted by Bhaduri and Ray (2004) examines the technological capability of exporting firms in the electrical and electronic equipment industry. Firms in this industry mainly depend on know-how rather than know-why capabilities. In addition to these approaches, innovation systems research focuses on interactive learning, interdependence and non-linearity wherein institutions play the central role (Joseph, K. J, 2009; Shekar, K. C., & Joseph, K. J., 2022). The innovation system perspective has become a widely used analytical tool for academic research, policy formulation and implementation which aim at effective relationships among the agents and increase the innovation efficiency (Dosi et al., 2006). Therefore, the innovation system, which has by now emerged as the most popular approach in innovation studies, involves a more holistic framework to study the inter-related character of innovation processes as it focuses on the interdependencies among the various agents, organizations and institutions while underlining the need for R&D (Freeman, 1987; Dosi et al., 1988; Lundvall, 1992; Nelson, 1993; Edquist, 1997; Shekar, K. C., & Joseph, K. J., 2022).

Since the late 1980s, innovation system concepts have been developed and presented primarily by innovation researchers as a response to the shortcomings of neoclassical attempts to explain innovation and technological progress (Edquist, 1997). According to Christopher Freeman, "…systems of innovation are networks of institutions, public or private, whose activities and interactions initiate, import, modify, and diffuse new technologies" (Freeman, 1987). The innovation system, with a focus on technology and information flows between people, businesses, and institutions, and was created as a tool to understand the innovation process (Lundvall, 1985). Innovation systems help identify how to stimulate innovation and what inhibits its development and have become a viable method for researchers and policymakers to study the innovation process, especially in emerging and developing economies (Weber and Truffer, 2017; Shekar, K. C., & Joseph, K. J., 2022).

Different types of innovation systems have emerged since the identification of the concept of innovation systems such as the National Innovation System (NIS) (Lundvall, 1992; Freeman, 1987; Edquist, 1997; Lundvall, 2007; Nelson, 1993), Regional Innovation System (RIS) (Saxenian 1994; Cooke & Uranga, 1997), Sectoral System of Innovation (SSI) (Malerba, 2002; Breschi and Malerba, 1997) and technological systems (e.g., Carlsson and Stankiewicz, 1991), also known as a technological innovation system (Bergek et al., 2008; Hekkert et al., 2007). The NIS as the common analytical framework for innovation to economic growth. This considers a country as a unit of analysis. It provides the macro indicators in regard to interactions among actors, organization structures, institutions and learning processes as well as the facilitation. It considers interactions among actors as key for innovations. Actors can be firms' organizations and non-firms' organizations (universities, R&D organizations) (Chaminade et al., 2018; Shekar, K. C., & Paily, G., 2019). The categories of organizations may generally be grouped as knowledge producers and knowledge users. Whereas the system is based on these categories and the interactions among them, institutions are very important in the innovation systems. In this context, institutions are considered as a set of routines, behaviour, regulatory tools, and policies (Edquist, 2005; Freeman, 1995). The set of organizations, institutions, knowledge, interactions, and learning make up an innovation system and this system can be analysed at a lower level as a sectorial innovation system. Types of activities, actors, and products; and how these are interconnected determines the sector.

Geographical factors define national and regional innovation systems, whereas sectorial and technological innovation systems are defined by the knowledgebase that supports a particular sector or technology (Carlsson, 2016). In the sectoral system of innovation, innovative activities within a particular sector, a set of new and established products and the set of agents involved in the creation, production and sale of those products are examined. SSI surpasses specific technological and geographical boundaries, with sectors being positioned sometimes in small regional clusters, yet sometimes covering global networks, as, for example, within multinational corporations (Stenzel, 2007).

In recent years, advances in innovation theory have gradually moved closer to a fully systemic, dynamic, and non-linear process that involves a range of interacting actors. This process emphasises the significance of knowledge flows between actors; expectations about future technology, market, and policy developments; political and regulatory risk; and the institutional structures that affect incentives and barriers. Thus, while conceptual and methodological specifics vary, these more recent innovation systems emphasise the role of multiple agencies and distributed learning mechanisms in technological change. Rather than all-powerful firms or unidirectional knowledge flows, the focus is on inter-organizational networks and feedback (Winskel and Moran, 2008). The system perspectives still acknowledge the existence of stages of technology development, but they attempt to put these in a broader context.

There are various channels of university-industry interactions that facilitate innovation development. Joseph and Vinoj (2009) provide empirical evidence that in spite of the low level of university-industry interactions in the country, firms that collaborate with universities achieve a high level of innovative activities.

In particular, the role of institutions at all levels in establishing and maintaining the "rules of the game" is a central theme since institutions may constrain choices, driving innovation along certain - possibly suboptimal - paths while often throwing up barriers to more radical change (Foxon, 2003). The importance of feedback between different parts of the system – both positive and negative - is also emphasised, as are the links between technological and institutional change. A well-functioning system vastly improves the chances for a technology to be developed and diffused (Negro et al., 2008; Shekar, K. C., & Paily, G., 2019; Shekar, K. C., & Joseph, K. J., 2022).

Hence, the guiding principle of innovation studies is that if we can discover what activities and contexts foster or hamper innovation (i.e., how innovation systems function) we will be able to intentionally shape the innovation processes (Hekkert et al., 2007).

2.2 Sectorial System of Innovation (SSI) Approach

The notion of sectorial system draws from evolutionary theory, the innovation system approach and the analysis of the dynamics and transformation of industries. According to the SSI approach, a sector is seen as a set of activities which are associated with broad product groups, are addressed to an existing or emerging demand, share a common knowledgebase, and are affected by a system of actors and institutions (Malerba, 2002). Malerba (2002) defines SSI as a "set of products and the set of agents carrying out market and non-market interactions for the creation, production, and sale of those products". SSI focuses then on the sector rather than on any geography. A sectorial systems framework focuses on three main dimensions (for a broader discussion see Malerba, 2004 and Malerba and Adams, 2019) that are typically distinguished as: a) knowledge and technological domains; b) actors and networks; and c) institutions (Malerba and Adams, 2019).

a. **Knowledge and technological domains**. A sector is characterised by a specific knowledgebase and technologies. Knowledge plays a central role in the sectorial systems approach. Knowledge is highly idiosyncratic at the firm level, does not diffuse automatically and freely among firms (Nelson and Winter, 1982), and must be absorbed by firms through the capabilities which they have accumulated over time (Cohen and Levinthal, 1990). Knowledge - especially technological knowledge- involves varying degrees of specificity, tacitness, complexity, complementarity, and independence (Winter 1987; Cowan, David, Foray 2000; Dosi and Nelson, 2010). From a dynamic perspective, it is essential to understand how knowledge and technology are created, how they are distributed and exchanged between firms, and how such processes can redefine industry boundaries.

b. **Institutions**. The cognitive frameworks, actions and interactions of agents are influenced by institutions, which include norms, common habits, established practices, rules, laws, and standards. Institutions may be binding and more or less formal (such as patent laws or specific regulations versus traditions and conventions). Many institutions have national dimensions (such as patent laws or regulations concerning the environment), while others are specific to sectors (such as standards) and may cut across national boundaries (such as international conventions or established practices).

c. **Actors and networks.** A sector is composed of heterogeneous agents that include firms (e.g., innovating and producing firms, suppliers and users), non-firm organizations (e.g., universities, financial organizations, industry associations) and individuals (e.g., consumers, entrepreneurs, professionals and scientists). These heterogeneous agents are characterised by specific learning processes, competencies, beliefs, objectives and behaviour. They interact through processes of communication, exchange, competition, control, and cooperation. Thus, in a sectorial systems framework, innovation is a process that involves systematic interactions among a wide variety of actors for the generation and exchange of knowledge relevant to innovation and its commercialisation. Actors are individuals and/or organizations that "interact through processes of communication, exchange, cooperation, competition, and governance, and various institutions shape their interactions (norms, common habits, established practices, rules, laws, standards, etc.)" (Malerba, 2002). Under this framework, many actors generate, and exchange knowledge related to innovation and its commercialisation. The sectorial innovation system undergoes changes and transformations through a co-evolution of its various elements (Nevzorova, 2021).

There are several limitations of the SSI approach. Firstly, interactions between various agents in the SSI are shaped by institutions at both sectoral and national levels. Therefore, delineating between national and sectoral boundaries is not easy. Furthermore, distinguishing the characteristics of these institutions (norms, routines, common habits, established practices, rules, laws, standards) at both levels is a challenge. Second, SSIs are also influenced by institutions at a global level. In some cases, the relevant geographical boundaries are global as well as sectoral and in such cases it is not easy to distinguish the boundary between them. Thirdly, the relationship between national institutions and sectoral systems could differ. That is, the same institution may play different roles in different countries, and thus may affect the same sectoral system differently in different countries. Finally, the nature of relationships and networks differ across sectoral systems and therefore it can be difficult and complex to compare them to each other (Baskaran, and Muchie, 2019).

No withstanding this, each of these components of a sectorial system has its own characteristics and its own set of dynamics which are important to disentangle to understand how innovation takes place. But each of these elements is also part of a broader system in which the interaction among the parts drives innovation and change.

Sectorial systems studies also expanded to the analysis of emerging and developing countries, as in Malerba and Mani (2009), Malerba and Nelson (2011), Luz and Salles-Filho (2011) and Muchie and Baskaran (2017), in which the cases of several sectorial systems in Asia, Latin America and Africa are examined. More recently catch-up by emerging and new leading countries in different sectorial systems has been examined by Lee and Malerba (2017 and 2020) and has been associated with opening of windows of opportunities and responses by firms and sectorial systems in catching-up countries and incumbent countries (see in this respect Giachetti and Marchi 2017, Morrison and Rabellotti 2017, Kang and Song 2017 and Lee and Ki 2017). The sectorial systems framework has also been adopted to examine China's catching-up in a variety of "green sectors" (Lema et al., 2020), such as solar photovoltaics (Binz et al., 2020), wind energy (Dai et al., 2020), biomass (Hansen & Hansen, 2020), and hydro energy (Zhou et al., 2020). In these sectors, the windows of opportunity for latecomers are primarily driven by institutional changes that favour clean and renewable energy and by demand conditions (Lema et al., 2020).

The existing literature (e.g., Bhagavan, 1985; Desai, 1985; Prameswaran, 2004) on India's manufacturing sector deal with Science, Technology and Innovation (STI) aspects of innovation strategies such as research and development activities and creating access to explicit codified knowledge, and technical efficiency, etc. The innovation system combining a strong version of the STI mode with a Doing, Using and Interacting (DUI) mode can provide a better picture of innovative behaviour of the firms (Jenson et al., 2007; Shekar, K. C., & Joseph, K. J., 2022).

2.3 System failure

As previously highlighted, the basic conceptual underpinnings of the SI approach are, first, that innovation does not take place in isolation and interaction is central to the process; second, that institutions are crucial to economic behavior and performance (Smith, 1996); and third, that evolutionary processes play an important role, they generate variety, select across that variety, and produce feedback from the selection process to variation creation (Hauknes and Nordgren, 1999).

In all these basic elements, systemic imperfections can occur if the combination of mechanisms is not functioning efficiently. This can translate into various types of system failure:

- Infrastructure failure, where there is a lack of formal institutions/institutional mechanisms as well as soft institutions, social norms, trust, values that hinder innovation.
- Institutional failure, where there is lack of networking/linkages among the different actors in the whole ecosystem.
- Network failure/Capability failure, which underscores the absence of the necessary capabilities of the actors to move up the value chain, adapt to new and changing circumstances etc.
- Directionality failure, where there is a lack of shared vision, collective coordination, regulation, targeted funding regarding the goal and direction of the transformation process.
- Demand articulation failure, caused by improper anticipation and learning about user needs, shaping innovation based on user needs, lack of instruments for supporting user-led and open innovation, novel

innovations/solutions not finding enough space in public procurement.

- Policy coordination failure, due to a lack of multi-level policy coordination, horizontal and vertical coordination, across and within different systemic levels; between regional and national or between technological and sectoral systems, etc.
- Reflexivity failure, as a result of an insufficient ability of the system to monitor, anticipate and involve actors in processes of self-governance (Woolthuis, et al., 2005).

The systemic failures as presented above cannot be addressed directly, or by one actor alone. If policy makers want to use the framework, they will have to address groups of actors to make changes in the innovation system possible. Consequently, as opposed to the market failure approach for driving policy, a systems approach to innovation is seen as more robust (Bergek et al., 2010).

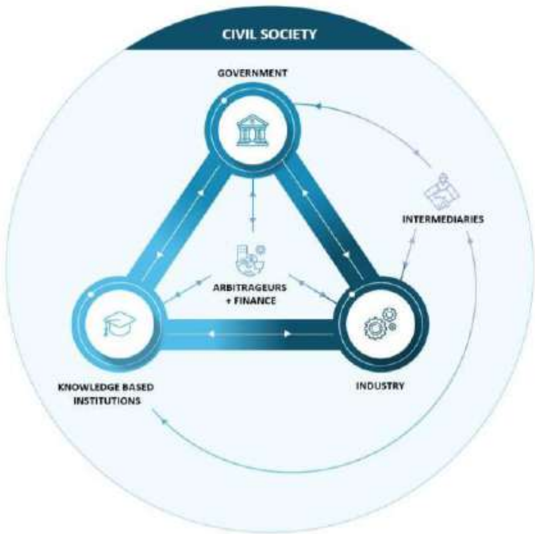
By using the systems framework as a tool for analysis, policy makers can identify: (1) where systemic failures occur; and (2) which actors should be addressed to make change possible. Most problems in the innovation system will not be uni-dimensional but will consist of a complex mixture of causes and effects and involve several actors. By using the framework, priorities can be given to the most stringent obstacles for innovation and thus also serve as a guideline to implement innovation policy.

2.4 The Triple Helix (TH) Model

Besides the systems approach, there are other tools that have the potential to offer similar facilitation for innovation at the sectorial level. The Triple Helix Model is advocated to be a powerful tool for linking universities to the rest. This can also be seen as a tool for operationalizing the IS concept. However, this might require setting-up a proper framework at a low scale to set the foundation for the running of the system, which is expected to be inclusive and socially embedded in the context of developing countries.

This interaction between government, universities and firms is addressed in the Triple Helix Model proposed by Etzkowitz and Leydesdorff (1997). This model is a descriptive construct of the components, interaction channels and functions or benefits of an effective NIS (Ranga and Etzkowitz, 2013; Santana, 2016).

FIGURE 2: Triple Helix Model extension



Etzkowitz (2002) states that interaction channels are necessary when firms and government are related with universities in knowledge-based economies. From a business perspective, the most important channels of transfer of knowledge are: open science, property rights, human resources, projects of collaborative research and development (R&D) and networking among actors (Cohen et al., 2002; Hanel & St.-Pierre, 2006; Arza, 2010; Bekkers & Freitas, 2008; Ruiz, Corrales and Orozco, 2017).

The triple helix is effective in understanding the dynamics of innovation at the sectorial, regional, national or international level, as it provides a well-elaborated framework for understanding central inquiries in innovation processes, including a) What the key actors are and b) What the mechanisms of interactions are (Cai and Amaral, 2021). Traditionally, the literature on the Triple Helix Model has focused on the relationships between universities and knowledge-based institutions (KBIs), firms, governments, and hybrid organizations at the intersection of these three helices (Etzkowitz and Leydesdorff, 1995; Leydesdorff, 2001). Etzkowitz and Leydesdorff developed the Triple Helix Model to explain the dynamic interactions between academia, industry, and government that foster entrepreneurship, innovation, and economic growth in a knowledge-based economy (Etzkowitz & Leydesdorff, 2000).

According to the literature, the scope and intensity of the interactions between the three actors are reflected in varying institutional arrangements, referred to as Triple Helix Type I, II, and III (TH-Type I, II and III) (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2003, 2008; Ranga and Etzkowitz, 2013).

In the TH- Type I, the three helices are strongly defined, with relatively weak interactions. Institutionally, "the nation state encompasses academia and industry and directs the relations between them" (Etzkowitz and Leydesdorff, 2000: p. 111). New knowledge is produced only within universities and research centres. Hence, TH-Type I is largely viewed as a failed development model with not enough room for 'bottom up' initiatives, where "innovation was discouraged rather than encouraged" (Etzkowitz and Leydesdorff, 2000, pg.112). To achieve statist reform "the first step [...] is the loosening of top-down control and the creation of civil society where one is lacking" (Etzkowitz, 2003a, pg.304). Otherwise, there is minimal direct connection to the needs of society, which in turn discourages the introduction and diffusion of innovations in the economy (Martin and Etzkowitz, 2000).

Triple Helix Type II is characterised by decreasing direct control of the state on the functions of Type I with a shift of focus on fixing market failures. The mechanisms of communication between the actors are strongly influenced by and deeply grounded in market mechanisms and innovations (Nelson and Winter, 1982; Bartels, et al., 2012). The point of control is at the interfaces (Leydesdorff, 1997) and consequently, new codes of communication are developed (Leydesdorff and Etzkowitz, 1998b). Research is also carried out outside universities and research centres. As research becomes increasingly multidisciplinary and applied, societal needs have a direct influence on it (Etzkowitz and Leydesdorff, 2000; Martin and Etzkowitz, 2000; Ranga and Etzkowitz, 2013).

TH-Type II can be considered a 'laissez-faire' model of interaction "in which people are expected to act competitively rather than cooperatively in their relations with each other" (Etzkowitz, 2003, pg.305). To summarise and compare TH-Types I and II, "statist societies emphasise the coordinating role of government while laissez-faire societies focus on the productive force of industry as the prime mover of economic and social development" (Etzkowitz, 2008, pg.13).

Furthermore, in TH-Type III, the three actors assume each other's roles in the institutional spheres as well as the performance of their traditional functions. With the emergence of TH-Type III, a complex network of organizational ties has developed, both formal and informal, among the overlapping spheres of operations. The transformation of universities is of particular relevance. After having incorporated research as an additional mission beyond teaching, universities recognise their role in the pursuit of economic and social development (Etzkowitz and Leydesdorff, 2000; Webster, 2000; Ranga and Etzkowitz, 2013; Etzkowitz, 2008, 2017). Hence, universities take on entrepreneurial tasks such as marketing knowledge, increased technology transfers and the creation of spin-offs and startups, as a result of both internal and external influences (Etzkowitz, 2017; Etzkowitz and Leydesdorff, 2000; Etzkowitz et al., 2000). These entrepreneurial activities are assumed with regional and national objectives in mind, as well as financial improvements to the university and the faculty (Etzkowitz, et al., 2000). In doing so, universities cease to be ivory towers, disconnected and isolated from society, but interact closely with industry and government (Etzkowitz and Leydesdorff, 2000; Etzkowitz et al., 2000). In addition to the above, "firms develop an academic dimension, sharing knowledge among each other and training employees at ever higher skill levels" (Leydesdorff and Etzkowitz, 1998, pg.98), as well as increasing collaboration with knowledge-based institutions (KBIs). Improved university-industry collaboration is visualised through: i) an increased patenting output, particularly as they are a "repository of information about how the socially organised production of scientific knowledge is interfaced with the economy" (Leydesdorff, 2004); ii) the increase in university revenues from licensing (Perkmann and Walsh, 2007); iii) a greater proportion of industry funds making up university income (Hall, 2004); and iv) the diffusion of technology transfer offices, industry collaboration support offices and science parks (Siegel et al., 2003, in Perkmann and Walsh, 2007, pg. 4). Governments therefore create incentives through "informed trade-offs between investments in industrial policies, S&T policies, and/or delicate and balanced interventions at the structural level" (Leydesdorff, 2005). Phrased differently, there is a shift in the traditional role of policy from the facilitation of basic science to its 'bridging function'. In a nutshell, the Triple Helix Type III assumes that the three spheres - universities, industry, and government - overlap, and their boundaries become more permeable. A complex network of organizational ties develops individuals and ideas move around the three helices, and synergies are maximised (Etzkowitz, 2002). Actors evolve and assume each other's roles, with new hybrid organizations emerging at the interfaces, for example incubators, accelerators, science parks, technology transfer offices, venture capital firms, angel networks, and seed capital funds (Etzkowitz, 2000; Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2002; Ranga and Etzkowitz, 2013).

The Triple Helix Model has also been applied to the context of developing economies. Case studies document how innovation and learning processes differ in developing economies, what factors constrain the adoption of more integrated Triple Helix models, and how actors and mechanisms cope with these factors (Sarpong et al., 2017). In this regard, it has been noted that while the components of the triple helix do not change, the intensity and quality of their interactions are often weaker than in developed economies (Dzisah and Etzkowitz, 2008). Generally, in order to address such challenges effectively, through tailored and targeted policy interventions, there is the clear need for system level measurement.

2.5 Towards an Analytical Framework

Our framework for analysis of the IASSI is grounded in the literature, but it extends the traditional model in two main ways and is referred to as Triple Helix (TH-Type IV) Type IV[16] [17]. The TH-Type IV has the additional features of arbitrageurs (banks, financial institutions, venture capital and angel investors) and intermediary organizations (industry associations, institutions supporting technical change and incubators), as well as diffused ICT in the context of the fourth industrial revolution.

Arbitrageurs can be defined as venture capitalists, angel investors/ networks and knowledge brokers. They are essential for the innovation process as it requires internal and external knowledge for the development of new ideas, business models and types of companies. As such, knowledge brokers and venture capitalists fulfil this requirement through the provision of links, knowledge sources and even technical knowledge so that firms can improve their performance, in terms of survival rate, as well as accelerate and increase the effectiveness of their innovation processes (Zook, 2003; Baygan and Freudenberg, 2000). Their resource allocation role is based on the assessment of advantages in information asymmetries (Williamson, 1969, 1971, 1973) (Bartels, et al., 2012, pg.7). However, information asymmetry and uncertainty can lead to transaction problems. “Countries seeking to encourage the emergence and growth of entrepreneurial firms need to devise ways that reduce transaction problems” (Li and Zahra, 2012, pg.95). It can be said that a combination of both formal institutions and (informal) cultural values can provide the proper incentives to reduce transaction problems. Arbitrageurs are therefore of vital importance as the innovation process requires internal and external intermediation (financial, knowledge, transacting and investment), and as such, complement the traditional Triple Helix Model.

Intermediaries are recognised as actors that place themselves in the middle of relationships between other actors, or actors that facilitate the process of interacting in exchange relationships. Four roles of intermediaries include: (a) consultant, providing information and advice in the recognition, acquisition and utilisation of the relevant intellectual property and technological capabilities; (b) broker, brokering a transaction between two or more parties; (c) mediator, acting as an independent third party who assists two organizations achieve a mutually beneficial collaboration and (d) resource provider, acting as an agent who secures access to funding and other material support for the innovation outcomes of such collaborations (Chunhavuthiyanon & Intarakumnerd, 2014; Chappin et al., 2008).

Nakwa et al., (2012) highlight the importance of intermediaries in transforming pre-existing inter-firm networks into more robust, dynamic, and sustainable system-oriented networks. In addition, Nakwa et al., (2012) indicate that “intermediaries play a sponsoring role at the policy level by channeling resources to industry; a brokering role at the strategic level by linking triple helix actors; and a boundary spanning role at the operational level by providing services that facilitate knowledge circulation”.

Intermediary organizations are pertinent in facilitating the flow of knowledge, technology, and skills among the actors of the SI. Within this actor group, institutions supporting technical change (ISTC) promote knowledge generation, technology development and commercialisation; facilitators like industry associations establish and reinforce the links between system actors through networking; enablers such as industrial parks and incubators support with infrastructure, framework conditions, capabilities and related resources and funders (Letaba, 2019).

Table 2 below shows core actors, arbitrageurs and intermediary organizations by the function they perform in the Indian food and beverages sector. These functions span across the innovation value chain, namely: knowledge generation and transfer; technology development, acquisition, and transfer; product development; testing services; commercialisation; and business development.

[16] Leydesdorff claims no ex-ante or necessary limitation to three helices for the explanation of complex developments, but instead propose that an N-tuple or an alphabet of (20+) helices can be envisioned. However, in scholarly discourse and for methodological reasons, one may wish to extend models step by step and as needed to gain explanatory power. (Leydesdorff, 2012).

[17] Civil society - comprising the activities of non-state organizations, institutions, and movements - has in recent years emerged as the major force for change in the realms of politics, public policy, and society both globally and locally. It is also recognized as an actor in the in the quadruple helix (Roman et al., 2020). Yet, despite the crucial importance of this political phenomenon to the principle and practice of democracy, it eludes definition and systematic understanding (Anheier 2004). The benefits of incorporating civil society within systems measurement, and hence policy craft include: i) the provision of bottom-up insights, particularly as civil society represents demand-side perspectives, such as innovation users and consumers; ii) supports the creation of social innovations, and legitimation and justification for innovations; iii) promotes commitment to and ownership of a development agenda. However, despite the benefits civil society comprises a heterogeneous group of actors who must themselves be approached differently and therefor measurement is a challenge. It would be important to note that participation of civil society should be included for the policy selection and implementation process.

TABLE 2: Intermediary organizations by function

Function	Knowledge based institutions	Government	Intermediaries	Arbitrageurs
Technology Development	• University-enterprise joint research centre • Science Park	• Technology Information Forecasting and Assessment Council (TIFAC)	• ACMA • SIAM • ARAI	
Technology Transfer	• Science Park • University-enterprise joint research centre • University-owned enterprise centre	• Technology Information Forecasting and Assessment Council (TIFAC) • Global Innovation & Technology Alliance (GITA)	• ACMA • SIAM • ARAI	
Technology Acquisition		• Global Innovation & Technology Alliance (GITA)		
R&D		• Auto Cluster Development and Research Institute	• Auto Cluster Development and Research Institute	
Knowledge Transfer	• Living Labs	• National Productivity Council • Global Innovation & Technology Alliance (GITA)	• ACMA • SIAM • ARAI	
IP Protection	• Science Park	• Patent offices	•	
Infrastructure Development		• Ministry of Heavy Industries	• ACMA • SIAM • ARAI	
Product Development		• National research & development corporation		
Human Capital Development	• University-enterprise joint research centre	• Automotive Skill Development Council (ASDC) • Indo German Tool Room, Aurangabad • National Institute For Automotive Inspection Maintenance & Training (NIAIMT)	• ACMA • SIAM • ARAI	
Business Development	• Science Park • Incubator • Industrial Park	• National engineering research centre • Incubator • Industrial Park	• Incubator • Industrial Park	
Funding	• University-enterprise joint research centre	• Ministry of Heavy Industries • Technology Acquisition and Development Fund (DPIIT) • Department of Scientific and Industrial Research (DSIR)	• ACMA • SIAM • ARAI	
Fund raising		• Ministry of Heavy Industries • Banks	• Venture Capital • Angel Investors • ACMA • SIAM • ARAI	
Agenda setting		• Ministry of Heavy Industries • NITI Aayog	• ACMA • SIAM • ARAI	
Testing & certification services	• University-enterprise joint research centre	• National Automotive Test Tracks (NATRAX) • Bureau of Indian Standards (BIS) • National Accreditation Board for Certification Bodies (NABCB) • BSCIC Certifications Pvt. Ltd. • National Institute for Automotive Inspection Maintenance & Training (NIAIMT)	• ARAI	

Source: Letaba, Petrus (2019)

Compared to the Triple Helix Type III, our augmented version of the model also gives prominence to the fourth industrial revolution (4IR) and digital transformation through ICTs. Through the spread of digital information and ICT, a new technological wave and a new corresponding mode of development has emerged (Perez, 1983; Freeman and Louça, 2001; Mowery, 2009). Innovation activities shape and use ICTs with lagged but often large effects on productivity and innovation in both developed and developing economies (Paunov and Rollo, 2016; Hjort and Poulsen, 2017). The channels through which ICTs affect firms' productivity and innovation are multiple, and often difficult to disentangle. For example, ICTs can facilitate access to information and knowledge, fostering learning and knowledge flows, or ease communication among firms and SSI actors, thereby promoting collaborative projects. To make the most of these new technologies, countries have put in place several policies. However, often their design does not take full account of the local environment in which actors operate, suggesting a potentially large role for evidence-based policymaking in this area (Koria et al., 2014).

Today, ICTs are at the centre of what many believe to be the Fourth Industrial Revolution (4IR) (World Bank, 2016). Each of the actors in the Triple Helix Type IV has a specific role to play in the context of the 4IR. Using analytics and data, the 4IR allows firms to identify new opportunities, expand their businesses and tap into new markets. 4IR technologies enable firms to increase their productivity, provide better customer experience, and optimise resources.

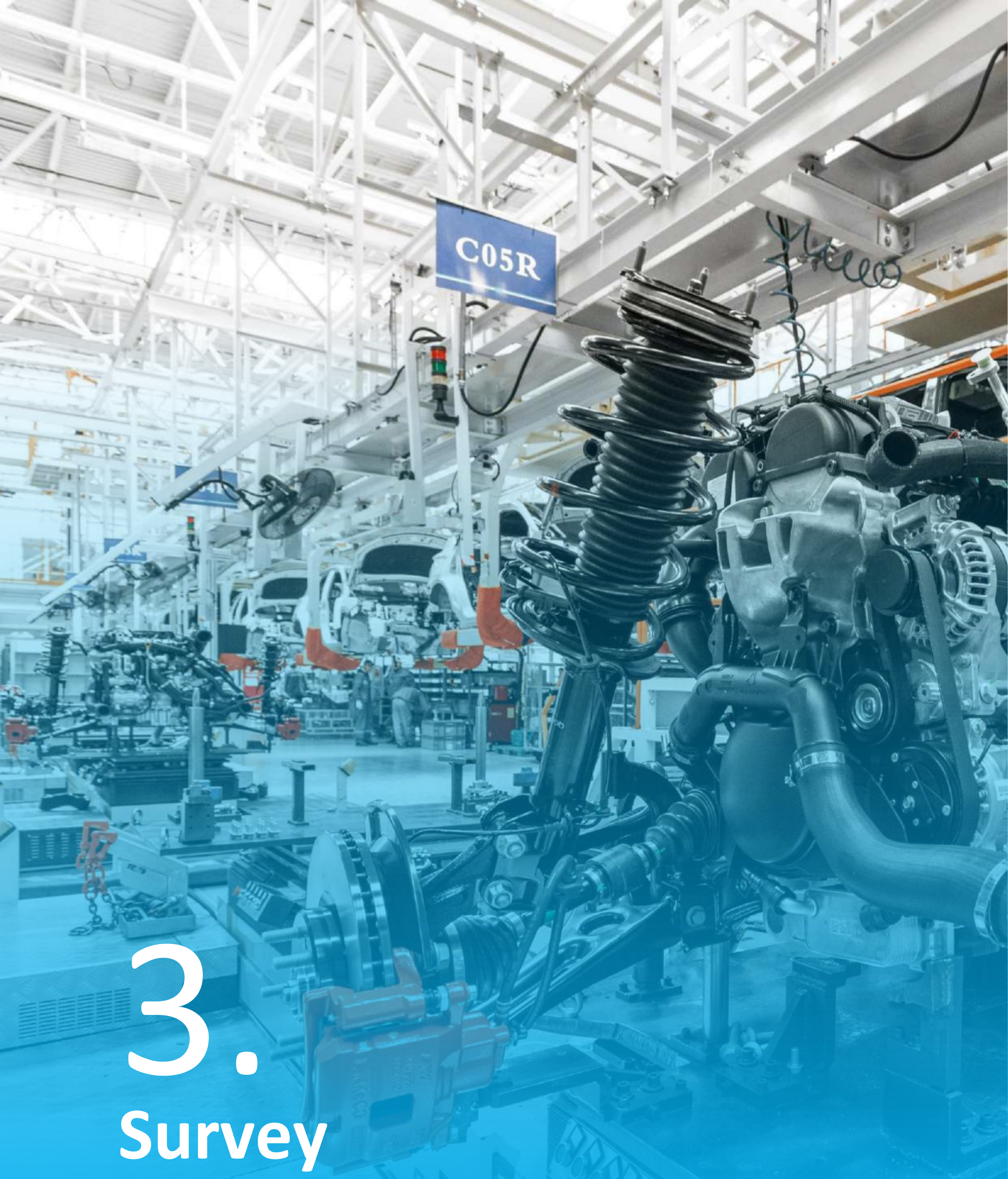
Universities have a great role to play to make the 4IR a reality, particularly through fostering the development of future skills as well as acting as test beds for new technologies. The role of the government in the context of the 4IR is to facilitate the adoption of emerging technologies through support infrastructure and regulations (Kucirkova, 2019).

The adoption of the 4IR and digital transformation requires investments which could be satisfied with the help of arbitrageurs such as venture capital (Deloitte, 2018a). Innovative technologies are becoming more prevalent and venture capitalists are making even greater investments in them. Venture capital investments in 4IR-focused startups have steadily increased, both in terms of size and number of deals. Globally, venture capital investments in this arena grew from approximately US$ 600 million in 2014 to US$ 2.3 billion in 2016, representing a 40% CAGR (Deloitte, 2018).

However, venture capitalists need to be mindful of conservative and risk-averse investment strategies that fail to consider a broad range of promising investments bias towards companies in specific narrowly defined industries. VCs should not conflate “risk averse” with prudent (Forbes, 2021). Regular communication between arbitrageurs and especially with industry and other actors such as KBIs, government and intermediaries can help VCs understand the dynamics of the sector and invest accordingly.

Due to the rapid changes in technologies linked to digital transformation and the 4IR, firms require the support of intermediaries as knowledge brokers. Intermediaries can ensure that knowledge spillover processes are more inclusive for firms and thereby contribute to developing their absorptive capacities. In addition, intermediaries have a vital role in building efficient technology transfer systems between actors of the system of innovation (Karlsen et al, 2022).

In light of the above, utilising the Triple Helix Type IV for measuring the Indian Automotive Sectorial System of Innovation (IASSI) provides an evidence-based framework for identifying barriers and priorities, leading to the articulation of policies and targeted short-, medium- and long-term interventions.



3. Survey Methodology

Survey Methodology

The Indian Automotive Sectorial System of Innovation (IASSI) Survey has been conducted to obtain a holistic view of the SSI as a basis for evidence-based innovation policy for the automotive sector; one of the five sectors surveyed under the sectorial system of innovation component of the National Manufacturing Innovation Survey 2021-22.

Essentially, two basic forms of data collection exist, those with and those without an interviewer, or, phrased differently: interviews and self-administered questionnaires (De Leeuw, 2009 in Dillman ed). Interview surveys can either be administered in person or over the telephone. There is a great deal of variation in the use of these methods across countries, due to technical reasons (lack of infrastructure) or cultural norms (Dillman, 1978; Dillman, 1998). Self-administered questionnaires take on many forms and can be used in group or individual settings. A well-known example of a self-administered questionnaire is the mail survey, and its computerized equivalent, the Internet survey, which is currently widely used (Raziano, et al., 2001; De Leeuw et al., 2003). Often a combination approach is used, particularly when there is the need to ask sensitive questions. All the taxonomical approaches mentioned are respondent orientated, and the method choice is complex and based on a delicate balance between the quality of the data acquired, time and costs.

The Internet-based approach was chosen in line with the reasoning of Koria, et al., (2012) that i) "… maximising the use of the budget, internet surveys can cover a much larger sample size than the conventional mail survey (Berrens, et al., 2003); ii) the time dimension associated with conducting web-based surveys is much lower in comparison to other forms (Cobanoglu et al., 2001); iii) the quality of retrieved data is higher in terms of non-response and the ability to include conditionality in a discreet manner (Olsen, 2009); iv) a higher reliability of data is achieved due to the reduced need for data entry (Ballantyne, 2004; and Muffo, et al., 2003)" (Koria, et al., 2012., pg.8); and v) the emergence of the COVID-19 pandemic restrictions during the implementation phase of the project which limited face-to face interaction.

3.1 Sample Selection

As per the "Theoretical Framework" chapter, the IASSI Survey focuses on five core actor groups, namely: government (GOV), knowledge-based institutions (KBI); arbitrageurs (ARB); intermediaries (INT) and industry (IND). The executive policy community, essentially the government (GOV), is represented by high-level officials (national and state level) in the relevant public institutions that are directly or indirectly responsible for innovation in the automotive sector. Knowledge-based institutions (KBIs) are represented by the heads of university faculties/ departments from the disciplines of engineering, technology and innovation, think-tanks, as well as both public and private research institutes (RIs). Arbitrageurs (ARB) comprise the venture capital, angel investors, and banks or other financial institutions and are represented by their respective heads or senior management. Intermediaries constitute industry associations and institutions supporting technical change such as regulatory bodies and are represented at the managerial level. The industrial community is represented by the CEOs of firms from the automotive sector.

Procedure:

Non-firm actors, namely GOV, KBI, ARB and INT were sampled on a convenience basis. A frame was prepared for the automotive sector with around 200 relevant non-firm actors within GOV (20), KBI (70), ARB (50) and INT (60) which was treated as the universe and the sample. Sampling for firms (IND) was conducted through stratified random sampling across 28 states and 8 union territories, the five sectors, including the automotive sector from the National Industrial Classification (NIC) 29 (2008) and their respective firm sizes were measured through a combination of turnover, investment in plant and machinery or equipment or employment.

The sampling frame for firm actors has been obtained from the "Annual Survey of Industries" (ASI) 2018-19 frame, the Centre for Monitoring Indian Economy's (CMIE) Prowess IQ database (2018-19) and the Department of Science and Technology's (DST) directory (2018-19). With a total of 6,004 firms from the automotive sector, after sampling 589 firms were surveyed.

FIGURE: - Firm size classification

Turnover	≤ 5 cr	Large	Medium	Small	Micro
	≤ 50 cr	Large	Medium	Small	Small
	≤ 250 cr	Large	Medium	Medium	Medium
	> 250 cr	Large	Large	Large	Large
Firm size classification		> 50 cr	≤ 50 cr	≤ 10 cr	≤ 1 cr
		Investment in plant and machinery or equipment			

The Government of India notification mentions that: If an enterprise crosses the ceiling limits specified for its present category in either of the two criteria of investment or turnover, it will cease to exist in that category and be placed in the next higher category but no enterprise shall be placed in the lower category unless it goes below the ceiling limits specified for its present category in both the criteria of investment as well as turnover.

In some cases, employment data was used as a proxy for firm size and the firms were reclassified after the survey.

- Large – 200 + employees (Kapoor., 2016, p.11)[18]
- Medium – 50 to 199 employees
- Small – 20 to 49 employees
- Micro – 0 to 19 employees (Kapoor., 2018, p.12)

Limitations:

- The data collection was impacted due to the covid crisis as businesses were closed. This has affected the survey response rate to some extent with an overall response rate of 70%, a firm response rate of 63.67% and non-firm response rate of 89%.
- Absence of a baseline for evaluating the performance of SSIs in India as there are no prior surveys conducted along the same lines.
- The classification of firms into large, medium, small and micro is only a rough estimate given that the universe is a combination of 3 databases with the absence of similar parameters to measure firm size.

3.2 Data Collection

Due to the technical nature of the data to be collected it is imperative that the quality and integrity of information is ensured. Consequently, the outlined approach was utilised to maintain a level of rigour in the selection of enumerators from Indian knowledge-based and technical institutions, as compared to standard data collection firms. The merits of the approach are outlined below:

Selection of enumerators and retention

Criteria: Given the highly technical nature of the information to be collected it is imperative that the selected enumerators were able to:

- Comprehend the specifics of innovation and systems of innovation.
- Effectively communicate innovation constructs to the target respondent.
- Guide the discussion as and when required, based on some degree of understanding and exposure to innovation in the sector, which will also enable them to support data analysis and reporting.
- Demonstrate experience in data collection and therefore be able to extract nuanced information.
- Communicate in the relevant regional language of the focus state; and
- Summarise the findings and participate in further analysis of the data to support the UNIDO team.

Enumerators were trained on systems of innovation, technical aspects related to the automotive sector and data collection techniques with the Lime Survey® interface. In order to ensure data quality, Lime Survey® enables real time tracking of enumerators to the respondent level through the back end. It also signals when surveys have been partially completed. The fact that an online interface is being used means that there is zero transcription error, that is, once the response to a question is given it is

[18] Small firms are defined as those having less than 50 employees, medium firms have 50-199 employees and large firms are defined as those having 200 or more workers.

automatically updated to the database. In addition, spot checks from the response data are randomly taken to ensure data quality at the level of each individual enumerator is being maintained.

3.3 The Data Acquisition Survey Instrument (DASI)

The Data Acquisition Survey Instrument (DASI) for the IASSI Survey was created using an iterative multi-step process, and currently stands at its fourth iteration. The provenance of the earlier iterations of the tool can be found in Ghana, Kenya and Cabo Verde National System of Innovation Survey Reports (UNIDO, 2012; UNIDO, 2015; UNIDO, 2019). The current iteration, DASI-V4, saw the introduction of new actor-specific questions to support measurement at the sectorial level and to provide better insights at the actor level. This enhancement of the DASI allows for greater accuracy and impact of the policy recommendations in the short-, medium, and long-term.

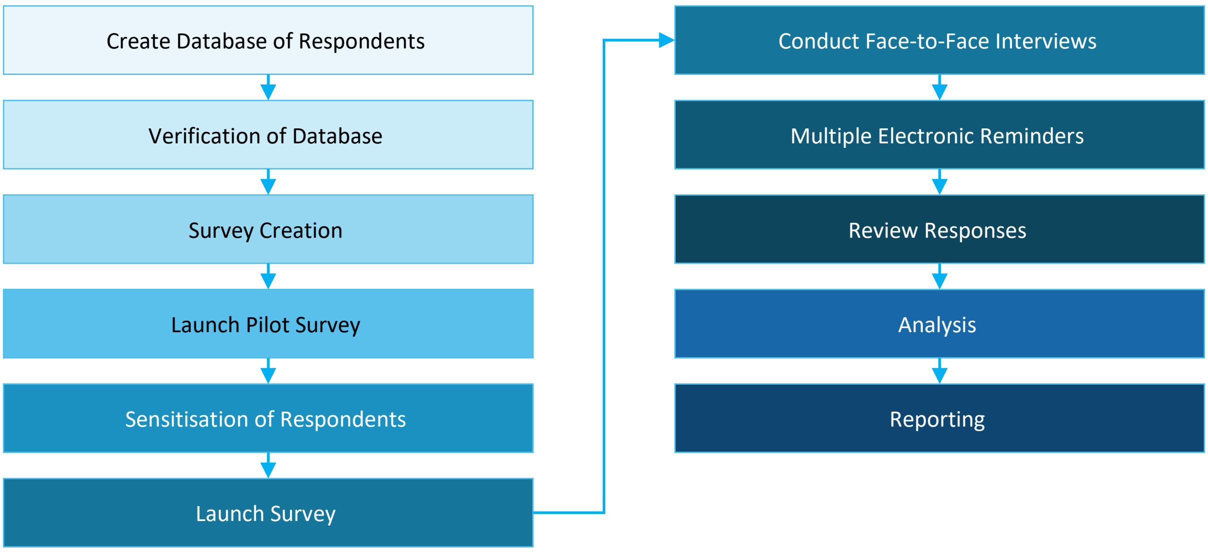
3.4 Survey Operationalisation

The launch of the survey was accomplished by using face-to-face interviews and telephonic interviews where the former was not possible, and the results were entered on a real-time basis into the Lime Survey®. The Lime Survey® tool is an advanced online survey system. The outputs from the verification protocol were uploaded into the Lime Survey® system and individual tokens were assigned to each target respondent. This restricted survey access solely to the survey enumerators who interviewed the targeted individual respondent, therefore greatly enhancing the fidelity, reliability and validity of the results obtained.

As previously mentioned, the IASSI Survey was launched remotely once the initial critical mass of target respondent contacts had been gathered. The survey was remotely and non-intrusively managed via the Lime Survey® interface by the project team at HQ. Electronic reminders were sent out to enumerators for the interviews that were only partially completed or not responded to at all. This process was facilitated by the structure of the Lime Survey® back-end, as the system logs the exact date and time at which the survey was accessed and to what degree it was completed.

For those survey enumerators who had not accessed the survey for a long period, a follow up was made telephonically to monitor any potential technical difficulties. Once responses were completed, they were automatically uploaded into the survey response database. On completion of data collection, the survey responses were analysed with the planned statistical analysis in mind. Figure 3 shows the steps associated with the data collection process.

FIGURE 3: Operational Methodology

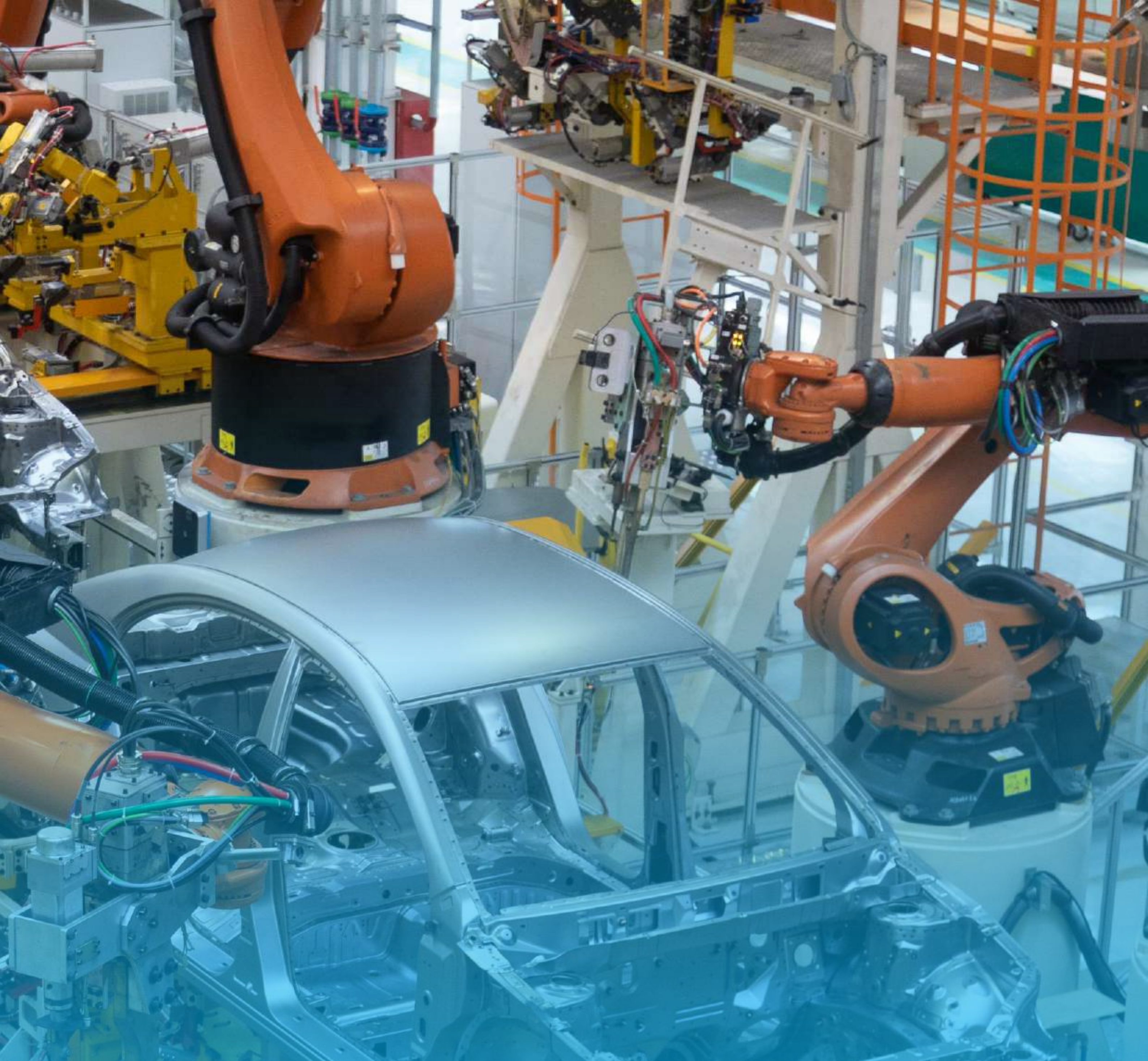


3.5 Secondary Data Collection

In addition to the primary data collection undertaken it is crucial to gain a view of what is being presented in the form of secondary sources at the sectorial level, particularly those from the government. The secondary sources that were analysed comprised qualitative material consisting of policy documents, government budget statements, development strategies and action plans at the national and sectorial levels. The purpose of analysing these documents was to gain an understanding of the policy direction that the Government of India is taking with respect to innovation in the pharmaceutical sector. Phrased differently, is there convergence or divergence between what is presented within policy documentation from the actual results obtained? The results of the analysis are presented in the "Results and Analysis" chapter of this report.

3.6 Stakeholder consultation

In order to garner preliminary insights into the results obtained from the survey, a stakeholder consultation was undertaken. Results were presented and discussed with sector experts and practitioners in order to understand whether or not the observations were meaningful. The platform provided an opportunity to orient the report writing through linking the findings to specific case examples as well as highlighting any supporting secondary research that may have been conducted at the national level. The process was important for the identification of any potential outliers in the results.



4. Manufacturing Trends in the Automotive Sector

Manufacturing Trends in the Automotive Sector

4.1 Indian Automotive Sector: Structure and Dynamics

The Indian automobile sector is the center of India's manufacturing economy, contributing significantly to growth and employment. In addition, it has a large, labour-intensive ancillary sector and has essential horizontal and vertical linkages with other industries, serving as a bellwether for the current state of the Indian economy.

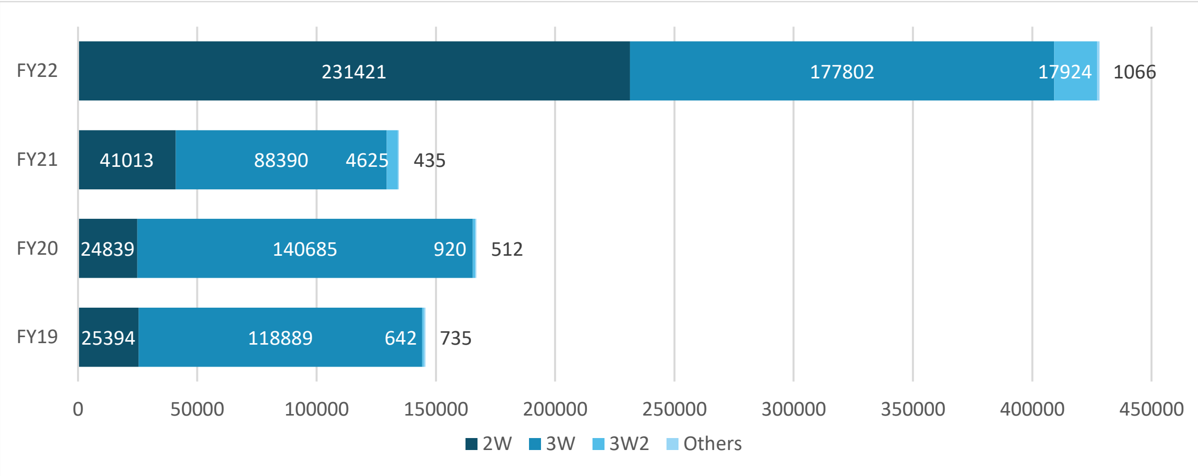
The Indian automobile sector was valued at US$ 222 billion in FY 2022 and is predicted to grow at a combined aggregate growth rate (CAGR) of 9% between FY 2022-2023 to US$ 300 billion by 2026[19]. The industry accounts for 7.1% of the Gross Domestic Product (GDP) of the Indian economy and comprises about 49%of its manufacturing economy. India has a robust domestic market in terms of demand, with exports from the country also showing significant growth in recent years. The number of vehicles manufactured in India during FY 2022 stood at 22.93 million, of which 17.51 million were sold in the domestic market (see Table 1). The rest were exported, with the US being the largest exporter (US$ 3 billion)[20,21]. While the industry numbers are reasonable compared to FY 2020-21, they have not yet reached their pre- COVID-19 strength. The industry also faces headwinds from supply chain restraints, high fuel and commodity prices, overbooking, and rural distress.

The sector can be broadly divided into two industries: the automotive industry and the auto component industry.

The well-developed Indian automotive industry is responsible for the manufacturing and sales of passenger cars, commercial vehicles, and two-three-wheelers, with the component industry complementing them in each case.

In spite of being the fourth largest automobile market in the world, India still has only 23 cars per 1000 person compared to the USA's 349, Europe's 580 and China's 116[22]. The majority of sales in the sector are for two-wheelers with passenger cars coming in second. The passenger car market is also dominated by small- and mid-size cars. The industry is expected to record strong growth in FY 2023, with electric vehicles (EVs), especially two-wheelers, likely to witness positive sales in FY 2023, continuing the trend of previous years (see Figure 4[23]). The Indian EV market is expected to grow at a CAGR of 36% until 2026. In addition, the EV battery market is forecast to expand at a CAGR of 30% during the same period and is expected to peak at US$ 200 billion by 2030[24].

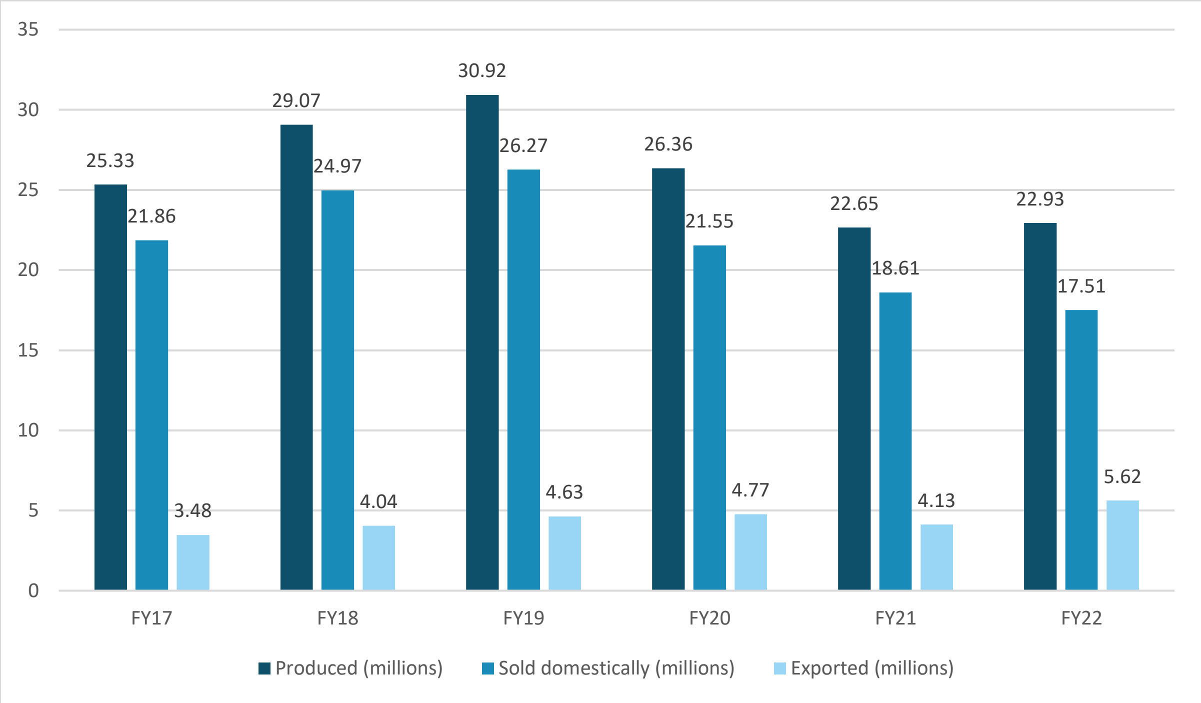
FIGURE 4: EV sales category-wise



[19] Invest in Indian Automobile Industry, Auto Sector Growth Trends: https://www.investindia.gov.in/sector/automobile
[20] India Brand Equity Foundation: https://www.ibef.org/industry/automobiles-presentation
[21] Sourced from: https://commerce.gov.in/press-releases/f-no-219-2020-stats-div-government-of-india-ministry-of- commerce-industry-department-of-commerce-directorate-general-of-foreign-trade-statistics-division-2/
[22] Road Transport Year Book (2021): https://morth.nic.in/sites/default/files/RTYB-2017-18-2018- 19.pdf
[23] Society of Indian Automobile Manufactures: https://www.siam.in/statistics.aspx?mpgid=8&pgidtrail=9
[24] Sourced from: https://www.newindianexpress.com/business/2021/nov/20/indian-ev-market-set-to-lead-globally-may-peak-usd-200-billion-by-2030-2385916.html

While the development in EV (Mohile, 2022) is commendable, it is important to note that the sector provides approximately 37 million of direct and indirect jobs, with the auto component industry directly employing 5 million people. According to data from the ACMA, ICE powertrains contribute to over 60% of the component sector's employment generation. The switch to all-electric powertrains could impact up to 5.6 million jobs by 2025-26.

FIGURE 5: Production, sales and export data of Indian automobile industry



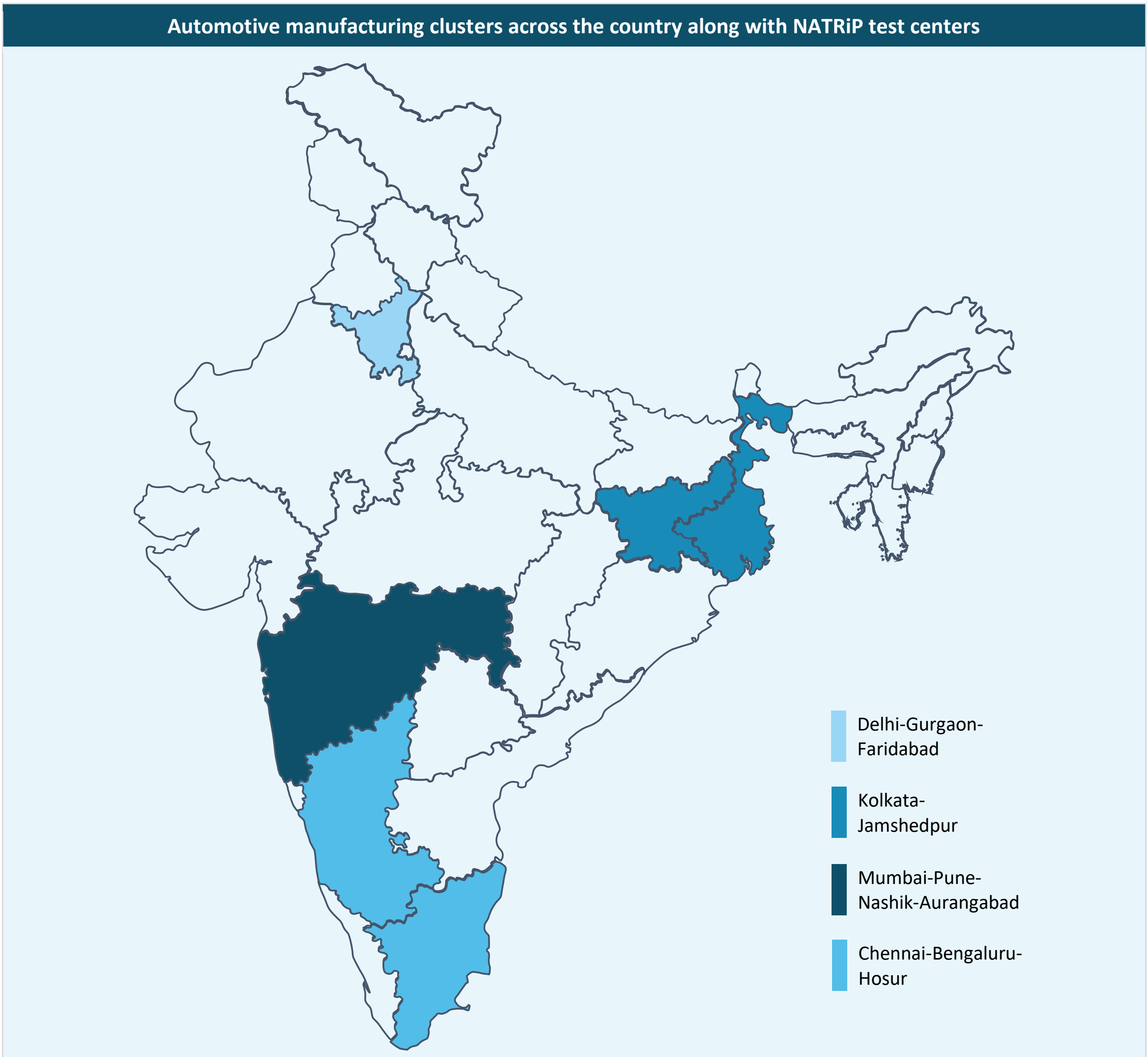
The auto-component industry also showed a robust 23% growth after two years of contraction. The industry's turnover stands at US$ 56.5 billion, which includes supplies to domestic OEMs[25], aftermarket and service sales, and exports. It is to be noted that 99% of the deals are in the domain of Internal Combustion Engine (ICE) vehicles, with EVs only accounting for 1% of total component consumption[26].

TABLE 3: Segment-wise domestic production

Category	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
Passenger vehicles	3801670	4020267	4028471	3424564	3062280	3650698
Commercial vehicles	810253	895448	112405	756725	624939	805527
Three wheelers	783721	1022181	1268833	1132982	614613	758088
Two wheelers	19933739	23154838	24499777	21032927	18349941	17714856
Quadricycles	1584	1713	5388	6095	3836	4061
Grand total	25330967	29094447	30914874	26353293	22655609	22933230

[25] An Original Equipment Manufacturer (OEM) makes systems or components that are used in another company's end product.
[26] Future of Mobility: Transforming to be ahead of the opportunity, ACMA Annual Report 2021-22: https://www.acma.in/uploads/publication/annual-report/ACMA-Annual-Report-2021-22.pdf

FIGURE 6: Automotive manufacturing clusters across the country along with NATRiP test centers



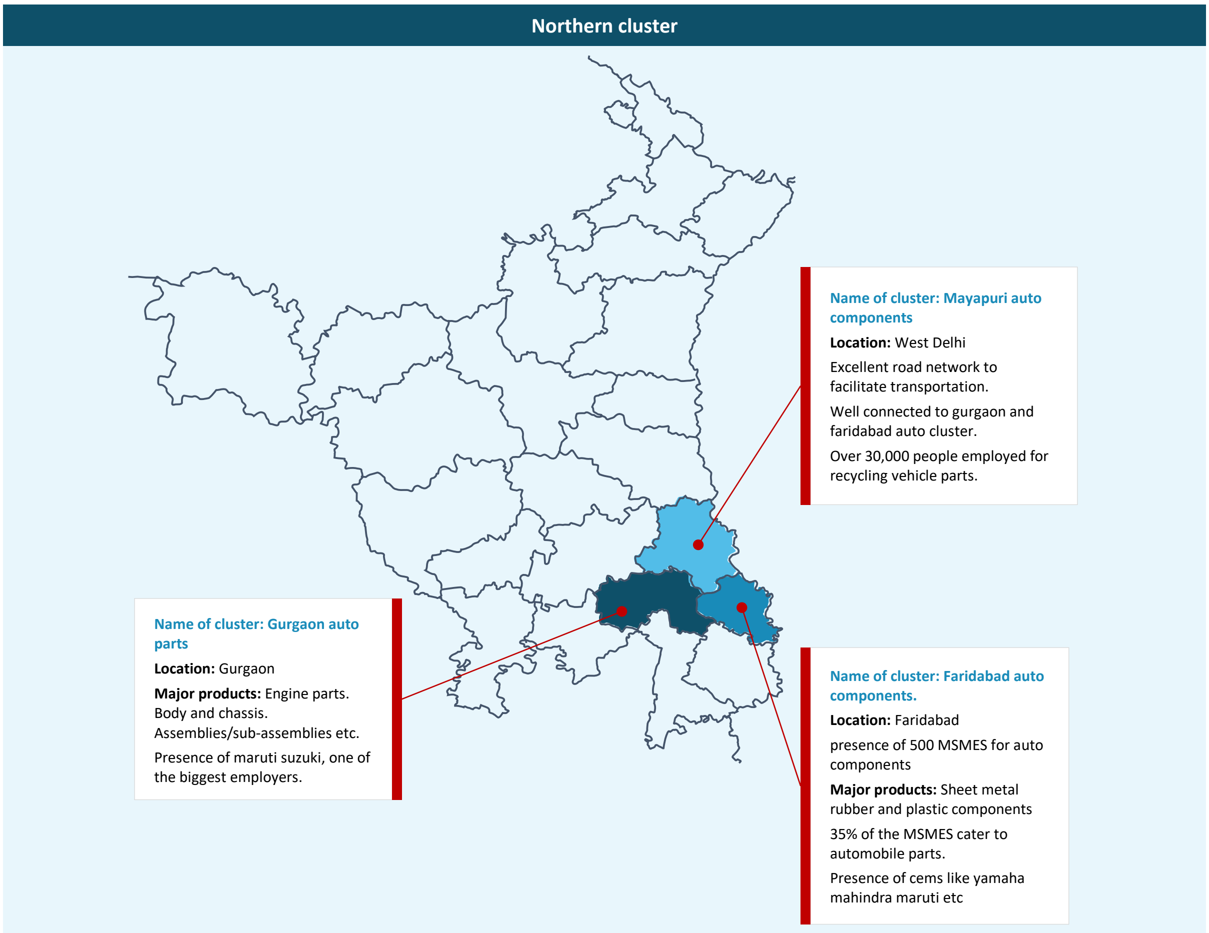
In terms of research and development, the Indian automotive industry constitutes 8% of the total R&D expenditure of the country. Major automotive companies spend on average 3-5% of their revenues on R&D (Narasimhan, 2019) and more than half of these investments have been used towards emission compliance and electrification. Investment flow into EV startups in 2021 touched an all-time high, increasing nearly 255% to reach INR 3,307 crore (US$ 444 million). There is a need to set-up proper charging infrastructure for EVs in India. To install electric vehicle supply equipment (EVSE) infrastructure for EVs, various public sector firms, ministries and railways have come together to create infrastructure, and to manufacture components. To help the automotive industry reach global standards, the Indian government started the "National Automotive Testing and R&D Infrastructure Project" (NATRiP) under the Automotive Mission Plan 2006-2016 with a total budget of US$ 388.5 million. The NATRiP has completed 21 of the planned 22 sanctioned facilities with one remaining facility still under construction in Chennai[27]. Out of these 22 facilities, six full-fledged test centres have been set-up nearby the major automotive clusters across the country.

Within India, there are three major automotive clusters, namely, northern, southern and western. The northern automobile cluster (see Figure 7) is located in the National Capital Region (NCR) covering Delhi, Gurugram and Faridabad (Haryana). The well-connected road network of Delhi and Haryana with the rest of the country and the 165 km long Yamuna expressway helped to form this cluster. Within the northern cluster, Haryana has a strong presence of automobile manufacturers such as Maruti-Suzuki, Hero-

[27] Annual Report 2020-21: https://static.investindia.gov.in/s3fs-public/2022- 04/Annual%20Report%202021-22%20MHI.pdf

Honda, Honda Motors and Escorts which have led to the development of a large number of ancillaries. The Gurugram-Manesar-Bawal region has been identified as an auto hub by the Government of India. A number of auto and auto component units have already set-up bases in this hub. The NCR cluster hosts R&D and testing facilities and is well-connected with the rest of India. For example, the International Centre for Automotive Technology (ICAT) located in Manesar provides testing and R&D services to the industry and was set-up as a part of the NATRiP.

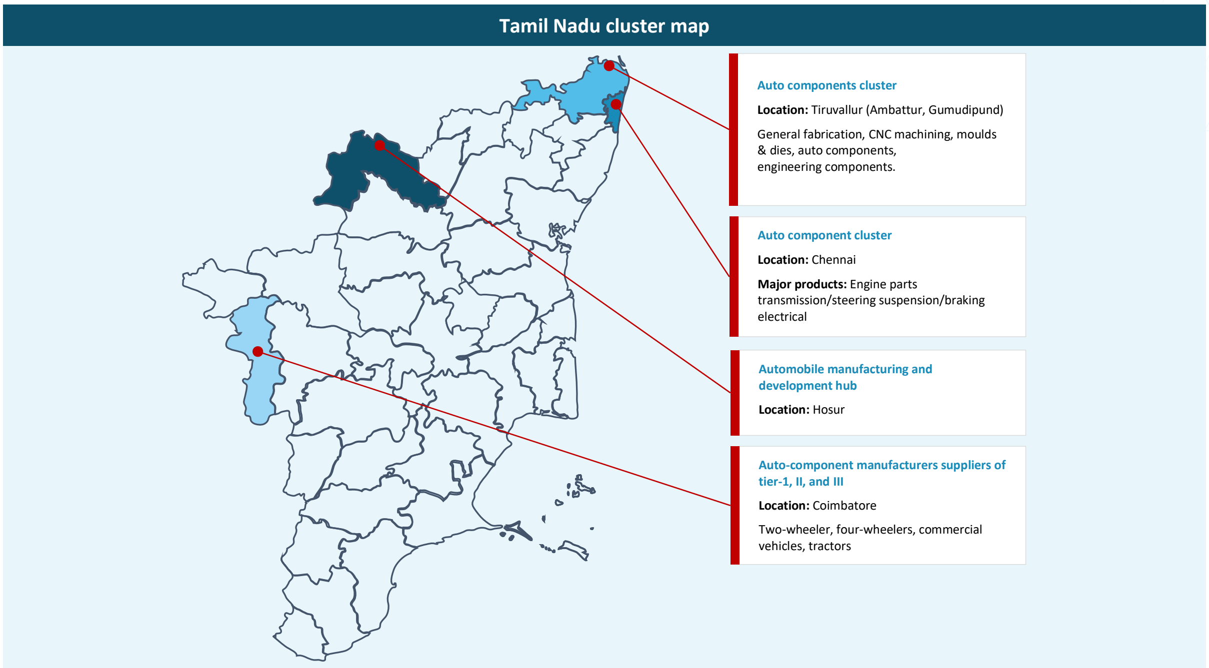
FIGURE 7: Northern cluster



Source: IBEF

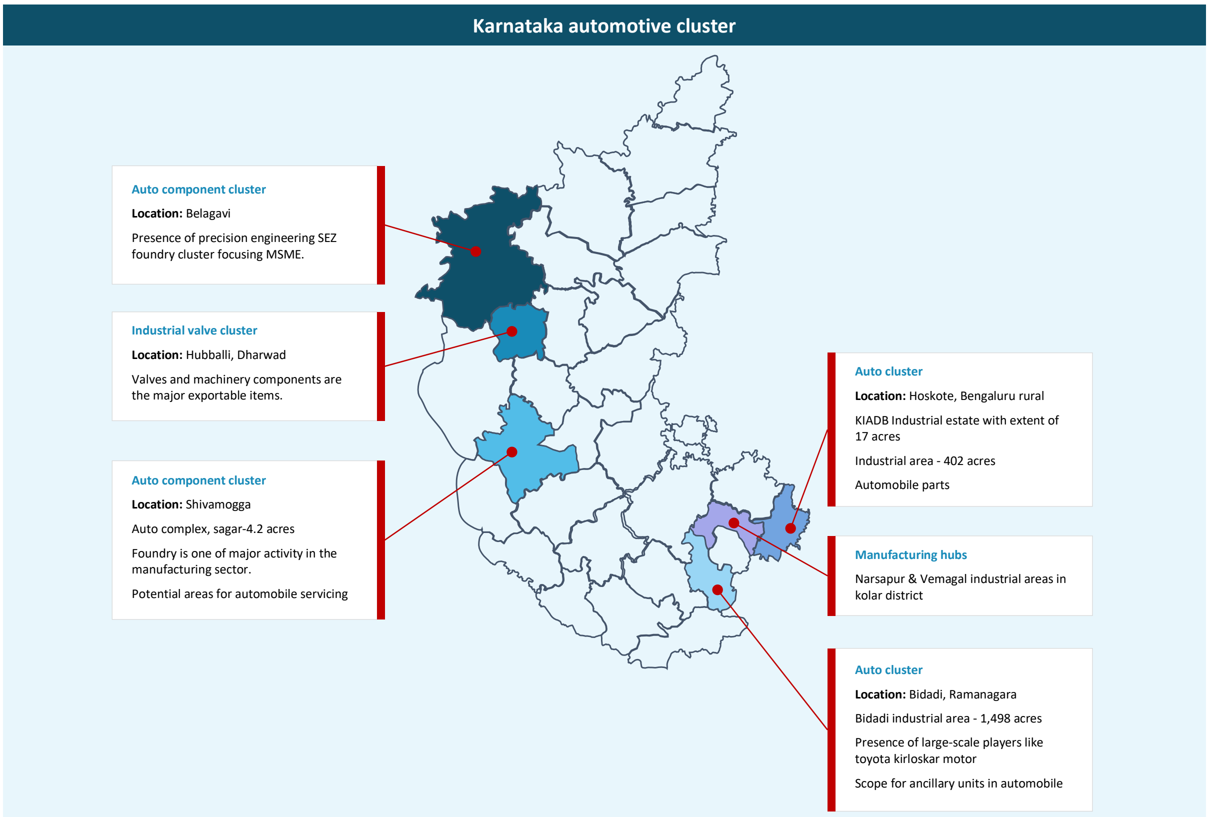
Chennai, Hosur and Bangalore form the major locations in the southern automotive cluster (see Figure 8) and the Chennai-Bangalore industrial corridor is also in this region. The state governments have been providing the required facilities and incentives in order to further promote the sector. One of the objectives of the Tamil Nadu Industrial Policy 2014 was to strengthen the state as a manufacturing hub and attract incremental investments of over 10% every year in the sector. Tamil Nadu has an advanced infrastructure with a superior road and rail network, 3 major ports, 23 minor ports, and 7 airports across the state providing exceptional connectivity (Frost and Sullivan, 2018). The presence of IT and technology parks, a skilled workforce, as well as a wide range of suppliers, institutes of collaboration and linked services have made the cluster highly competitive. It is considered among the top 10 global automotive clusters (Okada & Siddharthan, 2008). Hosur (Tamil Nadu) is located close to Bengaluru, a major IT hub which provides a plethora of investment opportunities in the region.

FIGURE 8: Tamil Nadu cluster map



Karnataka hosts five automotive clusters (see Figure 9) in Dharwad, Belgaum, Shivamogga, Ramanagara and Bengaluru Rural with excellent support infrastructure. The state has leading R&D institutions that provide knowledge services and sectorial training institutes that cater to the skills requirements of the cluster (Government of Karnataka, 2014).

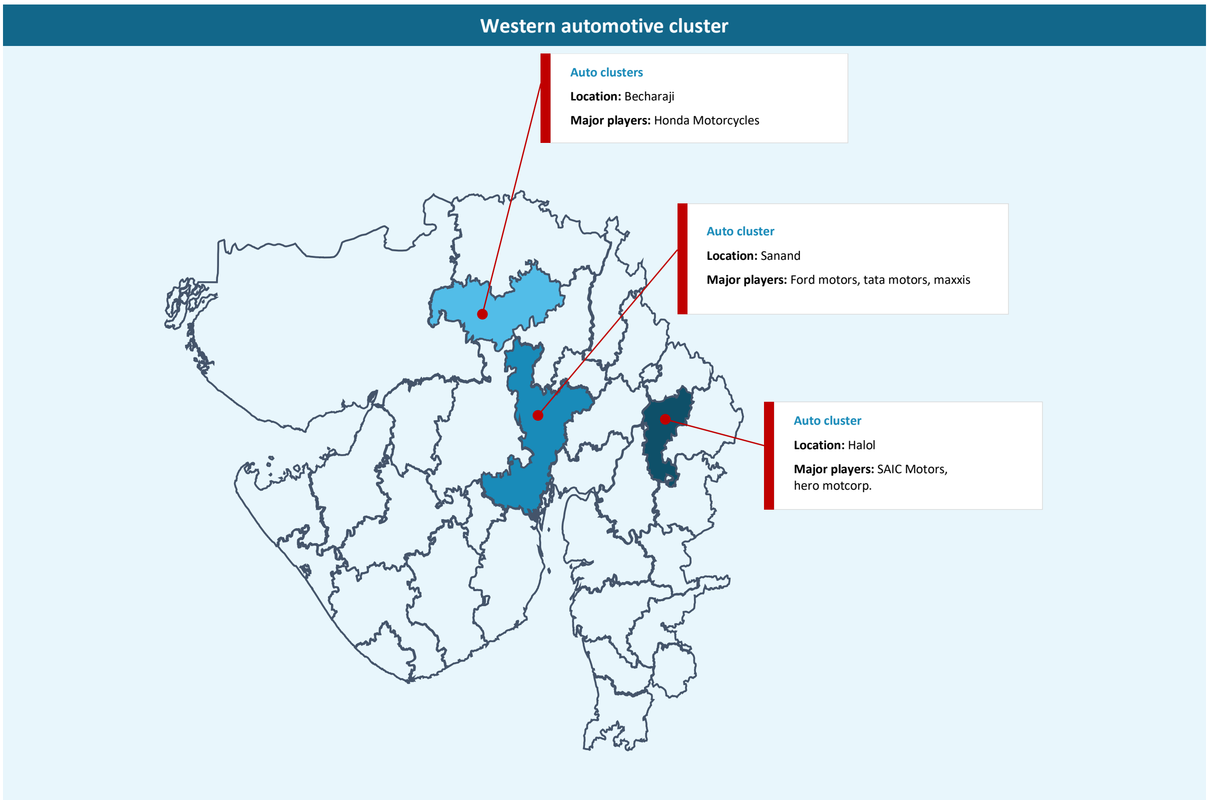
FIGURE 9: Karnataka automotive cluster

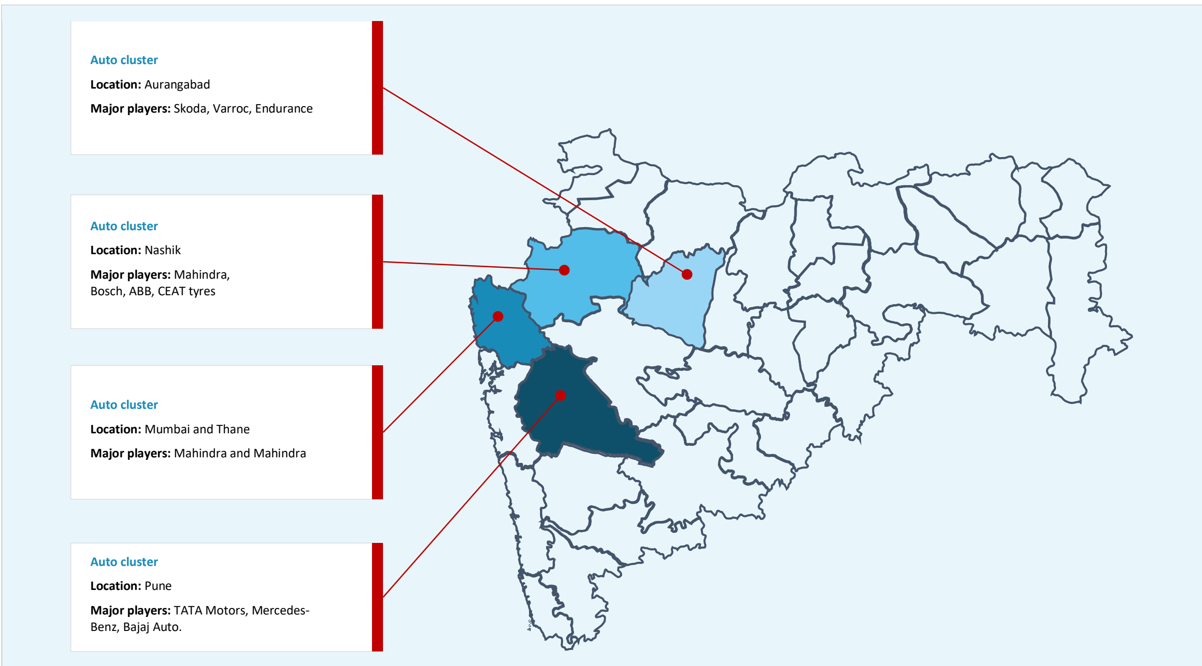


Source: IBEF

The western automotive cluster (see Figure 10) consists of Mumbai-Pune-Nashik-Aurangabad and Sanand-Dholera-Halol in Maharashtra and Gujarat, respectively. Automobile clustering in the Mumbai-Pune region started early in India due to its proximity to the coast for the import of heavy machinery via Mumbai port, an available power supply, a skilled labour pool and good infrastructure. Gujarat's strong cluster level approach has contributed to its emergence as a key investment destination for major automotive OEMs and ancillary companies, supported by modern infrastructure, premium social infrastructure, civic amenities, and Centres of Excellence (CoE).

FIGURE 10: Western automotive cluster





Source: IBEF

Building on the above success of spatial policies for the promotion of innovation, there is a clear requirement for an up-to-date repository of cluster information in India located within a national observatory where this information is accessible to all system actors. Coherent spatial policies are crucial for building a robust innovation ecosystem that encourages private enterprises in building in-house research capacity along with "collaborating with knowledge institutions to pursue market-relevant research through mutually decided agreements" (DST, 2020, p.20). Some automotive clusters have developed in locations like Chennai and Kolkata for historical reasons, while the other two clusters have come up due to easy geographical access and government policies.

4.2 Global vs. Indian Technology Trajectories

A Historical Perspective

Though cars were seen on Indian roads through the 1930s, they were imports as the Indian automotive industry only emerged in the 1940s. In 1942 Hindustan Motors was launched, closely followed by its competitor, Premier, in 1944. These two companies dominated the domestic market for more than four decades.

The evolution of the Indian automotive industry can be summarised[28] as follows:

1950 to 1980s

- Supply-driven market, limited models and designs.
- Emphasis on indigenisation of parts and assemblies.
- Focus on petrol and diesel.

1990s

- Shift from mere indigenisation to efficiency and better designs.
- Launch of an automobile policy, facilitating the entry of global assemblers.
- Emphasis on making fuel-efficient cars along with the availability of imported parts and designs.

Early 2000

- Fully delicensed and 100% FDI allowed.
- Focus on making India a part supplier in the global supply chain.
- Shift to a demand-driven domestic market.
- Introduction of robots and new manufacturing techniques on the factory floor.

2010 onwards

- Focus on making India the global automobile manufacturing hub.
- Increasing focus towards EVs and hybrids.
- Introduction of new materials and emergence of indigenous design capability.

Initially, the industry focused on importing technology from mainly European countries, starting from the assembly of automobiles, followed by government-enforced localisation to a full-scale manufacturing boost and export. The Tariff Commission (1955), which created the licensing regime, led many foreign car manufacturers, like Ford and GM, to leave the country. Although this policy is criticised for the slow growth of the sector (CAGR at 3.5% from 1959 to 1980), it insulated the local market from foreign competition and allowed them assured growth.

However, the improvement in technological capabilities of firms in developing countries results from both in-house R&D efforts and foreign technology imports. The protection policy did encourage the acquisition of basic production capabilities; however, it did not equip the firms with the coordination capabilities necessary for survival in a competitive environment. This changed with the introduction of foreign direct investment (FDI) in the sector in 1983. Suzuki and the Government of India formed the joint venture Maruti-Suzuki with a focus on localisation, which led to the creation of a chain of world-class component suppliers. The government's target to get the first model, "Maruti 800", 93% localised within five years led Maruti-Suzuki to develop local vendors from scratch (Kale, 2011). As more domestic firms created joint ventures with Japanese and US automotive companies, the influx of foreign technology along with capital resulted in a technological shift in the sector, from the batch production method to the conveyor belt method, along with introducing electronics in vehicles. The firms were also forced to increase their R&D spending to modify their designs to local needs, source components from local suppliers, and validate all parts for Indian standards (Narayanan, 1998).

During the 1990s, the government allowed 100% FDI in the sector. International firms saw India as a market for growth as the international auto market was slowing down during this time. Along with these firms came international component manufacturers resulting in increased quality and reliability. The impact of FDI on increased productivity

[28] White Paper - Automotive Industry: http://dcmsme.gov.in/white paper/1.%20Whitepaper- Automotive%20Sector-Year%201.pdf

and competitiveness has ensured that benefits accrue to consumers and labour. Some local assemblers went out of business because of the competition, and others entered into joint ventures with foreign firms to keep afloat.

Many manufacturers now adhere to global norms regarding emission/technology standards. They achieved significant success in garnering engineering capabilities and adapted to local requirements through local design. Indian firms like Maruti-Suzuki started to move towards their own designs and development capabilities. Tata Motors launched India's first indigenously designed car, "Indica", in 1998; Mahindra also launched "Scorpio" in 2002, an in-house development effort. With its potential to build low-cost quality products, India now edges over many other developing countries in the automotive sector. The Indian automotive firms, along with component makers, have come to the same level of innovation, quality, and reliability as their international counterparts[29].

4.3 Moving Forward

The Indian automotive sector has long been a stable industry with predictable ups and downs. What it is currently seeing has been previously seen in the US, 110 years back, with Henry Ford setting-up the assembly line. It can be termed the first inflection point in automotive history. At that time, EVs had a 38% market share in the US, which was slowly declining due to ICE vehicles. EVs lost out due to the increased reliability of internal combustion engines and shorter refueling times. This time it is the ICE vehicles on the losing side.

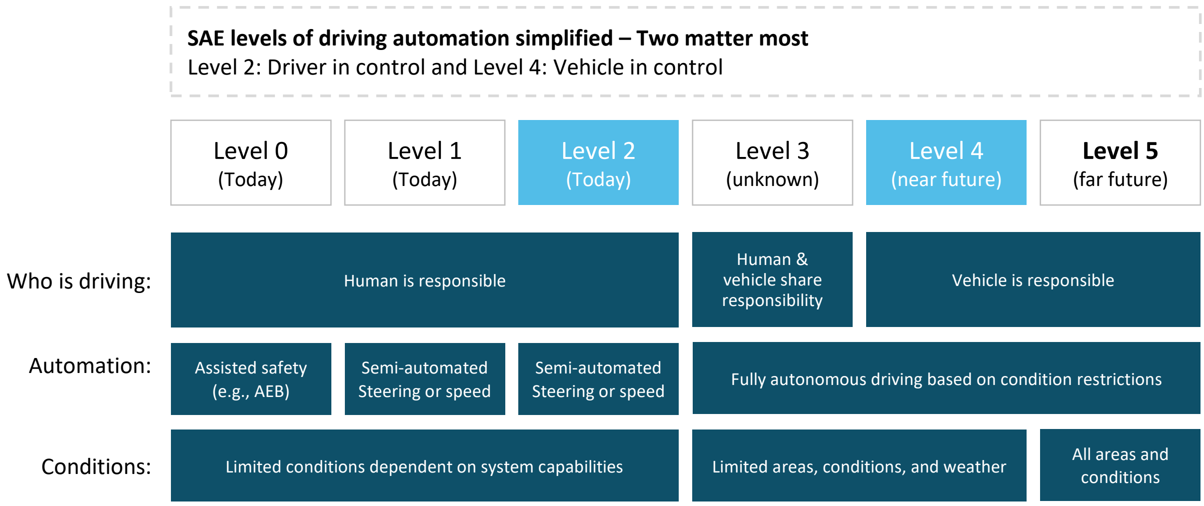
While Ford's "Model T" brought mobile transportation to the masses, the trade-offs also came along with it. Air pollution, CO2 emissions, traffic accidents, and traffic congestion. The global automotive disruption we are seeing today was years in the making. Rising temperatures, fossil fuel depletion, and the move towards smart cities and transportation, along with multiple breakthrough technologies made the industry push innovation boundaries and find new solutions. What we will see in the future may be termed the second inflection point in the illustrious history of the automobile.

Redefining Mobility

The automobile was never a 'metal box', it always integrated mechanical, electrical, and chemical technologies, and, later included software. Today a car is a computer on wheels, moving forward, it will become a data centre and then, ultimately, a component of the more extensive mobility network. The four major disruptive trends the industry is moving towards currently are known by the acronym ACES – autonomous, connected, electric, and shared. According to a McKinsey's report, more than US$ 200 billion has been invested by OEMs, component makers, and startups in ACES technologies since 2010. This paved the way for the transportation revolution along with the conventional jobs associated with them. Here is a summary of ACES.

Autonomous Vehicles

FIGURE 11: Levels of autonomous driving



[29] Research-driven (2016) Business Today: https://www.businesstoday.in/magazine/features/story/indian-automakers-are-focusing-hard-on-r-and-d-63613-2016-05-03

The journey that started as a technology to help humans drive a vehicle has now transformed into eliminating the driver from it. The Society of Automotive Engineers (SAE) charaterises this autonomy into 5 levels from level 0 (full driver control) to level 5 (no driver control).

Traditional automakers and technology startups are investing in the creation of autonomous-driving technology. OEMs across the world are adding incremental autonomous functions with each facelift of the model as technology and infrastructure improve over time. If autonomous driving takes off in a big way, with supportive regulations, up to 15% of all new vehicles sold globally in 2030 could be fully autonomous (McKinsey, 2016).

In India, however, the government is wary of fully autonomous driving due to fear of loss of driver jobs, which is a huge portion of organised and unorganised employment (Dash, 2017). In spite of this, many global automotive giants are working with Indian higher education institutes to incorporate machine learning (ML)/artificial intelligence (AI) into their autonomous systems to reduce traffic casualties. The Indian Institute of Technology (IIT) Madras' researchers are also working on creating bio-inspired neural networks to replicate human decisions during driving (Kumar, 2020). Several prominent Indian manufacturers have also launched vehicles with level 2 autonomous technology, with many more expected to follow suit.

Connected Vehicles

Automobiles today are also connected to the internet, with ongoing research to connect them to each other. Today the driver can get personalised in-car entertainment content along with optimised traffic routes according to traffic and weather conditions. In the future, it is expected that cars could talk to each other along with traffic lights to allow safer travel with shorter commute times.

Connected ecosystems are expanding fast in India, with manufacturers deploying on-board diagnostic (OBD)-based connected car solutions, fleet telematics and vehicle navigation.

Electric Mobility

Electric mobility is not a new concept, but the recent developments in battery technology, charging infrastructure, reduced cost of ownership, and stringent emission norms have again made them a viable option. Adoption rates for EVs across the world have increased significantly, with most countries expecting them to constitute 40 – 50% of total vehicle sales by 2030. A major reason for this rekindled interest is the disruption in battery technology. Battery costs for 35-50% of the EV cost. Battery costs have come down from US$ 1000/KWh in 2007 to US$ 200/KWh in 2020. In addition to costs, there have been improvements in battery safety, lifespan, and energy density. Newer battery chemistries that involve magnesium, sodium, or lithium-sulfur, with the potential to outperform lithium-ion batteries, are increasingly tested[30]. Research is also being conducted in battery swapping which could end the range anxiety and recharging time problem.

Globally, BYD, a Chinese corporation, leads the sales of EVs and plug-in hybrids, with Tesla coming second. However, Tesla leads in battery EV sales. The sales of EVs have shown a 62% growth in 2022 HY1 compared to 2021 HY1, with total sales of 4.3 million units[31].

Shared Mobility

Rapid urbanisation, the lack of proper city planning, and congested roads, along with the rise in the cost of owning a car have led to the rise of various cab aggregators like Uber, Lyft, Ola and DiDi. Along with this, major automobile companies around the globe are also starting car leasing programmes, or cars as a service (CaaS), to tap into new areas of growth[32]. While currently the per km cost of these services is still greater than owning a car, it is expected that the rise of electric vehicles and improvement in autonomous driving could make way for robotaxis.

In India, many tech startups are directly working with automotive manufactures to introduce EV and ICE vehicles. Along with this many industry giants are funding carpooling startups. For two-wheeler vehicles, cases include last-mile delivery like Zomato and Blinkit whereas for three-wheeler and four-wheeler vehicles, passenger mobility is the largest demand driver[33].

4.4 Electric Vehicles and the Case of India

According to India Energy Storage Alliance (IESA), the Indian EV market is expected to grow at a CAGR of 49% between 2021-2030, with total sales reaching 17 million units. Most of these sales are expected to come from two- and three-wheelers. The Government of India has introduced production linked incentive (PLI) schemes of INR 18,100

[30] Indian auto industry 2.0 - grant Thornton Bharat: https://www.grantthornton.in/globalassets/1.- member-firms/india/assets/pdfs/indian_auto_industry_2.0.pdf

[31] Global EV sales for 2022 H1 EV: https://www.ev-volumes.com/

[32] Vehicle-as-a-service: Deloitte Deutschland: https://www2.deloitte.com/de/de/pages/consumer-industrial-products/articles/vehicle-as-a-service.html

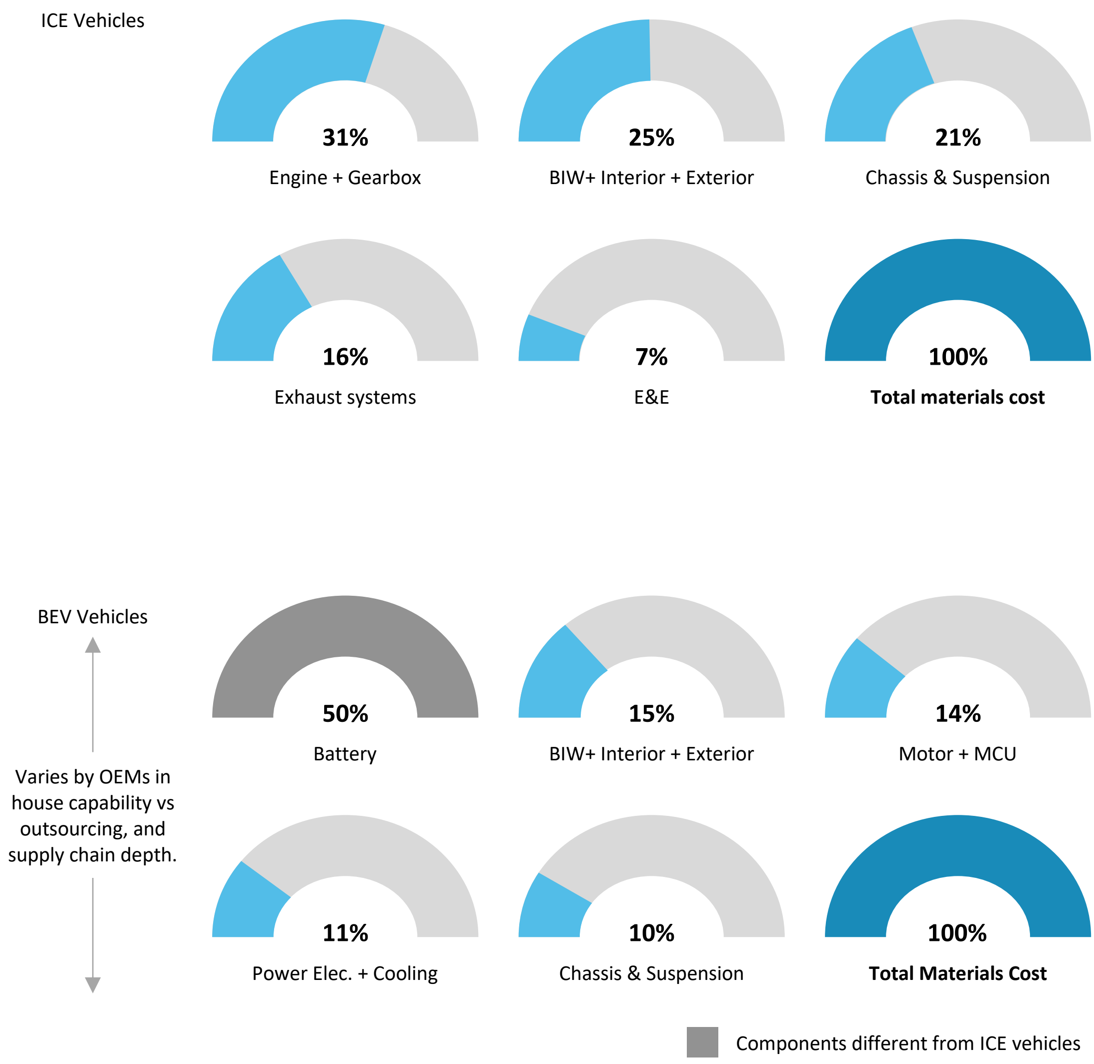
[33] The unexpected trip: The future of mobility in India beyond covid-19 (2020). McKinsey & Company: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the- unexpected-trip-the-future-of-mobility-in-india-beyond-covid-19

crore to boost local manufacturing of advanced chemistry cells to bring down their prices[34]. To boost EV demand, subsidies worth INR 10,000 crore would be given under the "Faster Adoption and Manufacturing of Hybrid and Electric Vehicles" (FAME II) scheme. Furthermore, the government is also working towards setting-up charging stations in 22,000 out of 70,000 petrol pumps across the country[35].

Many technology startups in India are also working on battery-swapping technology[36] and EV conversion kits. These conversion kits can convert an ICE vehicle to EV for as low as INR 4 lakh. Many Indian manufacturers have launched EVs at a slightly higher price point competitive to their ICE counterparts. While these EVs are based on their ICE counterparts, work is being done to create EV-specific platforms.

Higher education institutes in the country are also collaborating with the industry to work towards improving the battery energy density, recycling of Li-ion batteries, new algorithms for better battery utilisation and improving charging infrastructure. Most IITs have started new centres and programmes specifically designed for EVs. Such research collaborations and programmes are expected to help the industry by bringing down the costs of these technologies. At the same time, academia will gain by improving their research outcomes and creating a skilled workforce.

FIGURE 12: Bill of materials for an ICE vehicle compared to a battery EV



[34] Invest in Indian Electric Mobility Industry. FDI & Companies: https://www.investindia.gov.in/sector/automobile/electric-mobility

[35] India, P.T.of (2021) Work on to set-up EV charging stations at 22,000 petrol pumps across India: Centre, NDTV: https://www.ndtv.com/india-news/work-on-to-set-up-ev-charging-stations-at-22- 000-petrol-pumps-across-india-centre-2636279

[36] EVreporter (2021) List of battery swapping solution providers in India: https://evreporter.com/battery-swapping-solution-providers-in-india/

In light of these developments, critical challenges for the Indian automotive industry moving forwards are:

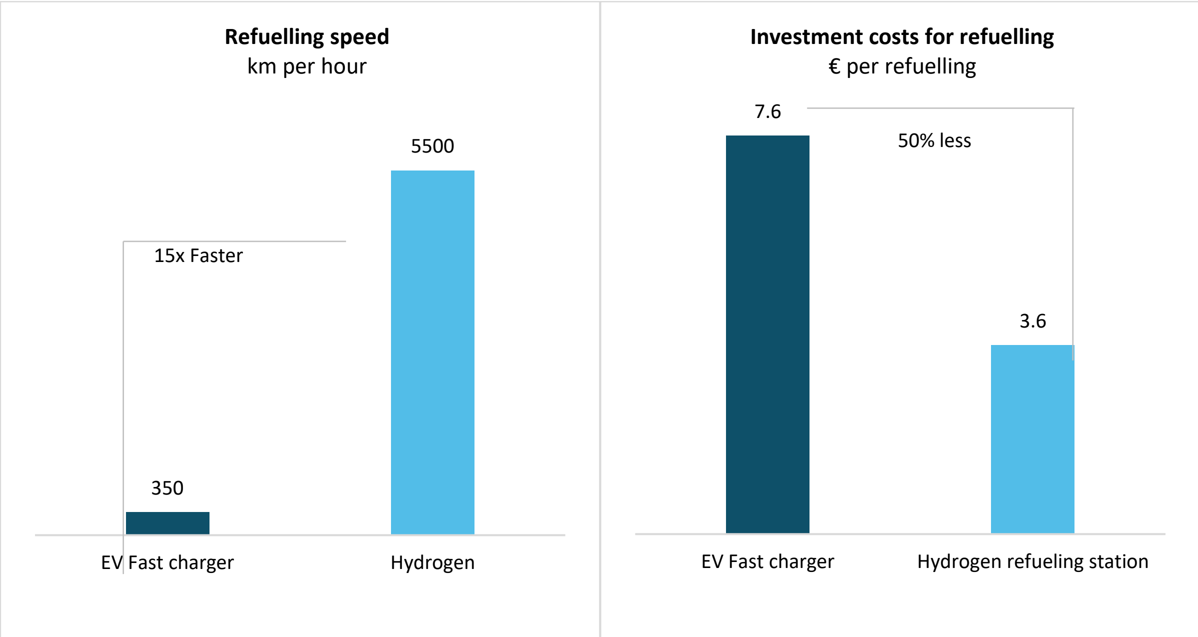
- A transition to EVs could impact up to 50% of the traditional ICE bill of material (BOM), disrupting the auto-component industry and making many of them incumbent.
- Many jobs in the sector have been in their present shape for decades. With new technologies emerging and repetitive jobs becoming automated, upskilling current employers and training new ones is challenging.
- The cycle for introducing new models is going to shorten. The accelerating speed of innovation and stringent norms will pressure OEMs to shorten their R&D cycles while constantly integrating the latest technologies to remain competitive.
- With EVs becoming more common, companies and government need to address the concerns emerging from additional requirements on the current power grid, as most of these personal EVs would be charged at home.

4.5 India's Hydrogen Fuel Cell Pilot Project

Hydrogen fuel cell powered vehicles have also emerged as an alternative to battery EVs. The refueling time of hydrogen cells is 15 times less than fast-charging EVs. It is less capital intensive than those fast chargers and takes up less space. The only by-product of a hydrogen cell-powered vehicle is H2O.

But producing hydrogen is costly, and the technology is still nascent, with most technological structures yet to be developed. These issues make this technology unviable for personal vehicle use but suitable for heavy commercial vehicles for long distances with a heavy payload[37].

FIGURE 13: Refuelling comparison of hydrogen fuel cell with BEV



The Indian government has started a pilot project in collaboration with Toyota Kirloskar Motors to test the technology for Indian roads and climate conditions[38]. Furthermore, the government has also instructed the public sector company National Thermal Power Corporation (NTPC) to start hydrogen fuel cell-powered buses from Delhi to Jaipur.

The Traditional Factory Floor

The ACES trends are the technological way forward for the automotive industry. Apart from these, the factory floor has also been in line for a major overhaul since the 1980s.

Industrialisation started with the first machines that mechanised some of the work. Subsequently, there was a

[37] McKinsey & Company. The trends transforming mobility's future (2019) McKinsey & Company: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-trends-transforming-mobilitys- future

[38] Moneycontrol. Toyota Mirai: India's first hydrogen fuel cell vehicle is here: https://www.moneycontrol.com/news/business/indias-first-hydrogen-fuel-cell-vehicle-is-here-8245151.html

move towards electricity and assembly lines, before computers and robots replaced them. Industry 4.0 connects these computers and robots with minimal human support.

Industry 4.0 has highly intelligent connected systems that create a fully digital value chain. It is based on cyber-physical systems that integrate communications, data, IT, and physical elements to transform the traditional factory floor into smart factories.

4.6 Eight Key Technologies That Make Up the Foundation of Industry 4.0[39, 40]

Big Data

Data is the next big thing in today's connected world. Today all the systems produce data, and too much data makes it difficult to extract useful information that can lead to intelligent analysis. 'Big Data analytics' enable extracting useful information for individual components and their operating restrictions to prevent any future failure. The analysis of data produced by the machines can help better job scheduling and estimate losses, if there are any. Automotive companies can use the data generated by ECUs to predict the failure or improve the performance of their next model. The automotive insurance sector can also analyse the driving patterns to provide customised plans.

Cloud Computing

The cloud is currently being employed in the industry to roll out faster over-the-air (OTA) updates, better and distributed computing, and faster delivery options than standalone systems. With continuous improvements in technology, machine learning and increased functionality, more and more industries will be moving to the cloud. Various automotive manufacturers have already integrated the machine learning-based in-car infotainment solutions in their model along with OTA updates for driver assistance systems.

Internet of Things (IoT)

The IoT is the key technology of Industry 4.0 which interconnects the machine and computers. It allows seamless data transfer and wireless control of devices with minimal human intervention. Advancements in wireless communication technologies like WiFi 6 and 5G made it possible for machines to talk with each other with minimal latency. As the 5G infrastructure in India develops, so will the market for the IoT. Manufacturers around the world are moving towards using autonomous robots in manufacturing, with advancements in IoT and integration of various Industry 4.0 technologies, a fully autonomous factory floor could be achieved.

Simulation

Simulation helps in understanding how the operation will pan out in different scenarios. Once the ideal scenario is found, cost-effective solutions can be developed, tested, and brought to market with reduced time and cost. Industries worldwide use simulation for tasks such as estimating the total production time and material requirement.

Autonomous Robots

These robots are used to automate various tasks across the factory floor and are powered by the IoT. These robots can be used to transport material around the factory floor in a coordinated way while being connected to the central server.

Augmented Reality

Augmented reality (AR) gives humans new ways to interact with the machine along with providing real- time information. It is used for various tasks, from faster repairs on the consumer end to training personnel under challenging environments.

Cyber Security

As machines become more and more connected to "the cloud", the security and reliability of these connections are of paramount importance for trouble-free operation. The development in connected and autonomous cars have also raised the debate on passenger safety and data privacy. Being autonomous and connected to a central server, these vehicles are prone to cyber-attacks which can not only harm the passengers but also lead to traffic congestions (in large metropolises).

Additive Manufacturing

Additive manufacturing is beneficial for small-batch production and personalised products. It provides the supplier with improved design, increased performance, flexibility and cost-effectiveness which is difficult to achieve using traditional manufacturing methods. Currently additive manufacturing is very slow compared to the traditional manufacturing processes used in the automotive industry, hence they are not widely used. But many luxury auto manufacturers are utilising the technology to personalise their offerings according to customer specifications.

[39] IBM. What is Industry 4.0 and how does it work? https://www.ibm.com/in-en/topics/industry-4-0

[40] SAP. What is Industry 4.0? Definition & Technologies: SAP insights: https://www.sap.com/india/insights/what-is-industry-4-0.html

4.7 India and Industry 4.0

According to the 2016 World Economic Forum (WEF) research, India ranked 91 out of 139 countries in the Network Readiness Index. After that, the Government of India's "Digital India" initiative helped the country climb up 30 slots to 61st place, as per the Network Readiness Index 2022[41].The current report also states that India has secured 1st place in "AI talent concentration" and 5th place in "AI scientific publications"[42] If the Indian manufacturing industry wants to win against its global counterparts, it needs to integrate Industry 4.0 principles to bring operational efficiencies. The major area of focus should be on the Industrial Internet of Things (IIoT), additive manufacturing, 3-D sensors, augmented reality and location awareness.

Major Indian states have started initiatives to usher into Industry 4.0. The Andhra Pradesh government has initiated an IoT policy which aims to build 10 IoT hubs along with the participation of 100 IoT companies to set-up manufacturing and research hubs in the state[43].

The Indian Institute of Science (IISc) is working with The Boeing Company to set-up India's first smart factory in Bengaluru. The factory will include smart sensors and data exchange combined with the IoT to move from automation to autonomy. Bajaj Auto has introduced 100-120 "cobots" to assist humans in their tasks, Maruti-Suzuki uses approximately 1700 robots in its five assembly lines and Hyundai has 400 robots in their Sriperumbudur plant to reduce labour costs.

Apart from this, the Indian government has started a "Big Data Initiative" to build a sustainable ecosystem that creates strong partnerships between industry and government[44]. The initiative aims to define a strategic roadmap outlining the roles of various stakeholders in the economy and the outcome for the next decade.

Industry 4.0 presents tremendous opportunities for growth and advancement of the Indian automotive sector. India will need to augment its workforce with Industry 4.0 technologies and improve the quality of its production processes to seize these opportunities. Moreover, India needs to focus on developing national policies and frameworks that can unleash the benefits of Industry 4.0. The next chapter offers a review of initiatives undertaken by the Government of India to enable innovation and usher in the new era.

[41] Network Readiness Index 2022: https://networkreadinessindex.org/

[42] Sourced from: https://pib.gov.in/PressReleasePage.aspx?PRID=1877303#:~:text=India%20has%20improved%20its%20position,NRI%202022)

[43] Andhra Pradesh first to have IOT policy, Deccan Chronicle: https://www.deccanchronicle.com/nation/current-affairs/030316/andhra-pradesh-first-to-have-iot-policy.html

[44] Big data initiative, Department of Science & Technology, Department of Science: https://dst.gov.in/big-data-initiative-1

5. Policy Landscape

Policy Landscape

In many ways the Indian automotive industry has been shaped by the government's industrial policy and nurtured in the microeconomic environment it helped to create (Miglani, 2019). It has evolved through policy regimes characterised by an era of protectionism (1950-1983), deregulation (1983-1993) and liberalisation (post-1993). In addition to direct impact through fiscal policy instruments, the industrial policy also contributed to the development of innovation and technological capabilities at the firm level (Kale, 2012). The liberal policies of the 1990s exposed automotive firms to new competitors and encouraged them to innovate and acquire advanced technology through partnerships and investments in research and development (R&D). At the same time, the industrial policy protected domestic firms by imposing local content requirements that led to the development of basic capabilities in automotive manufacturing and laid the foundations of the auto-component industry (Kale, 2012). As part of India's transition from a closed to an open economy, the government opened up the automotive sector to Foreign Direct Investment (FDI) in the 1990s and also progressively relaxed import barriers (McKinsey, 2006). In keeping with the view that FDI generates positive spillovers for local firms, India's policy approach has been to attract FDI to serve the local market and to impose local content requirements to stimulate assembly as well as the local supply base (Ray and Miglani, 2018). This determined thrust towards indigenisation is considered a key policy measure responsible for enhancing technological capabilities in the automotive sector (Sagar and Chandra, 2004).

A lot has happened in the automotive sector post liberalisation, and it has emerged as a sunrise sector in the Indian economy. The past decade has witnessed policies and initiatives launched to support Industry 4.0 and green mobility. The Government of India and the Indian automotive industry articulated their collective vision for the future of the Indian automotive sector through automotive mission plans spread over two decades that seek to define the path of the evolution of the automotive industry in India. Moreover, many analogous policies were launched in parallel that supported the growth of the automotive sector in multiple ways.

Explained below are the core policies of the automotive sector in India that are addressed in turn, along with the supporting policies that have a bearing on the Indian automotive sector.

5.1 Core Policies of the Indian Automotive Sector

Automotive Mission Plan 2006-2016 (AMP 2016)

With the intention of increasing the manufacturing output and employment in the sector, the "Automotive Mission Plan 2006-16" (AMP *2016*) was the foremost sector-specific plan released on a pan-India scale. The "AMP 2016 was the outcome of a protracted in-depth dialogue with all stakeholders (industry, academia, authorities) over a period of fifteen months" (Department of Heavy Industry (DHI), 2006; p. ix). The key objectives of the AMP 2016 were as follows:

- To establish India as a key player in the manufacture and export of two-, three-wheelers, tractors and more importantly, auto components.
- To provide favorable investment opportunities and appropriate tariff policy for the automobile sector.
- To integrate automation and IT in manufacturing and to promote infrastructure development in the auto clusters.
- To facilitate the expansion of domestic demand and to encourage exports.
- To support development of R&D and incentivise modernisation of the sector.
- To undertake labour reforms and ensure the availability of trained manpower.
- To create world class infrastructure for testing, certification, and homologation under the "National Automotive Testing and R&D Infrastructure Project" (NATRiP).

The government states that the AMP 2016 had many of its objectives/targets completed (DHI, 2016). It achieved its target of generating an incremental 25 million jobs as well as the sales target (number of units sold) of commercial and passenger vehicles. India's emergence as a global hub for small cars is one of the key accomplishments of the AMP 2016 (DHI, 2016). Apart from that, the sector achieved a significant quantum of investments from global and local Original Equipment Manufacturers (OEMs) as well as component manufacturers, exceeding the target of INR 1.5 lakh crore (DHI, 2016).

Despite these accomplishments, the AMP 2016 faced two main challenges that were taken into consideration while drafting its successor, the "AMP 2016-26" (AMP 2026). The first challenge pertained to the low involvement of government bodies and institutions at all levels (central, state and local) in the implementation of the AMP 2016 and the lack of coordination among them. Secondly, the AMP 2016 was positioned as a document primarily meant for the manufacturers and not positioned with other interest groups or stakeholders in mind, which is why the AMP 2026 seeks to be more inclusive by design than its predecessor (DHI, 2016).

Automotive Mission Plan 2016-26 (AMP 2026)

The "AMP 2026 Vision Statement" announces that the Indian automotive industry will be among the global top three in the fields of engineering, manufacturing, and exports by 2026, encompassing the promotion of safe, eco-friendly, and affordable mobility for the majority (DHI, 2016). The "Final Draft" document released by the Government of India in January 2016 for the next phase of the automotive mission plan lists the core objectives of the AMP 2026 as given below:

- To propel the Indian automotive industry to be the engine of the "Make in India" programme.
- To make the Indian automotive industry a significant contributor to the "Skill India" programme and make it one of the biggest drivers of employment creation in the country.
- To enhance mobility keeping in mind the environmental protection and affordability aspects.
- To become one of the major automotive export hubs of the world.
- To promote comprehensive and stable policy dispensation for all regulations and policies that govern the auto sector.

The "AMP 2026 seeks to define the trajectory of the evolution of the automotive ecosystem in India including the glide path of specific regulations and policies that govern research, design, manufacturing, technology, import/export sales, use, repair and recycling of automotive vehicles, components and its ancillary services" (DHI, 2016; p. vii). It emphasises that all regulations and policies impacting the sector should be comprehensive in scope and scale and should be implemented harmoniously across the nation. The AMP 2026 mandates to "position itself as the guiding document for all institutions that frame policies impacting the manufacture and use of automotive products in India" (DHI, 2016; p. xi). Thus, it recommends interventions in policy areas (with relevance to the automotive sector) such as investments and trade, tariffs, trade agreements, fiscal and taxation measures, exports, environment protection and global competitiveness. It purports to make inputs to supporting policies of the Government of India that have a huge impact on the growth and well-being of the automotive industry (DHI, 2016).

With regards to the trade policy of the government, the AMP 2026 supports the rationalisation of custom duties on raw materials used in automotive components and vehicles; and calls for an emphasis on the domestic capacity creation of imported items such as automotive electronics in order to boost local manufacturing and to support the Make in India initiative. Though it welcomes the thrust given to promote exports in the "Foreign Trade Policy 2015-20" by way of consolidation of various export promotion schemes and further simplification of procedures, it also calls for an additional duty drawback to be given to both vehicle and auto component exports. In doing so, it aims to improve the export potential of the automotive sector. Considering the competitive nature of the sector, the AMP 2026 suggests that Free Trade Agreements should only be signed with countries that do not have a significant automotive production base. Such inputs are expected to ensure that the automotive industry in India is subjected to a fair and predictable governing environment (DHI, 2016).

The Indian automotive sector needs adequate fiscal support, and this can be in the form of lower taxes, weighted tax deduction for R&D expenditure and accelerated depreciation rates for the capital equipment manufactured in India. It further supports setting up of a Technology Acquisition Fund that finances the acquisition of cutting-edge technology by the automotive sector. In the area of environmental protection and safety, the AMP 2026 pronounces a glide path for fuel usage by automobiles in India and supports the establishment of emission norms based on internationally accepted methodologies. It also advocates the formulation of appropriate regulations along with monitoring and enforcement agencies to check the proliferation of spurious components. It supports the implementation of an appropriate inspection and certification policy along with establishing necessary infrastructure across the nation. Lastly, the "AMP 2026 envisages that the government and the Indian automotive industry will work together to address all the key issues to take India to its rightful position in the global automotive industry's sweepstakes" (DHI, 2016; p. 64).

National Automotive Policy (NAP) 2018

Complementary to the AMP 2026, the "National Automotive Policy" (NAP 2018) has been drafted by the DHI (on the lines of the NAP 2002) for the holistic development of the automobile sector in India through a comprehensive policy framework. With the objectives mainly aligned with the AMP 2026, it identified five key areas for policy intervention, namely: a) innovation and R&D, b) vehicle manufacturing, c) components manufacturing, d) green mobility and lastly, e) an enabling ecosystem for the achievement of the policy objectives. Though it envisions the growth of the industry as per the goals set out in the AMP 2026, it prescribes policy guidelines specific to automotive value chain focus areas to address the issues faced by different stakeholders. Another unique aspect of the draft NAP 2018 is that it seeks to establish an automotive ombudsman to strengthen the grievance redressal system with an emphasis on quality and compliance standards. Effective implementation of any policy requires coordination among government bodies. The NAP 2018 proposes the formation of a nodal body for the industry to act as a consultative agency for all ministries engaged in the formulation of automotive-related policies and regulations. The body will be responsible for reviews every four years and recommend course corrections. “It will also serve as the repository of technical domain expertise and data on all aspects of automobiles and their manufacturing and be the technical advisor and the secretariat. The proposed nodal body will be a two-tiered structure with an apex body supported by the National Automotive Council (NAC).” (DHI, 2018; p. 29).

National Electric Mobility Mission Plan (NEMMP) 2020

The growth of the automotive industry poses the key challenges of rising energy costs, increasing oil import bills, and faster depletion of traditional energy sources, among others. The launch of the “National Electric Mobility Mission Plan 2020” (NEMMP) was part of the government’s plan to mitigate these challenges and reduce the impact of mobility on the environment (DHI, 2013). In accordance with the objectives of the AMP 2016, the NEMMP promotes the sales and manufacturing of electric vehicles through various reforms. To boost its Make in India initiative, the government planned to make the electric vehicles market in India self-sustaining. Accordingly, the DHI formulated the **“FAME (Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India)”** scheme aimed at making xEV (hybrid and electric vehicles) self-sustaining by increasing domestic capabilities for product and technology development. It proposed a slew of measures to achieve the objectives of the NEMMP. Phase I of the FAME scheme, under the ambit of the NEMMP, was launched on 1st April 2015. It promoted manufacturing and encouraged the buying of reliable, efficient, and more importantly, affordable electric/hybrid vehicles to ensure sustainable growth. Initially launched for a period of 2 years, it was subsequently extended to 31st March 2019. Phase I had four focus areas, namely: (i) demand creation, (ii) technology platform, (iii) pilot project and (iv) charging infrastructure. While Phase I was still ongoing, a “Draft Taxi Policy” for the promotion of sustainable public transport was introduced by the Ministry of Road Transport and Highways (MoRTH) in December 2016. It enumerates provisions for e-rickshaws with a view to promote urban mobility. The policy suggests that e-rickshaws can be proactively used for last mile connectivity in cities as these offer low cost and zero-pollution transportation. With nearly 32% of the Indian population living in urban areas (Census 2011), there has been a continuous shift in the population. Seeking to get the most out of this opportunity, the Ministry of Housing and Urban Affairs launched the “Urban Green Mobility Scheme” in November 2017 for the promotion of a low carbon sustainable public transport systems to reduce the carbon footprint.

Phase II of the FAME scheme came into effect from 1st April 2019 with a larger allocation of INR 10,000 crore and an implementation period that is spread over 3 years. Apart from budget, the policy brings in changes in demand incentives and the target number of vehicles, along with new xEVs technology definitions and performance and eligibility criteria for vehicles (DHI, 2019). It advocates proactive support from the state governments to complement the efforts of the central government for the promotion of e-mobility. The DHI is the nodal agency for laying guidelines. A committee comprising secretaries of various ministries named the Project Implementation and Sanctioning Committee (PISC) and headed by the Secretary (DHI) was constituted to oversee the monitoring, sanctioning, and implementation of Phase II. As opposed to Phase I, Phase II focuses more on public transportation, projecting it as an environmentally friendly and affordable transport option for the masses. Furthermore, the “Phased Manufacturing Programme” (PMP) announced alongside Phase II, primarily focused on providing an impetus on the manufacturing of e-vehicles, sub-assemblies, parts, and sub-parts through a graded duty structure in order to increase value addition and capacity building in the country. The PMP announced an increase in the tariffs for the import of battery modules, electric buses, and trucks to promote indigenous production. Until August 2019, for 64 cities a total of 5,595 buses for -intra and inter-city operation were sanctioned under Phase II (DHI, 2019). In addition, the scheme sanctioned 2,636 charging stations in 62 cities across 24 states/UTs. As on 15th July 2022, a total of 532 charging stations have been installed - 479 under FAME-I and 53 under FAME-II (Make in India)[45].

[45] Sourced from: https://www.makeinindia.com/sector/automobiles

Furthermore, in order to strengthen and institutionalise the collaboration between the Department of Heavy Industry (DHI) and the Department of Science & Technology (DST) in R&D and technology development in electric mobility, a joint programme called the "Technology Platform for Electric Mobility" (TPEM) was set-up in 2016. Its aim is to provide a collaborative platform for developers, suppliers and automotive manufacturers to work together to develop technologies and products that cater to the development of e-mobility (Mukherjee, 2017). Responsibilities of the platform also include updating the technology roadmap of the NEMMP and FAME, maintaining an updated and prioritised list of relevant R&D programmes and developing white papers on critical technologies (DHI, 2016). As a nodal agency, the DHI has many platforms and policies formed under its purview with one of them being the Development Council for Automobiles and Allied Industries (DCAAI). The DCAAI was constituted in 2008 for the productive utilisation of the Cess Fund allocated to the DHI's annual budget to promote R&D projects for automobiles and allied industries. The council is chaired by the Secretary (DHI) and it meets at least twice a year to discuss issues related to the development of the auto sector. It consists of 25 members and has projects approved amounting to INR 13.5 crore and INR 8.8 crore for the years 2018-19 and 2019-20, respectively[46].

Dealing with aspects of logistics infrastructure and last mile connectivity, the **"Pradhan Mantri Gram Sadak Yojana" (PMGSY)** was launched in 2000 with the purpose of providing good all-weather road connectivity to remote villages across India so that the automotive sector can reach the hinterlands of the country. Five years later, the government announced an ambitious highway development programme, called the **"Bharatmala Pariyojna"**, bringing a new wave of development for the sector in the form of well-maintained and developed roads and economic corridors. In addition, the AMP 2026 lays emphasis on the development of dedicated facilities for the automotive sector in several ports. It also highlights the requirement of dedicated rail links and multiple dedicated freight corridors with the capacity to facilitate the movement of freight trains. Last mile connectivity to ports and stations is equally important. Given the crucial connection between the automotive and the infrastructure sector, the government needs to adopt a holistic approach to the Indian transport sector factoring in all the modes of transport (rail, road, air, and ports) instead of developing each in isolation (Kumar and Sharma, 2019).

Intending a cleaner environment and wanting to lower the import dependency on fossil fuels, the **"National Policy on BioFuels" (NPBF)** under the Ministry of Petroleum and Natural Gas (MPNG) was approved in May 2018, which envisages a target of 20% blended ethanol and 5% of biodiesel in petrol and diesel respectively by 2030 (MPNG, 2018). For providing sustainable mobility and accessibility to all citizens, the Ministry of Urban Development (MoUD) issued an updated version of its **"National Urban Transport Policy" (NUTP)** in 2014 with an 'avoid-increase in demand for travel, shift-from personal vehicles to mass rapid transport and improve-include clean fuels and clean technology' approach as advocated by the Asian Development Bank for making transport more climate-friendly (MoUD, 2014). Besides this, a prescribed framework for vehicles on roads, **"The Motor Vehicles Act" (1914)**, was amended in 2019 with regard to the issues of recall of vehicles, taxi aggregators, various offenses and related penalties. It also proposes a probable development of a National Transportation Policy, in consultation with state governments, among many other things[47].

Fiscal measures also play a crucial role in the performance and growth of the automotive sector. Measures such as the slashing of excise duty for hybrid vehicles, an increase in customs duty on imported vehicles, or the provision of additional income tax deduction on the interest paid on the loans taken to purchase EVs have a huge bearing on the sector. The introduction of the Goods and Services Tax (GST) led to the overhauling of the taxation regime in India. Tax rates for commercial, used and personal cars varied across all categories of the GST. Initially, the chargers and charging stations for EVs were taxed at 18%, and this was subsequently revised to 5% by the 36th GST Council Meeting held in July 2019 (post the start of FAME II) for the promotion of sustainable and green mobility[9]. The government also needs to build a supporting environment for innovation from a taxation perspective. The income tax law in India provides a weighted deduction of 200% for in-house R&D facilities and 175% on outsourced R&D from national labs or research institutions in the automotive sector. But automotive R&D is likely to take a hit due to the reduction in this allowance from 1st April 2020. Nevertheless, given the complexity of the Indian taxation system (including the multiplicity of taxes), fiscal support to the automotive sector is indispensable for its long-term growth and advancement.

[46] Sourced from: https://dhi.nic.in/UserView/index?mid=2477
[47] Sourced from: http://egazette.nic.in/WriteReadData/2019/210413.pdf

National Intellectual Property Rights Policy 2016 (IPR Policy 2016)

Government support is needed for businesses not only to innovate new technologies, but also to safeguard their technological inventions with effective IP protection. In May 2016, the Department for Promotion of Industry and Internal Trade (DPIIT) rolled out the country's first "National Intellectual Property Rights (IPR) Policy 2016" to foster creativity and to implement a strong IP-led innovation model. Prof. Sunil Mani, in his critique on the "New IPR Policy 2016: Not based on evidence" argues that even before the IPR policy, India had a functioning legal regime with individual acts on patents, trademarks, designs and geographical indications, all of which were suitably amended over time to comply with TRIPS (Agreement on Trade-Related Intellectual Property Rights) (Mani, 2014). He contends that "some measures in the IPR policy are laudable but the policy objectives are not evidence-based and are tailor-made to suit the requirements of the western governments." He further argues that the government should rather be spending time and money on improving the performance of patent offices that are understaffed and underfunded leading to major delays in patent approval in the country.

It is evident that India has been taking a decisive stand on patents to the advantage of domestic manufacturers, but it needs more such incentive programmes, with effective and widespread implementation. India has built pockets of knowledge-based growth but has not yet translated this into a broader economic model. Actions to promote knowledge-based economies will require strong, coordinated government policies coupled with investment in ICT (ADB, 2014).

Production Linked Incentive (PLI) Schemes

In September 2021, the **"Production Linked Incentive (PLI) Scheme for the Automobile and Auto Components Industry"** sectors was launched with a budgetary outlay of INR 25,938 crore (US$ 3.50 billion) to incentivise the domestic manufacturing of Advanced Automotive Technology (AAT) products and to attract investments in the automotive manufacturing value chain. The scheme was open for receiving applications up to January 9th, 2022, and it will be implemented over a period of five years starting from FY 2022-23. According to the press release by the government on 15th March 2022, the PLI scheme has been successful in attracting proposed investment of INR 74,850 crore against the target estimate of investment INR 42,500 crore over a period of five years. It has also been a huge success in terms of the applications received from local as well as globally headquartered groups engaged in/ proposing to manufacture AAT vehicles/ products (PIB Release ID: 1806077, 2022).

In May 2021, the Government of India approved the "**PLI Scheme for Advanced Chemical Cell (ACC) Batteries**" with an outlay of INR 18,100 crore (US$ 2.49 billion) to boost battery manufacturing in India and make it globally competitive. As on 28th July 2022, three selected bidders had signed the Programme Agreement under this scheme. The two PLI schemes along with the FAME scheme are intended to enable India to leapfrog to environmentally cleaner, sustainable, advanced, and more efficient EV-based systems (PIB Release ID: 1846078, 2022).

5.2 Industry 4.0 Initiatives

A closer look at the policies adopted by India since the 1990s reveals a clear intention to shift from an agriculture-based economy to one that emphasises manufacturing to drive economic growth and jobs. Recent initiatives like **"Make in India"** and **"Skill India"** show the government's resolve to encourage manufacturing in the country; and the automotive sector has long been identified as having the competitive advantage and potential to fuel the rapid growth of manufacturing. But with the introduction of the 4IR, the government is formulating a "**National Policy for Advanced Manufacturing**" as part of India's plan to embrace the 4IR and exploit the huge potential of emerging technologies such as additive manufacturing, cloud computing, artificial intelligence (AI), the Internet of Things (IoT) and robotics.

Another initiative in this direction is the **"Smart Advanced Manufacturing and Rapid Transformation Hub (SAMARTH) - Udyog Bharat 4.0"**. It is an initiative by the DHI to set-up 4IR centres (demo-cum-experience centres) across the country for promoting smart and advanced manufacturing to help SMEs implement the 4IR (automation and data exchange in manufacturing technology). This is being done to enhance competitiveness in the Indian capital goods sector and to build awareness about the 4IR among Indian manufacturing industries. There is no escape from integrating principles of the 4IR with the Make in India initiative if indigenous manufacturing has to win against global competition. Such initiatives have been taken to ensure that the automotive sector remains relevant in terms of making its products and manufacturing processes innovative across the automotive ecosystem.

Disruptive technologies, such as AI hold great potential for the manufacturing sector, particularly the automotive sector. Recognising this, the Finance Minister of India, in his budget speech for 2018 – 2019, mandated the premier policy think tank of the government - NITI Aayog - to establish the **"National Programme on AI"** with a view to guiding the research and development in new and emerging technologies.

A discussion paper entitled **"National Strategy for Artificial Intelligence: #AIForAll"** was released by NITI Aayog in June 2018 in which it emphasised that AI-enabled mobility solutions can effectively address the challenges faced by the Indian automotive sector.[48]

The emerging technologies also need to be integrated in the supply chain of the automotive sector so that the benefits can be reaped by all participants of the supply chain. Logistics being an important area of the supply chain have a crucial role to play in the complex ecosystem of supply chain partners. The draft **"National Logistics Policy" (NLP)** released by the Department of Commerce in 2019 allows for the seamless movement of goods through a single window with a focus on employment, skills, and making small and medium enterprises competitive. It aims to "enhance efficiency across the value chain through increased digitisation and technology adoption" (Department of Commerce, 2019; p. 3). This can greatly ease the process of adoption of digital supply chain solutions to meet the increasing product complexities and changing market dynamics of the automotive sector (CII and EY, 2019).

To keep pace with global technology and promote cutting-edge research, a project named **the "National Automotive Testing and R&D Infrastructure Project" (NATRiP)** was set-up in July 2005 (under AMP 2006-16) as an independent society for creating core global competencies by having state-of-the-art automotive testing, homologation, and R&D infrastructure facilities in India. Set-up with an initial outlay of INR 1,718 crore that was increased to INR 2,288 crore and finally hiked to INR 3,727 crore billion in 2016, it is one of the largest and most significant initiative in the sector so far (NATRiP Annual Report, 2017-18). There are a total of seven centres under its ambit; four of them are green field projects (see Table 4[49]) and set for different areas of automotive testing with state-of-the-art infrastructure, while three facilities have been upgraded with new technology and equipment.

TABLE 4: Centres of Excellence under NATRiP

Facility	Location	Centre of Excellence (COE)
International Centre for Automotive Technology (ICAT)	Manesar	Components, NVH,
Global Automotive Research Centre (GARC)	Chennai	Passive Safety and Infotronics
National Institute of Automotive Inspection, Maintenance & Training (NIAIMT)	Silchar (Assam)	Automotive Inspection and Training (Hilly Terrain)
National Automotive Test Tracks (NATRAX)	Pithampur (Indore)	Vehicle Dynamics and R&D Tracks
National Centre for Vehicle Research & Safety (NCVRS)	Rae Bareli (UP)	Accident Data

Each and every centre contributes to a different area of automobiles and mainly focuses on indigenous R&D. The two existing facilities, the Automotive Research Association of India (ARAI-Pune) and the Vehicle Research & Development Establishment (VRDE – Ahmednagar) have been upgraded with new technologies. The International Centre for Automotive Technology (ICAT) is currently undergoing upgrading for passive safety and test tracks.

Since the automotive sector is highly competitive and innovation-driven, any modification in the country's intellectual property (IP) regime can have major implications for the sector. Recognising the important role of a robust IP ecosystem in fostering the direction and quality of innovation, the Department for Promotion of Industry and Internal Trade (under the Ministry of Commerce and Industry), designed the "National IPR Policy", which was adopted by the Union Cabinet in 2016 (Mukherjee and Chawla, 2018). Such policy and supporting initiatives, including the amendment of the Patent Rules 2003 to streamline the process, making it faster and more user-friendly by the augmentation of technical manpower handling the IP applications and the setting-up of a network of Technology and Innovation Support Centres across India

[48] Building further on the National Strategy on AI, Sourced from: https://www.niti.gov.in/sites/default/files/2021-02/Responsi ble-AI-22022021.pdf, the first part of the following approach paper titled "Towards Responsible AI for All'', aims to establish broad ethics principles for design, development and deployment of AI in India – drawing on similar global initiatives but grounded in the Indian legal and regulatory context. The second part of the strategy which will be released shortly explores means of operationalisation of principles across the public sector, private sector and academia. Within this framework, it is hoped that AI can flourish, benefiting humanity while mitigating the risks and is inclusive bringing the benefits of AI to all.

[49] Sourced from: http://www.natrip.in/download/Natrip architecture.pdf

have opened up new opportunities for automotive manufacturers.

Just as mechanisms are needed to protect the intellectual property rights of the firms in the automotive sector, integration of business processes through Information and Communication Technologies (ICT) are equally important for the automotive sector that operates on a global level (Biethahn et al., 2013). ICT is crucial for any sector that depends on connectivity, efficiency, the use of technology and innovation and linkages within and across sectors. To support this, the government has launched initiatives such as Make in India, Digital India, Startup India and many other parallel initiatives. The government also brought in policies like the “National Cyber Security Policy 2013” and the draft “Internet of Things (IoT) Policy” (drafted in 2015 and revised in 2016) to regulate as well as promote the ICT sector in India (Mukherjee and Chawla, 2018).

With an objective to develop programmes and policies for fostering innovation across industry sectors, the **“Atal Innovation Mission” (AIM)**, a flagship initiative set-up by NITI Aayog was launched to promote a culture of innovation and entrepreneurship in the country. The **“Atal New India Challenge” (ANIC)** is one of the sub programmes that seeks to provide resources for piloting, testing and for market creation for new challenges/ project ideas such as the smart mobility projects that come under the aegis of the Ministry of Road Transport and Highways[50].

5.3 Initiatives for the Future Workforce

As India is home to the largest youth population in the world, there is an imminent need to cater for the ever-growing technical aspirations and provide employment, driven by skill development and R&D. An Ernst & Young and National Association of Software and Service Companies (NASSCOM) study (2017) on the future of jobs in India found that by 2022, around 46% of the workforce will be engaged in entirely new jobs that do not exist today or will be deployed in jobs that require radically changed skill sets. In this ever-changing and increasingly complex world of today, it is all the more important to prepare a dynamic and evolving workforce that is fluent in Science, Technology, Engineering and Mathematics (STEM). The STEM workforce is critical for the economy and global competitiveness and the Indian government is working for STEM enhancement through smart class platforms, upgradation of library infrastructures, implementation of library management systems and gamification. India still needs a new approach to education and skills development. When the “National Policy on Education 1986/1992” was formulated, it was difficult to predict the path of technological innovation, particularly the impact of disruptive technologies, which is why the government initiated the process of formulating a new education policy. The **“National Education Policy 2020”** clearly states that “our present education system’s inability to cope with these rapid and disruptive changes places us (individually and nationally) at a perilous disadvantage in an increasingly competitive world. India must take the lead in preparing professionals in cutting-edge areas that are fast gaining prominence such as AI, 3-D machining, big data analysis and machine learning, among others in technical education.” The National Education Policy 2020 also endorses the recommendations made by NITI Aayog pertaining to the use of emerging technologies for improving access to and the quality of education as well as for preparing tomorrow’s generation to leverage technology disruptions to the country’s advantage.

The AMP 2026 recognises that among all the sectors, the automotive sector offers one of the highest potentials for providing skills to youth and is more proactive about upskilling. One of the objectives of the AMP 2026 is to be a prime exporter in terms of technology and research, so policies and councils for the same allow expedite management and arrange for vital inputs for the sector. It envisages a bigger role for the Automotive Skill Development Council (ASDC) by making it an apex industry body for skill development under various programmes by the government and an independent testing and certification agency for sector skills. ASDC is the first sector skill council of India set-up as part of the initiatives taken to strengthen the automotive sector under the AMP 2016. Currently governed by the National Skill Development Corporation (NSDC), the ASDC is working to understand the dynamic workforce requirements of the automotive industry and accordingly develop digital learning models. The ASDC is adding new job roles (called “Qualification Packs” or “QPs”) to address the policy initiative of moving over to electric mobility as outlined in the FAME II initiative. Emerging job roles with respect to the 4IR are being validated with the support from industry and academia. Existing QPs are getting enhanced by the ASDC Expert Group, consisting of members from industry; These QPs are based on robotics process automation, 3-D printing and big data analysis (ASDC Brochure, 2019).

Where India tops in producing science and engineering graduates, it severely lags in the number of researchers who drive innovation. According to the “Science and Engineering Indicators 2018 Report” released by the US-based National Science Foundation, the US tops spending

[50] Sourced from: https://aim.gov.in/ANIC_1.0_SSC_Selection_Summary.pdf

on R&D, followed by China, but India does not rank among the top 10. The "Science and Technology Innovation Policy (STIP) 2013", released by the Department of Science and Technology (DST), aims to accelerate the pace of discovery and increase the quantum of science-led innovations for faster, sustainable and inclusive growth. It lays focus on areas "such as prioritizing critical R&D areas, promoting interdisciplinary research, creating an environment for private sector participation in R&D, and supporting STI-driven entrepreneurship viable models" (STIP, 2013; p. 14). In 2008, a Science and Engineering Research Board (SERB) was established under DST for funding research in frontier areas of science and engineering. Industry Relevant R&D (IRRD) is one of the schemes launched by the SERB in 2016 that aims to utilise the expertise available in academic institutions and national laboratories to solve industry-specific problems. It is constantly looking for proposals with outcomes that will bring new scientific and technological innovations (SERB, 2016).

The draft STIP 2020 outlines the need for short-, medium-, and long-term mission mode projects for building a research and innovation ecosystem aimed at evidence and stakeholder-driven STI planning, information, evaluation, and policy research in India. Establishment of a National STI Observatory as a central repository for all data related to the STI ecosystem is an objective of the policy. This observatory will consist of an open centralised database platform for all financial schemes, programmes, grants and incentives in the STI ecosystem. It will be centrally coordinated and organised in a distributed, networked and interoperable manner among relevant stakeholders (DST, 2020).

Another component of STIP 2020 is a forward-looking Open Science Framework (OSF) that will be built to provide access to scientific data, information, knowledge, and resources to those engaging with the Indian STI ecosystem on an equal partnership basis. While all data used in and generated from publicly funded research will be available to everyone under findable, accessible, interoperable and reusable (FAIR) terms, a dedicated portal will also provide access to the outputs of such publicly funded research through the Indian Science and Technology Archive of Research (INDSTA) (DST, 2020). Through skills building, training and infrastructure development, the government aims to improve STI education making it inclusive at all levels and more connected with the economy and society. Interdisciplinary research will be promoted through Higher Education Research Centres (HERC) and Collaborative Research Centres (CRC) that can also provide research inputs to policymakers and bring together stakeholders. Using ICT, online learning platforms will be developed to address the issue of accessibility and to promote research and innovation at all levels. Faculty members will be upskilled through Teaching-Learning Centres (TLCs) to improve the quality of education (DST, 2020).

If India intends to leverage 4IR concepts and technologies, it must expand the skill base of its workforce and create a robust ecosystem for research and innovation. As the automotive industry is at the forefront of adopting 4IR technologies, it will be the first to witness an increased demand for new skills in the domain of ICT, Human-Machine Interaction (HMI), Cyber-Physical Systems (CPS), data analytics, etc. A future workforce equipped with a technology-driven education and 4IR-related skills can also ensure India's competitiveness in the dynamic global labour market.

In conclusion, to drive growth in any sector, strong linkages and synergetic effects from policy initiatives in cognate policy areas are crucial. The policies can be devised as per the applications or skills that govern the scientific progress of the sector, such as research and development, along with a focus on upgrading infrastructure and increasing manufacturing power and sales. Both scholars and practitioners often link the effectiveness of policies to the need for coordination and integration (Tosun and Lang, 2013). Involvement of stakeholders in the policy-making process may also result in better policy design and more efficient policy implementation (Tosun and Lang, 2013). Ultimately, the idea is to ensure that sectorial policies get duly enacted and fulfilled in a way that ensures the rapid progress and technological advancement of the sector.

6. Results and Analysis

Results and Analysis

This chapter sets out to analyse the results of the "Indian Automotive SSI Survey" (IASSI). It uses a combination of univariate and multivariate analysis which provides a strong empirical foundation. The frame of analysis can be divided into the following sections: Firstly, the characteristics of the survey are described in terms of the composition of the sample and its respondents. This is followed by a comprehensive analysis of the relationships/linkages between the actors of the system. This then leads to the elucidation of the barriers that exist within the automotive system of innovation, and those that are most predominant for each actor group. This is also linked to the question of how successful existing policies are at highlighting either the convergence or divergence between the results and what is articulated in government policy. With this in mind, this chapter aims to highlight the avenues that need attention within the IASSI.

6.1 Descriptives

The composition of the actors in the IASSI Survey has been detailed in the "Survey Methodology" section. In this section, we will discuss the characteristics of the IASSI Survey that are described in terms of the composition of the sample and its respondents. Table 5 below shows the actor distribution and response rate.

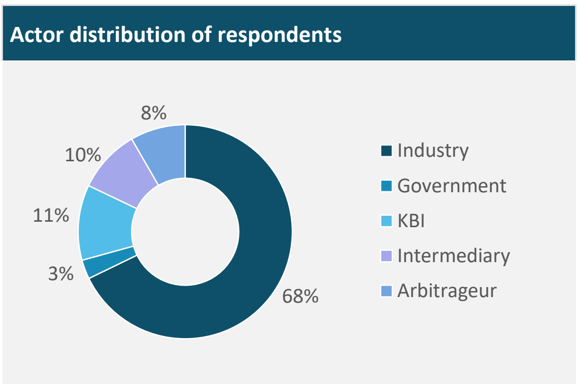
TABLE 5: Indian Automotive SSI - Convenient sample, data collected and response rates.

Firm			Non-firm				Total Number of Non-Firm Actor			Total
Industry			Government	Knowledge based institution	Intermediary	Arbitrageur				
Sample	Data collected	Response rate	Data collected				Sample	Data collected	Response rate	
589	375	63.67%	16	63	53	46	200	178	89.00%	553

The overall response rate of the automotive survey is 70%. As seen in Table 5 above, the response rate of industry is 64% while the response rate of non-firm is 89% out of which KBIs account for 35% of the data collected in the non-firm category, followed by intermediaries and arbitrageurs accounting for 30% and 26%, respectively. With only 16 responses, the government accounts for 9% of the data collected in the non-firm category.

Figure 14 below summarises the distribution of respondents by actor group. The composition is 68%, 11%, 10%, 8% and 3% from industry, KBIs, intermediaries, arbitrageurs and government, respectively.

FIGURE 14: Distribution of respondents by actor group



As shown in Figure 15, the majority of firms surveyed are domestically owned (61%), while the proportion of foreign-owned firms is 10%.

FIGURE 15: Ownership structure of firms

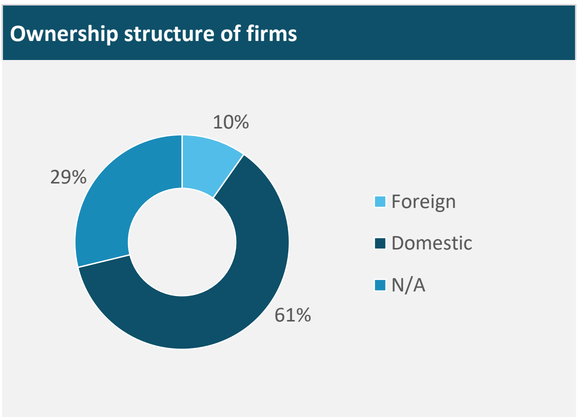
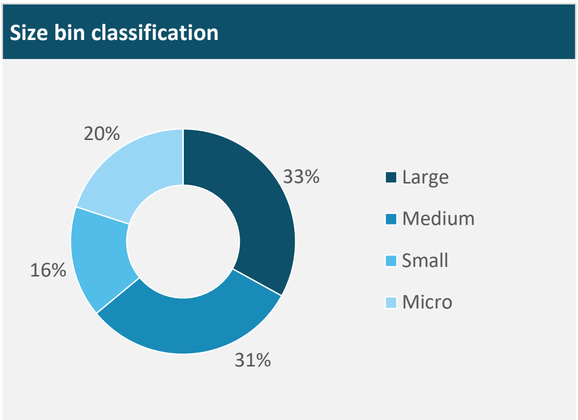


Figure 16 below shows the size classification of the firms surveyed. It is important to know the size of firms that participated in the survey as it can determine the level of innovation, internationalisation, and adoption of emerging technologies, etc. It can be seen from the figure below that the majority of firms surveyed belonged to the 'Large' size category (33%), closely followed by 'Medium' size firms (31%). 'Micro' and 'Small' size firms constitute 20% and 16% respectively, of the total firms surveyed in the automotive sector.

FIGURE 16: Size classification



The following figures depict the distribution of respondents by affiliation for each actor group. Figure 17 shows the industry actor group is made up of OEMs, Tier 1, Tier 2 and Tier 3[51] automotive manufacturers, the majority being Tier 1 manufacturers. Figure 19 depicts the KBI affiliation comprising universities, public and private research institutes and think tanks, the majority being universities. Subsequently, Figure 19 shows that intermediaries are composed of institutions supporting technical change, incubators, and industry associations. Arbitrageurs are composed of banks, angel networks and venture capitals while the government comprises both central and state governments, with majority representation from the central government agencies. This is outlined in Figure 20 and 21, respectively.

FIGURE 17: Industry – Affiliation

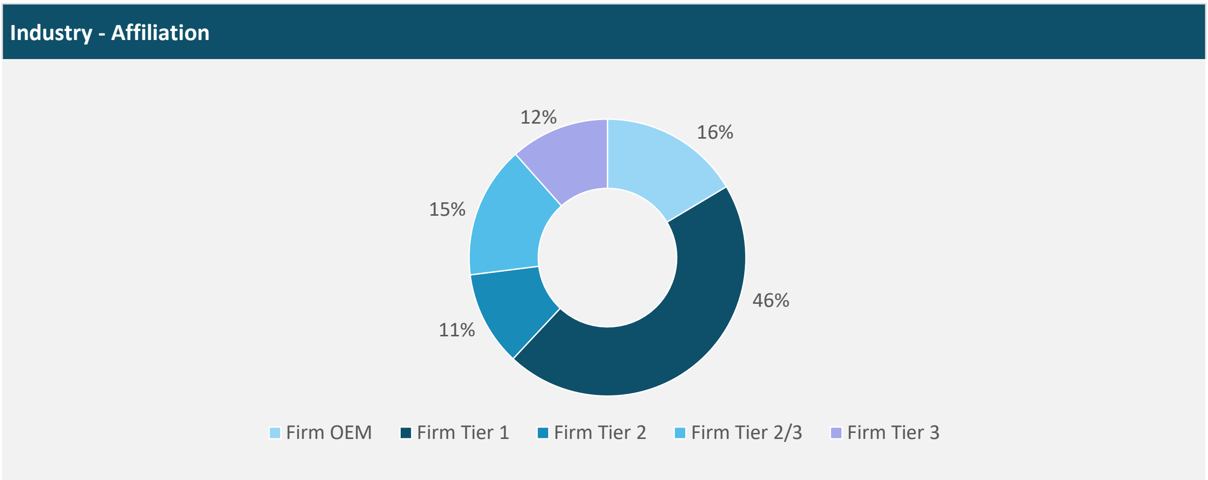
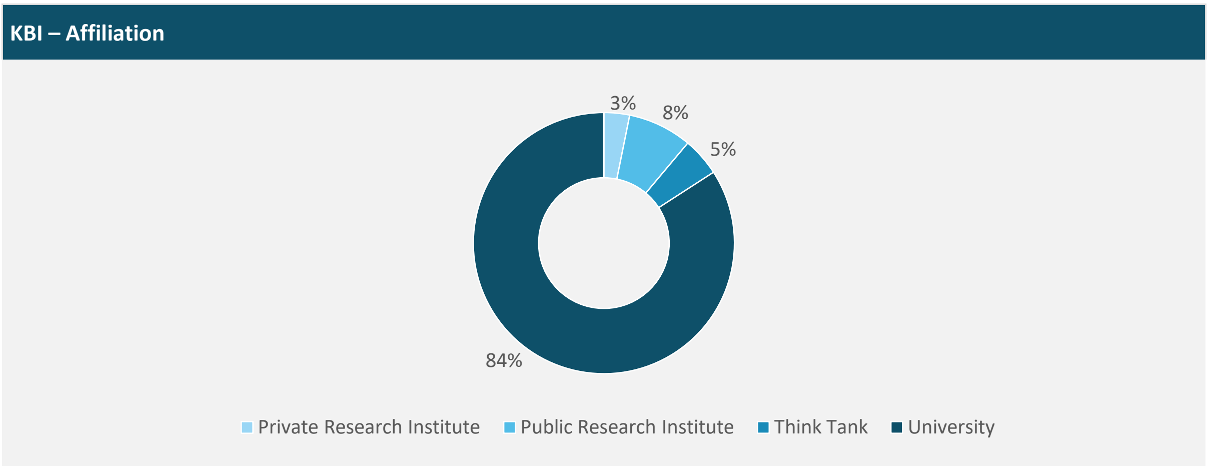


FIGURE 18: KBI – Affiliation



51 Tier 1s supply directly to the OEMs, Tier 2s supply products to Tier 1s (who then supply to the OEMs) and Tier 3s are suppliers of raw or close-to-raw materials like metal or plastic.

FIGURE 19: Intermediary – Affiliation

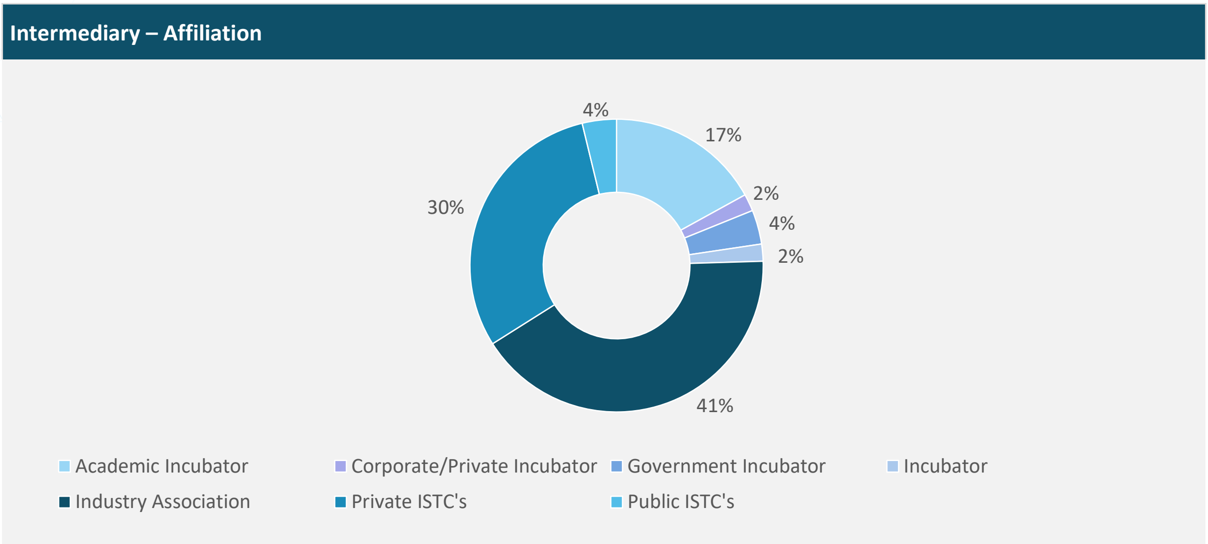


FIGURE 20: Arbitrageur – Affiliation

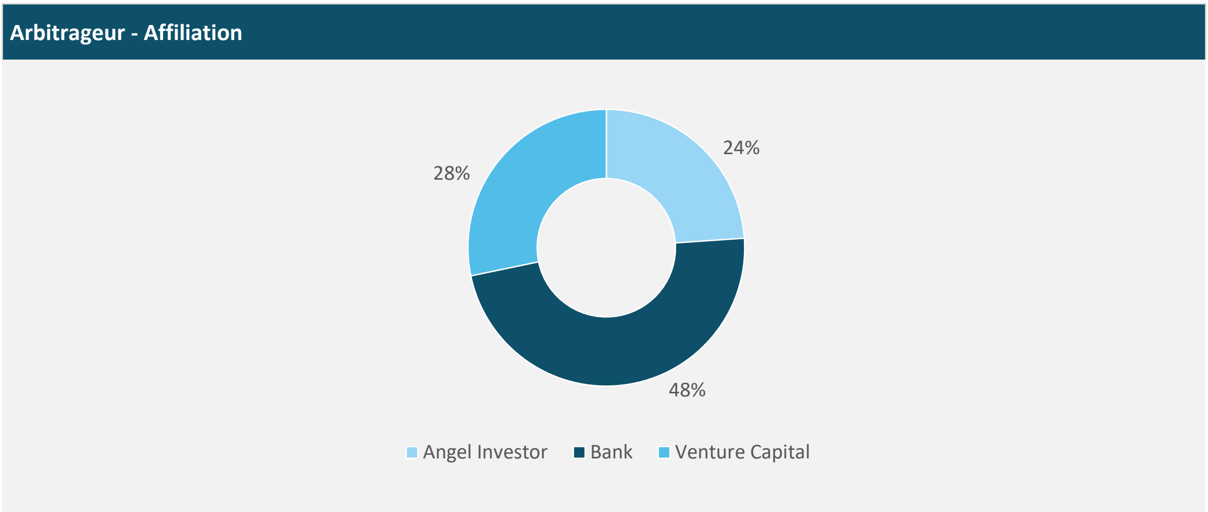
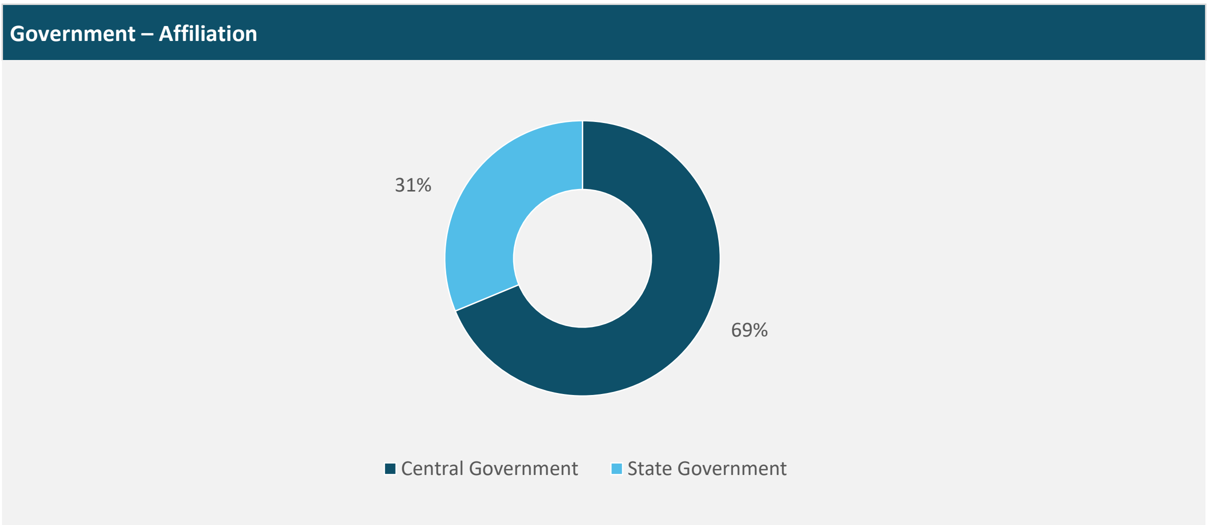
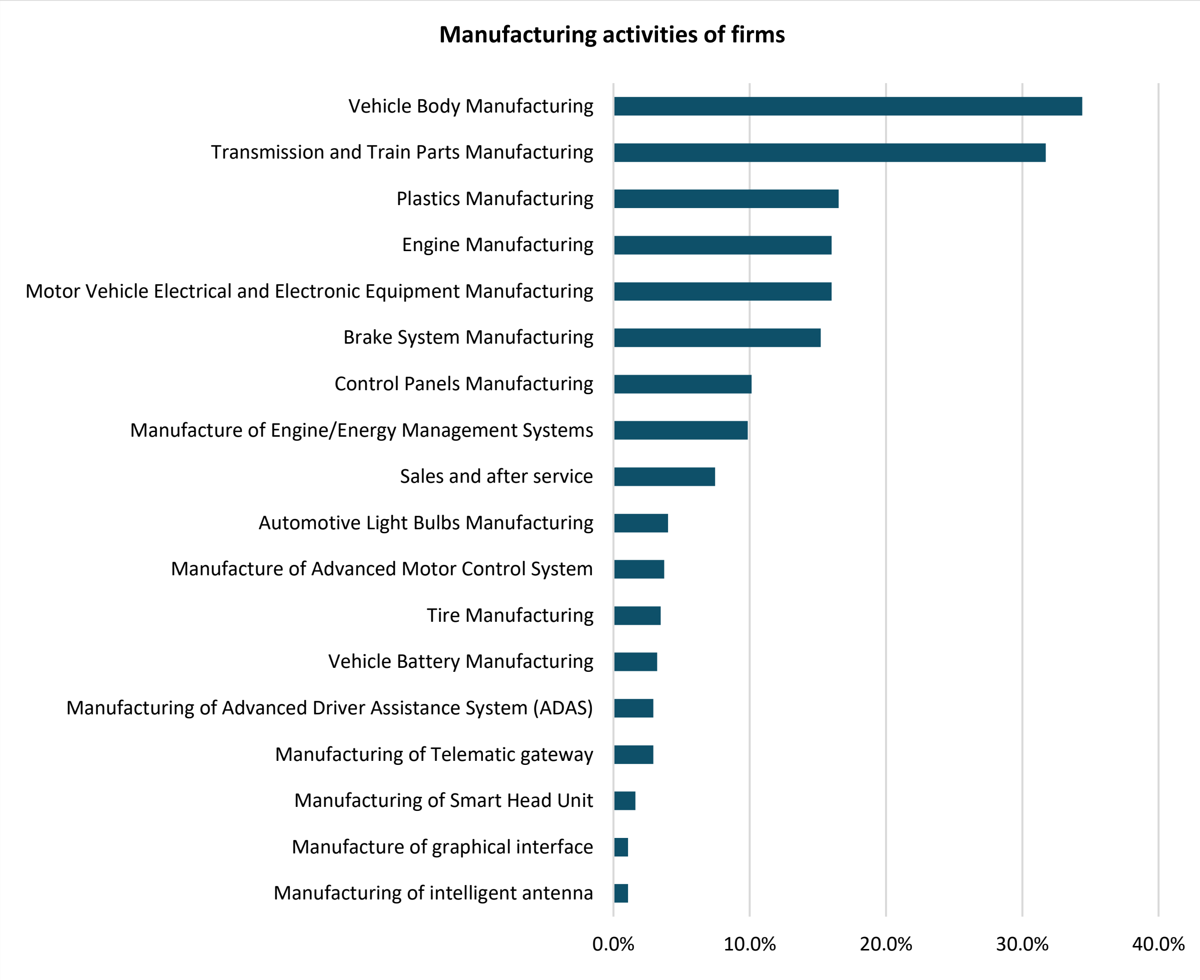


FIGURE 21: Government – Affiliation



It is important to get further clarity with respect to the industry actors to better elucidate the data in this report, particularly as the majority of innovation takes place at the firm level. Figure 22 below depicts the manufacturing activities of the firms surveyed.

FIGURE 22: Manufacturing activities of firms



The lion's share of the firms surveyed are involved in transmission and train parts manufacturing, vehicle body manufacturing and engine manufacturing. Only a limited number of the firms surveyed are involved in Industry 4.0-related production such as the manufacturing of advanced motor control systems, smart head units, telematic gateways, intelligent antennas and advanced driver assistance systems.

6.2 Linkages

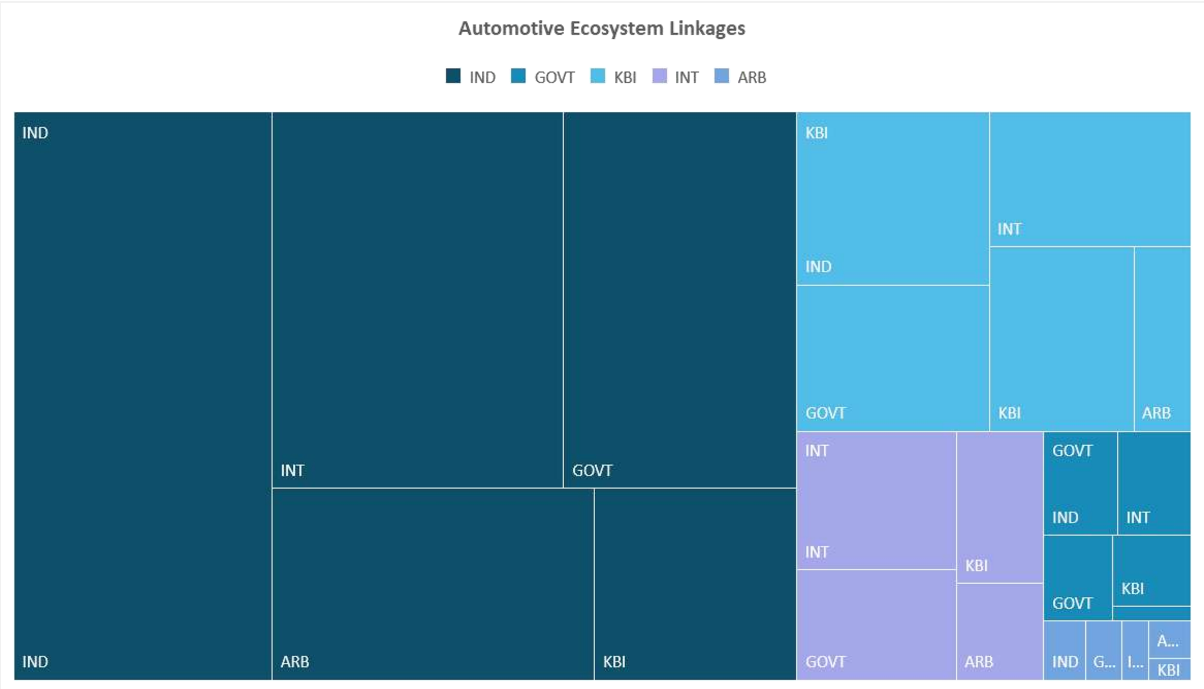
Before the issue of the linkages between the actors in the IASSI is brought to the fore, it is important to reiterate the importance of linkages from the perspective of the SSI. For instance, in their critique of the linear approach to innovation, Edquist and Hommen (1999) stress the importance of interactive learning and innovation networks, for which linkages between actors are crucial (Oyelaran-Oyeyinka, 2005). Cavalcante (2011) articulates that interaction between agents through formal and informal linkages can take the form of: joint research and publications; personnel exchanges; patents and licenses; the purchase of equipment, or the transfer of technologies or methods. In this light, the analysis conducted is twofold: an understanding of the type of relationships that are present and who initiates them.

Type of Linkage

The next point of analysis is to determine which type of engagement occurs when an actor interacts with players in the system. This can be broken down in terms of intra- and inter-relationships. Each respondent was asked to list other actors (industry, government institutions, KBIs, intermediaries and arbitrageurs) their organization engaged with and the respective type of engagement. The types of linkages indicated include. 'Contract buyer', 'Contract supplier', 'Joint patents', 'non-disclosure agreements', 'Trademarking', 'Joint research', 'Co-publishing', 'Secondments', 'Licensing agreements', 'Procurement contracts', 'Formal meetings', 'Informal meetings', 'Seminars/Training', 'Recipients of funding', 'Recruitment/Placement' and 'Joint ventures'. This chapter highlights both the major and minor intra- and inter-relationships as well as the strategic interactions that are crucial to driving innovation in the SSI. Finally, those interactions that are truncated or missing are highlighted in order to better understand and articulate interventions that need to be undertaken to bolster the SSI.

In general, it can be seen from Figure 23 that the majority of relationships are, in proportional terms, between the actors in the sectorial system of innovation. Firstly, in terms of the number of respondents, the actors who participated in order of magnitude are industry, knowledge-based institutions, intermediaries, followed by government, arbitrageurs, and financial institutions. Industry actors have the lion's share of interaction with themselves; knowledge-based institutions primarily interact with industry and government; intermediaries mostly interact with themselves and the government interacts with industry and intermediaries. Finally, financial institutions and arbitrageurs primarily interact with industry.

FIGURE 23: Ecosystem relationships



Sankey diagrams (refer to Figures 24, 25, 26, 27 and 28 below) have been used to display the types of relationships (intra- and inter-linkages) between the system actors, from the perspective of each actor. The diagram is composed of two distinct sections. The left-hand side of the diagram shows the specific system actors being engaged from the perspective of a selected actor, as well as the number of interactions. This provides an indication of who is connected to whom.

From the right-hand side of the diagram we can see the various types of interactions, as well as the total cumulative number for all actors engaging in these types of interactions. However, the specific number of interactions for each actor are not represented in this visualisation.

Overall, the Sankey diagram offers valuable insights into the complex network of relationships and linkages that exist within a particular sector. It can help identify knowledge and resource flows between actors, thus making it a useful tool for understanding the dynamics of the sector.

6.2.1 Industry

Figure 24 highlights the industry intra- and inter-linkages.

Intra-relationships

With respect to industry actors the major intra-relationships are user-producer relationships in the form of contract buyer and supplier. User-producer relationships indicate ancillary units supplying to Tier 1/OEM firms, for example Varroc Engineering Ltd. supplying to OEMs like

Bajaj Auto, Volkswagen, Yamaha, MG Motors, Royal Enfield and Mahindra & Mahindra[52].

The presence of formal and informal meetings indicates that there is a level of knowledge and information flow between firms, and they do not function in isolation. This is evident from Volvo India Managing Director Kamal Bali's speech at the Republic Economic Summit held in October 2022, in which he stated, the "...era of collaborations and partnerships has started. No one automotive company will be able to provide a 360-degree solution to the consumer. In the last few years we've partnered with eight companies we may not have earlier."[53]

Formal meetings contribute to the process of sharing information, exchanging and developing ideas, as well as expressing disagreement, and managing conflict (Shasitall, 2022), however this mechanism indicates there is a structured approach with a focused agenda. Whereas informal communication is more flexible and seen to be crucial for idea generation and the sharing of timely information (McAlpine, 2017). The combination of formal and informal channels of communication greatly boost innovation (Grimpe and Hussinger, 2008).

Knowledge dissemination in the form of seminars and training along with disclosure agreements also emerge as prominent means for engagement between firms. Seminars and training facilitate the improvement of the supplier landscape, for example, Mercedes Benz offers supplier training courses in cooperation with other vehicle manufacturers. It addresses issues of sustainability standards for suppliers and their integrity code. They have developed a supplier compliance awareness module that helps suppliers address possible integrity- and compliance-related risks. In addition, it clearly stipulates what is expected of suppliers when it comes to integrity and provides information about legal requirements and ethical standards. The module is provided to all suppliers via the Mercedes-Benz Supplier Portal for easy access, and they forward it to their business partners in the supply chain. From the service side, Tata Motors Service Training Centre imparts automotive maintenance and repair training to the manpower of channel partners (both domestic and international), fleet owners, private customers and institutional customers such as defense establishments, paramilitary forces, police, state transport units and other government agencies. Training is also given to their own senior executives, field staff, trainees and apprentices for upgrading and enhancing their technical knowledge, soft skills and skills for existing as well as future products to ensure total customer satisfaction. Training is also offered for various other aspects including sales, quality, legal, production, etc., as per specific needs and requirements.

Critical formal interactions between manufacturers and intermediaries such as the institutions supporting technical change (ISTCs) like the Automotive Research Association of India (ARAI), International Centre for Automotive Technology (ICAT), Global Automotive Research Centre (GARC), Pollution Control Board (PCB), etc., are related to patent approvals, standards certifications, and factory inspection.

Non-disclosure agreements (NDAs) are commonplace in the transactional relationships between system actors as the motive is to control the use and disclosure of confidential information. They are particularly common in the case of confidential and proprietary information or an offer to a potential partner or investors (Sharma and Shrivastav, 2020).

Inter-relationships

When examining the collective inter-relationships with other actors of the system, the most prominent interactions are in terms of formal and informal meetings, seminars and training, and as recipients of funding.

Formal communications with the government generally focus on issues of regulation, compliance, and trade. This indicates tacit knowledge transfer coupled with funding in the form of various schemes implemented by the Ministry of Heavy Industries (MHI) like "Faster Adoption and Manufacturing of Hybrid & Electric Vehicles (FAME) India", the "Production Linked Incentive (PLI) Scheme for the Auto-Component Industry", the "PLI Scheme for the National Programme on Advanced Chemistry Cell (ACC) Battery Storage", and the "Project Import Scheme"[54]. Licensing agreements are also common with the government; For instance, industry is required to take a pollution license/certificate from the Central or State Pollution Control Board based on the classification of industrial sectors under red, orange, green and white categories[55].

In the case of industry relationships with intermediaries, formal and informal meetings can be seen as manufacturers interacting with sectorial industry associations such as the Automotive Component Manufacturers Association of India (ACMA), the Society of Indian Automobile Manufacturers (SIAM) and the

[52] Sourced from: https://www.autocarpro.in/news-national/varroc-engineering-wins-orders-worth-rs-500-crore-in-ongoing-fiscal-77821

[53] Sourced from: https://www.republicworld.com/business-news/india-business/after-mega-revolution-in-automotive-sector-volvo-india-and-mg-motors-md-reveal-next-steps-articleshow.html

[54] Sourced from: https://heavyindustries.gov.in/UserView/index?mid=1378

[55] Sourced from: https://cpcb.nic.in/categorization-of-industrial-sectors/

Automotive Research Association of India (ARAI). For instance, Erisha Agritech Private Limited has signed a Memorandum of Understanding (MoU) with the ARAI towards the design and development of powertrain systems and components for electric vehicles and hydrogen fuel cells developed under Erisha Agritech Private Limited[56]. Matter, a technology startup focusing on electric mobility solutions, has signed an MoU with the ARAI for collaborating in the areas of functional safety, electronics reliability and cyber security for next-generation mobility solutions[57].

A crucial part of intermediary function is knowledge dissemination as is exemplified by both formal and informal platforms. One such example is the national and regional fora held by the ACMA, as well as training and seminars held both at the national and regional level for the Indian automotive industry. The typical focus of such initiatives ranges from sessions on advanced excel tools to regional best practices. Similar initiatives exist for both the SIAM and the ARAI.

At the fourth edition of the Auto Retail Conclave in September 2022, the Federation of Automobile Dealers Associations (FADA) launched the **"**Model Dealer Agreement**"** (MDA) in a bid to offer a level playing field for OEMs and dealer partners, in addition to further extending the responsibilities towards the end-customers. Media reports suggest that the FADA researched over 100 global and Indian OEM-dealer contracts before coming up with the draft and proposed an MDA to keep the agreement balanced[58]. The launch of the MDA is a tangible outcome of the industry-intermediary interaction and marks a significant turning point for the automotive community.

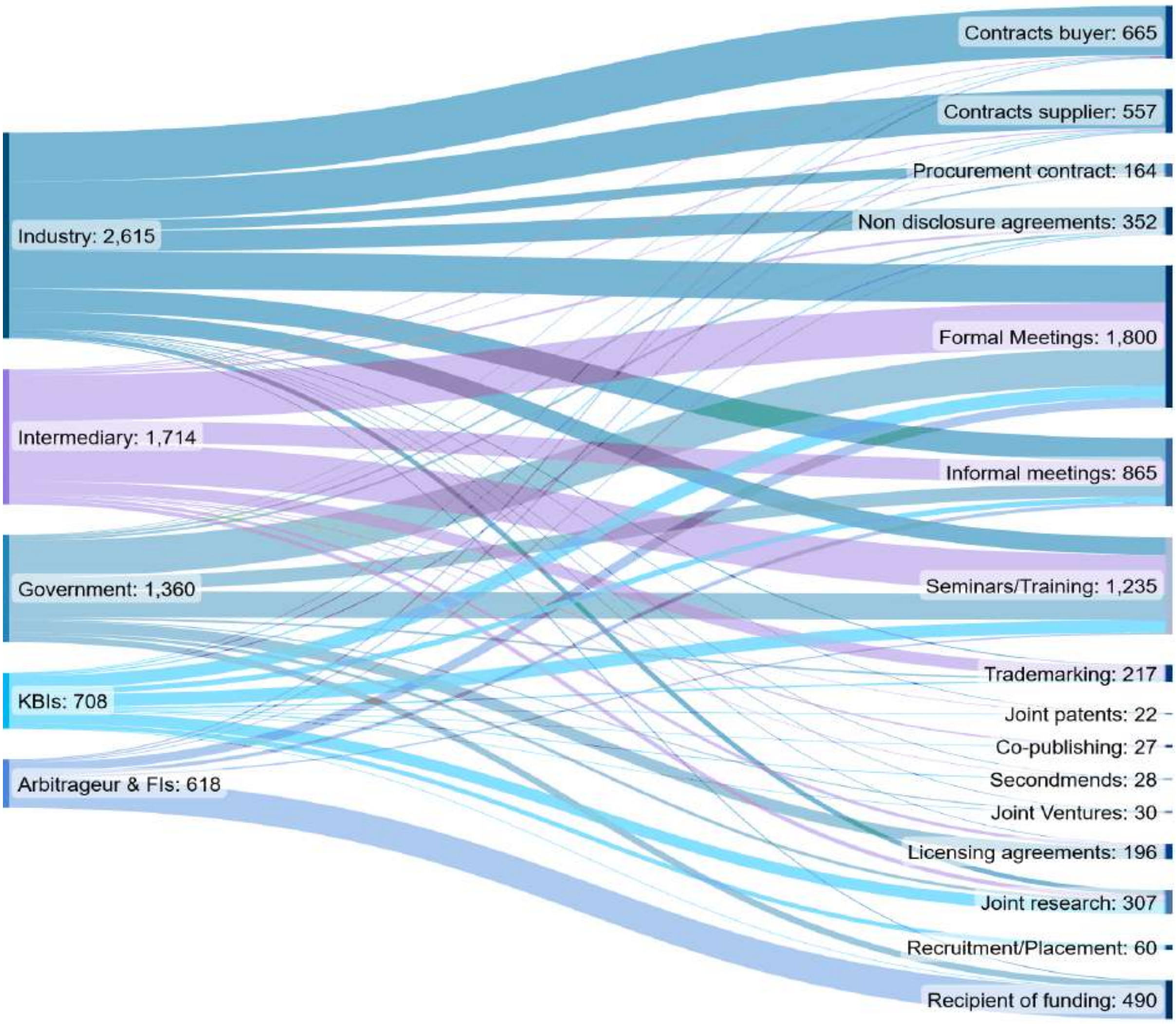
Industry relations with KBIs are mainly in the form of formal meetings, seminars and training, and joint research. MG Motors India joining hands with IIT Delhi's Centre for Automotive Research and Tribology (CART) for ground-breaking research in the field of electric and autonomous vehicles is an example of joint research between industry and KBIs. Hero Electric, India's largest electric two-wheeler company, is collaborating with Delhi Skill and Entrepreneurship University (DSEU) and research think tank, World Resources Institute (WRI) India, to provide internships and placements for students with a Diploma in Automobile Engineering. This co-created programme will cover numerous aspects of EVs and there will be selected Hero Electric employees as guest lecturers for three training sessions every semester. Hero Electric will also be creating and updating the curriculum regularly while WRI India will offer research, monitoring, and evaluation support[59]. Toyota Kirloskar Motor (TKM) has signed an MoU with the National Skill Development Corporation (NSDC) and Automotive Skill Development Council (ASDC) to enhance student skills in rural areas to make the youth more employable through the company's training initiative, the **"**Toyota Technical Education Program (T-TEP)**"** [60].

State governments are taking steps to create synergies between the industry and academia, imparting technical education to help bridge the skill gap and upskilling youth so that they can be gainfully employed. For instance, the technical education and industrial training department of the Government of Punjab organised the first-ever edition of Industry Academia Meet in May 2022 in a bid to boost collaboration between industry and academia in the state. Later in October 2022, the Ministry of Heavy Industries organised the National Conference on Industry 4.0 with the aim of bringing in more convergence between the industry, educational institutions, youth, entrepreneurs and policymakers. During the conference, the Central Manufacturing Technology Institute (CMTI), Indian Institute of Science (IISc), IIT Madras, Bharat Heavy Electricals Limited (BHEL) and C4i4 presented the steps they have taken towards Industry 4.0[61].

With respect to the flow of funds, the results highlight that the industry receives funds mostly from banks rather than through venture capital, however, startups in the automotive sector receive traction of funds from investors (VC's/angel investors).

[56] Sourced from: https://timesofindia.indiatimes.com/erisha-agritech-private-ltd-inks-mou-with-leading-automotive-rd-organization-the-automotive-research-association-of-india-arai/articleshow/90776303.cms
[57] Sourced from: https://www.autocarpro.in/news-national/matter-inks-mou-with-arai-for-nextgeneration-mobility-solutions-80527
[58] Sourced from: https://www.financialexpress.com/express-mobility/fadas-4th-auto-retail-conclave-seeks-improve-oem-dealer-synergy-to-drive-automotive-growth-in-india/2665776/
[59] Sourced from: https://indiaeducationdiary.in/hero-electric-partners-with-dseu-for-a-skill-development-program-in-the-ev-segment/
[60] Sourced from: https://www.financialexpress.com/express-mobility/toyota-nsdc-and-asdc-sign-mou-to-strengthen-rural-skill-enhancement/2599446/
[61] Sourced from: https://pib.gov.in/PressReleasePage.aspx?PRID=1865905

FIGURE 24: Industry relationships



6.2.2 Knowledge-Based Institutions

Figure 25 highlights the knowledge-based institution intra- and inter-linkages.

Intra-relationships

The majority of intra-linkages reported by KBIs are as seminars/training, formal and informal meetings, joint research and co-publishing.

An example of knowledge diffusion through seminars and training includes the joint webinar series hosted by IIT Delhi and University College London (UCL) focusing on six key research themes including: assistive technology, robotics, PPE, diagnostics, and AI for healthcare, imaging and impact of assistive technology on the international collaborations in disability innovation. This was attended not only by students and researchers from IIT Delhi but also from other Indian and international institutes and universities.

As previously highlighted, a combination of formal and informal communication drives the innovation process. Firstly, this result highlights that there is some degree of collaboration between KBIs in the automotive sector. However, there is more formal than informal meetings which indicates a level of rigidity to the exchange. Collaborations between universities, and public and private research institutions are excellent sources of research data. Therefore, its successful management can generate firm level benefits leading to innovative ideas and impulses and the provision of support for technological development (Steel et al., 2018 and Broström & Mckelvey, 2015). Consequently, it is crucial that intra-linkages between KBIs are strengthened to result in the bolstering of direct support to the industry. A successful example of such collaboration is that of the ARAI Academy, ARAI's academic wing with VELTECH University (Chennai), College of Engineering (Pune), Christ University (Bangalore), and the Department of Technology SPPU (Pune) for the joint programme of building up human resources by commencing educational programmes (graduate, postgraduate, PG diploma and doctoral) with specialisation in automotive engineering.

Examples of successful joint research include IIT Roorkee and IIT Delhi collaborating with neighbouring institutes in terms of knowledge sharing, technically skilled manpower development and creating joint intellectual property. More recently, the National Institute of Technology (NIT), Andhra Pradesh has been collaborating with state universities to implement joint academic programmes and has identified areas of joint research like agriculture, robotics and smart mobility and is planning to execute them with the help of neighbouring universities[62].

There is also the externalisation of knowledge with respect to co-publishing which may very well be associated with the National Assessment and Accreditation Council (NAAC) accreditation under the pillar of research innovation and extension, or the National Institutional Ranking Framework (NIRF) under the pillar of research and professional practice.

Inter-relationships

Among the collective inter-relationships with other actors of the system, the most prominent interactions of KBIs are in the form of formal meetings, seminars and training, joint research, informal meetings and as recipients of funding.

From the perspective of knowledge-based interaction with other system actors, the combination of formal and informal mechanisms of interaction enables the dissolution of organizational rigidities and better exchange of ideas to some extent, which may then be formalised in terms of formal transfer mechanisms like licensing and the acquisition of patents (Jensen and Thursby, 2001; Thursby and Kemp, 2002), joint research (Cockburn and Henderson, 1998) or consulting (Thursby et al., 2007).

Within the innovation process, intermediaries are important organizations in mitigating systemic failures (Sutthijakra and Intarakumnerd, 2015). An example where industry associations are coming together with the knowledgebase for knowledge dissemination is the ACMA initiating a "Lean Concepts in Manufacturing" elective subject in IIT Palakkad, Kerala[63]. This is crucial as the knowledgebase is seen as a source of technical knowledge. In addition to the knowledgebase, the inclusion of industry actors ensures relevance of pedagogy based on real world problems, as well as continuous learning between industry and the knowledgebase (Kaklauskaset al., 2017).

Examples of KBI-industry joint research include an agreement signed by Mobis India Limited, a research and development centre for Hyundai Mobis with IIT Hyderabad for collaborative research in the field of advanced automotive technologies[64]. Joint research between KBIs and industry and the funding flow from government is highlighted by researchers from the IIT Delhi's Department of Energy Science and Engineering (DESE), Indian Oil Corporation (IOC R&D), and Ashok Leyland Ltd., who have developed a technology which enables a diesel-powered automotive vehicle to run in flex fuel mode - either 100% diesel or Dimethyl Ether (DME) plus Diesel mode. The project was funded by the Department of Science and Technology (DST), Government of India. Other such examples include Sona Comstar, a leading automobile component manufacturer working with IIT Delhi to support, fund and mentor innovative startups[65]. Arbitrageurs also play a key role in the process of ideation to market and are a dominant source of finance for commercialising risky new ideas and technologies (Lerner and Nanda, 2020).

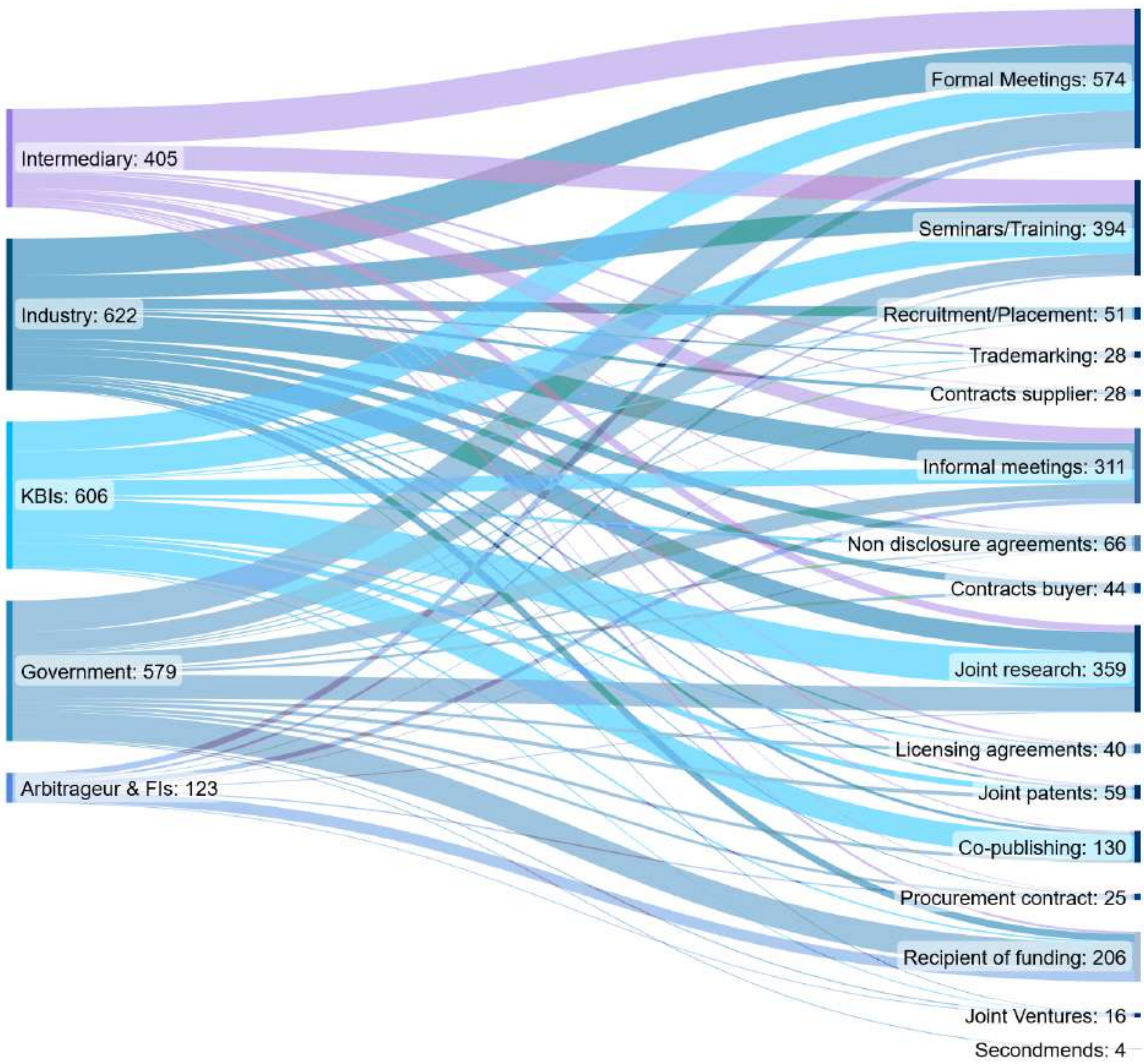
[62] Sourced from: https://timesofindia.indiatimes.com/education/news/why-institutions-are-collaborating-to-enhance-their-research-capacity/articleshow/88321592.cms

[63] Sourced from: https://www.acma.in/uploads/publication/impact/Impact-Aug-2021.pdf

[64] Sourced from: https://www.thehindubusinessline.com/info-tech/mobis-india-iit-h-sign-pact-for-research-in-automotive-tech/article65230313.ece

[65] Sourced from: https://www.livemint.com/companies/start-ups/sona-comstar-ties-up-with-iit-delhi-to-fund-start-ups-11592399368227.html

FIGURE 25: Knowledge-based institution relationships



6.2.3 Government

Figure 26 highlights the government intra- and inter-linkages.

Intra-relationships

The main intra-linkages reported are formal and informal meetings, seminars and training, joint research, co-publishing, and as recipients of funding.

Due to the complexity of policymaking, the division of labour between government agencies makes it almost impossible for one agency to dominate the process. Joint efforts involving different agencies are essential as is highlighted by formal and informal communication. Therefore, communication, coordination and mutual adjustment between these stakeholders and between the stakeholders and the environment against which policy is made is required (Flanagan et al., 2011). In the automotive sector, the challenge of availability of skills particularly due to the paradigm shift associated with the advent of Industry 4.0 is recognised by the government. This has led to a strategic partnership across ministries[66] namely, the Ministry of Skill Development and Entrepreneurship (MSDE) and the Ministry of Heavy Industries (MHI). This is articulated in a formal communication and expounds the following joint activities:

- Create a national ecosystem for development of skills for the manufacturing sector.
- Support related sector skills councils.

[66] Sourced from: https://heavyindustries.gov.in/writereaddata/UploadFile/scan0009.pdf

- Mobilise financial support through engaging public sector units (PSUs) under the DHI.
- Develop a multi-location National Institute for Manufacturing Technologies (NMIT) for training education and research.
- Creation of Centres of Excellence (CoE) by upgrading existing training facilities at PSUs under the DHI.
- Bring and disseminate international best practices in the field of skills development.
- Leverage private partnerships in the entire value chain or skilling through targeted entrepreneurship and skills development programmes.
- Promote awareness activities across all actors.
- Facilitate courses with Qualification Packs (QPs) in the ministry affiliated training institutes as well as PSUs and adequate funding for the same.
- Promote and facilitate Recognition of Prior Learning (RPL) for the existing and potential workforce of PSUs.
- Provide equipment and working spares for use in laboratories and workshops of ATIs/ITIs/RVTIs and NDC-affiliated training partners.
- Promote and scale apprenticeship training in PSUs.
- Promote the adoption of Industrial Training Institutes (ITIs) by PSUs.
- Introduce vocational training courses aligned with the National Skills Qualification Framework (NSQF) in schools run by PSUs.

Another collaborative initiative that focuses on joint research and aims to strengthen and institutionalise the collaboration between the Department of Heavy Industry (DHI) and Department of Science & Technology (DST) in R&D and Technology Development in Electric Mobility, is the "Technology Platform for Electric Mobility" (TPEM). The TPEM provides a collaborative platform for developers, suppliers and automotive manufacturers to work together to develop technologies and products that cater to the development of e-mobility (Mukherjee, 2017).

Funds flow between government entities include the central government providing financial assistance to state governments for the setting-up of MSME technology centres/tool rooms under the "Setting up of New Mini Tool Rooms (MTRs) under Public Private Partnership (PPP) Mode Scheme[67]".

Inter-relationships

On review of the inter-relationships between government and other actors, the most prominent types of interactions are formal and informal meetings, seminars and training, and joint research.

The National Conference on Industry 4.0: Challenges Ahead, 2022 organised by the Ministry of Commerce and Industry, is a clear example of a platform for tacit knowledge exchange, which aims to understand strategies to promote Industry 4.0 in India's manufacturing sector and encourage Industry 4.0 technologies to enable systems, products, and processes for growth and competitiveness by 2030[68]. Senior representatives from India's top manufacturing companies took part in sessions to talk about new technologies that support process innovation, international standardisation, and how automobile manufacturers can adopt Industrial Internet of Things (IIoT) technologies and software to enable seamless communication between machines for greater efficiency and utilisation.

In July 2022, 60 Memorandum of Understandings (MoUs) were exchanged between the Tamil Nadu government and companies from across the world that pledged an investment of INR 1.25 lakh crore in varied sectors like green hydrogen, electric vehicles, flight training and automobile components[69]. In another example, Facilitating MSMEs of Tamil Nadu (FaMe TN), an autonomous agency of the Government of Tamil Nadu, has signed an MoU with the World Resources Institute (WRI) India to work together to support the low carbon transition of MSMEs in Coimbatore's automotive sector and help them adopt EVs through research, capacity building and skilling[70]. Similarly, Karnataka Government has signed two MoUs with Malaysia-based Petronas Hydrogen and Continental Automotive Components that will usher in an investment of INR 32,000 crore in the state[71].

On the other hand, Continental Automotive will be making an investment of about INR 1,000 crore in an R & D centre for the expansion of the Technical Centre India (TCI). The TCI will seek to work on automotive software development

[67] Sourced from: http://www.msmediagra.gov.in/writereaddata/mtr_gudelines.pdf
[68] Sourced from: https://pib.gov.in/PressReleasePage.aspx?PRID=1865836
[69] Sourced from: https://www.deccanherald.com/national/south/tamil-nadu-signs-60-mous-worth-rs-125-lakh-crore-1123821.html
[70] Sourced from: https://boldoutline.in/fame-tn-and-wri-india-sign-mou-to-prepare-msmes-in-coimbatores-automotive-sector-for-ev-transition.html
[71] Sourced from: https://www.saurenergy.com/solar-energy-news/karnataka-signs-mous-with-petronas-hydrogen-and-continental-automotive-components-for-investment-worth-rs-32000-cr

and mobility technology development, thereby adding about 6000 jobs[72].

In relation to fostering linkages between firms and knowledge-based institutions, the[73] "Automotive Solutions Portal for Industry Research & Education" (ASPIRE) initiative by the Ministry of Heavy Industries is another platform for exchange to help promote innovation and strengthen the ecosystem. This technology platform will facilitate the Indian auto industry (including OEMs, Tier 1 Tier 2 & Tier 3 companies), R&D institutions and academia (colleges & universities) to come together for R&D, technology development, shop floor/ quality/ warranty issues resolution, expert opinions, etc., on issues involving technology advancements.

With respect to interaction between government and intermediaries, the Federation of Indian Chambers of Commerce and Industry (FICCI) has promoted and set-up the Capital Goods Skill Council (CGSC), under the NSDC framework for capital goods. It is an autonomous body which has been set-up with the support of the Department of Heavy Industry, capital goods industry and industry associations[74]. Its focus is to bridge the gap between the industry needs and skilled manpower as per competency standards defined by the industry and the training and education system. The benefits to members include, amongst other things, direct access to enhanced productive manpower, through:

- Articulating and validating the competencies required in the National Occupational Standards by industry members, leading to nationally and internationally recognised qualifications.
- Certification of contractual / non-certified workforce through a process of Recognition of Prior Learning (RPL).
- Linking affiliated and quality assured training centres for sourcing the future workforce, trained in industry approved National Occupational Standards.
- Preferential access to the existing database of CGSC certified manpower.
- Access to CGSC certified candidates under the "Pradhan Mantri Kaushal Vikas Yojna" (PMKVY) who could be directly hired under the Apprenticeship Act.

Joint research and co-publishing undertaken by government and intermediaries is highlighted by the "Auto Electronics: Master Plan Development for Auto Components Industry in India", a joint report by the ACMA and DHI focusing on current and future opportunities in the burgeoning auto electronics market in India for the automotive component manufacturing industry in India (ACMA, 2016). The objectives of this work are to:

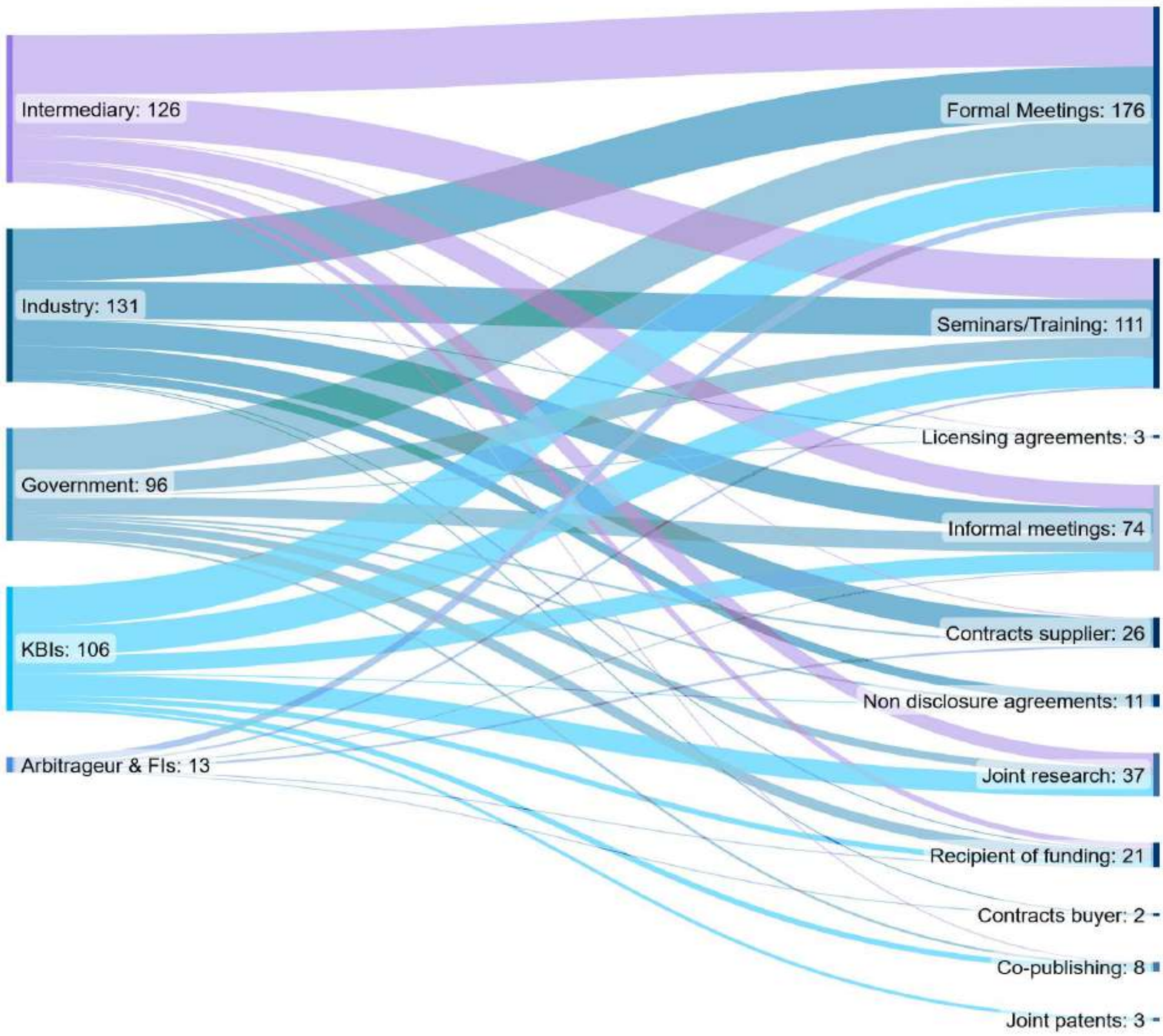
- Understand the global mega trends that are affecting the automotive electronics industry.
- Understand the emerging automotive trends related to technology (engine, transmission, chassis, safety, and infotainment) at the cluster level only, including regulations.
- Outline the market opportunities that exist in the key global automotive regions for Indian suppliers and map the value chain.
- Recommend a broad-based strategy, policy, capability development approach to grow business opportunities for the industry, the ACMA and government.

Although not highlighted as a major linkage, funding is key to the innovation process, related to bolstering research. The Ministry of Heavy Industries funding IIT Delhi for setting-up a national common engineering facility centre on smart technology enabled manufacturing[75] under the "Capital Goods Scheme" is an example of the same.

Another initiative that needs to be highlighted is the "Production Linked Incentive (PLI)[76] Scheme for Automobile and Auto-Component Industry" which proposes financial incentives to boost domestic manufacturing. The scheme has two components – the "Champion OEM Incentive Scheme" and the "Component Champion Incentive Scheme". A total of 95 applicants have been approved under this PLI scheme. The Ministry of Heavy Industries (MHI) had earlier approved 20 applicants (along with their 12 subsidiaries) for the Champion OEM Incentive Scheme. Subsequently, the MHI has processed the applications received under the Component Champion Íncentive Scheme and 75 applicants (along with their 56 subsidiaries) have been approved under this category.

[72] Sourced from: https://www.financialexpress.com/express-mobility/components/continental-targets-rs-1000-crore-investment-for-technical-centre-india-in-karnataka/2585015/
[73] Sourced from: https://aspire.icat.in/
[74] Sourced from: https://www.cgsc.in/membership.html
[75] Sourced from: https://heavyindustries.gov.in/writereaddata/HEMT/MOU/CEFC%20at%20IIT-Delhi%20by%20IIT-D%20AIA%20on%20Industry%204/SignedMoU.pdf
[76] Sourced from: https://heavyindustries.gov.in/writereaddata/UploadFile/PRESS%20RELEASE%20ENGLISH%2015%2003%202022.pdf

FIGURE 26: Government relationships



6.2.4 Intermediary

Figure 27 highlights the intermediaries intra- and inter-linkages.

Intra-relationships

The main intra-linkages reported are formal and informal meetings along with seminars and training. This indicates high tacit knowledge transfer between intermediaries which, as was previously elucidated, is crucial for idea generation and sharing. Such communication has culminated in joint research initiatives, for example, in order to have a holistic understanding of the nature of imports and the current localisation levels, the SIAM and ACMA jointly commissioned a study to prepare the "Localization Roadmap for the Indian Automotive Sector", covering all components and raw materials used in the auto sector. Seven cross functional teams were formed with members from the SIAM, ACMA and other industry bodies like the Automotive Tyre Manufacturers' Association (ATMA), and the Tool and Gauge Manufacturers Association (TAGMA). The roadmap was prepared for a time period of 0-2 years and for 2-5 years highlighting the % reduction in imports to be targeted, for every category, thereby, highlighting the business potential available for domestic component suppliers. Specific actions required by the industry and support required from the government was also identified for each of the categories (SIAM Annual Report, 2020-21).

Knowledge exchange being a core function of intermediaries is showcased by the Conference on Safer and Sustainable Road Transportation organised under the "ACMA- SIAM-VDA Partnership Programme", which was implemented in India with the support of the German Federal Ministry of Economic Cooperation and Development (BMZ), and the German organization Sequa GmbH. The objective of this conference is to share the challenges that are being faced in Germany for reducing road accidents and the research that is being undertaken in this regard to address this issue. Correspondingly, it is expected that the Indian experts would also highlight the work that is being done to improve vehicle safety and deliberate on undertaking similar research in India for enhancing the safety performance of future product lines. Furthernore, the conference will also focus on sustainability along the whole vehicle life cycle, which includes production, operation, scrapping and recycling[77].

Inter-relationships

With respect to inter-relationships, the most prominent are those of the intra-relationships, namely: formal and informal meetings, seminars and training, with the exception of joint research and as recipients of funding. For instance, a tripartite MoU was signed between Guidance Tamil Nadu - an investment promotion agency of the Government of Tamil Nadu and Mando – a Korean automotive component manufacturer and the Directorate of Technical Education (DoTE) in June 2022. The MoU enables Mando to be the industrial partner for DoTE in launching two new sandwich polytechnic programmes under automobiles and mechanical engineering, in which over 130 students will undergo industrial internships at Mando for one year during their course[78].

A part of the role of industry associations is to guide the policy process and act as a conduit to report the needs and interests of their members to the government through formal channels. Within this context the Ministry of Road Transport, Highways & Shipping (MoRTH&S) acts as a nodal agency for the formulation and implementation of various provisions of the Motor Vehicle Act and CMVR; in this function it has constituted three committees to deliberate and advise the ministry on issues relating to safety and emission regulations, namely:

- CMVR- Technical Standing Committee (CMVR-TSC)
- Standing Committee on Implementation of Emission Legislation (SCOE)
- Automotive Industry Standards Committee (AISC)

These committees advise MoRTH&S on various technical aspects related to CMVR and these committees have formal representation from various organizations, of which the SIAM, ARAI and ACMA are members.

Major functions of the committees are:

- To provide technical clarification and interpretation of the Central Motor Vehicles Rules having technical bearing to MoRT&H, as and when so desired.
- To recommend to the government the international standards which can be used in lieu of the standard notified under the CMVR. Permit use of components/parts/assemblies complying with such standards.
- To make recommendations on any other technical issue(s) which have direct relevance in the implementation of the Central Motor Vehicles Rules.
- To make recommendations on the new safety standards of various components for notification and implementation under the Central Motor Vehicles Rules.
- To make recommendations on lead time required for implementation of such safety standards.
- To recommend amendments to the Central Motor Vehicles Rules having technical bearing and keeping in view the changes in automobile technologies.

This indicates tacit knowledge transfer/regular communication taking place between industry and industry associations like annual conferences, workshops hosted by the ACMA, CII, SIAM, etc. One such example is the International Conference on International Material Data System (IMDS) and End of Life Vehicle (ELV) Regulations hosted by the SIAM and ACMA. The objective being to focus on the IMDS and ELV regulations which are gaining importance due to the harmonisation of technical regulations in the automotive sector. Non-compliance to these technical regulations and standards would have a negative impact on competitiveness in international trade.

A second function of industry associations is knowledge dissemination to its members and generally occurs through regular meetings and conferences. One such example is of the Ministry of Heavy Industries & Public Enterprises, SIAM and ACMA's jointly organised "National Workshop on FAME India" under the National Mission for Electric Mobility (NMEM)[79].

In the case of incubators, regular communication takes place through the Indian STEP & Business Incubator Association (ISBA) which boasts a membership base of over 70 organizations active in entrepreneurship development and incubation. It annually hosts its flagship networking event that brings together incubators, experts, investors,

[77] Sourced from: https://www.siam.in/event-overview.aspx?eid=193
[78] Sourced from: https://www.thehindu.com/news/national/tamil-nadu/korean-firm-mando-inks-mou-with-guidance-tamil-nadu-and-dote/article65582672.ece
[79] Sourced from: https://www.siam.in/event-overview.aspx?eid=172

government, and other stakeholders of the techno-entrepreneurship ecosystem. Creative actions undertaken and promoted in the incubator space related to the automotive and mobility space include the "Sustainable Mobility Challenge". This is a multi-pronged programme by Villgro Innovations Foundation targeting startups at different stages of maturity who are focused on solving problems related to sustainable mobility through creating a cohort of tech startups to bring about a socially impactful change in the mobility sector. The challenge seeks to support startups creating innovative and impactful solutions which: solve multi-modal mobility; optimise traffic flow, routes and fleets; enhance road safety and provide equitable access to mobility; and introduce EV interventions to one or more of these areas.

A unique example of collaboration between intermediaries and knowledge-based institutions includes SAKSHAM – the ACMA Centre of Excellence established at IIT Delhi Sonipat Campus with an investment of INR 4.5 crore. It hosts two state-of-the-art labs for mechatronics and a design lab focusing on supporting research and delivering technical know-how on automation and new technologies[80]. Another example of such collaboration is the ICAT signing an MoU with Northcap University to enhance industry-academia partnership for conducting joint courses and research in the field of EVs and other emerging technologies[81].

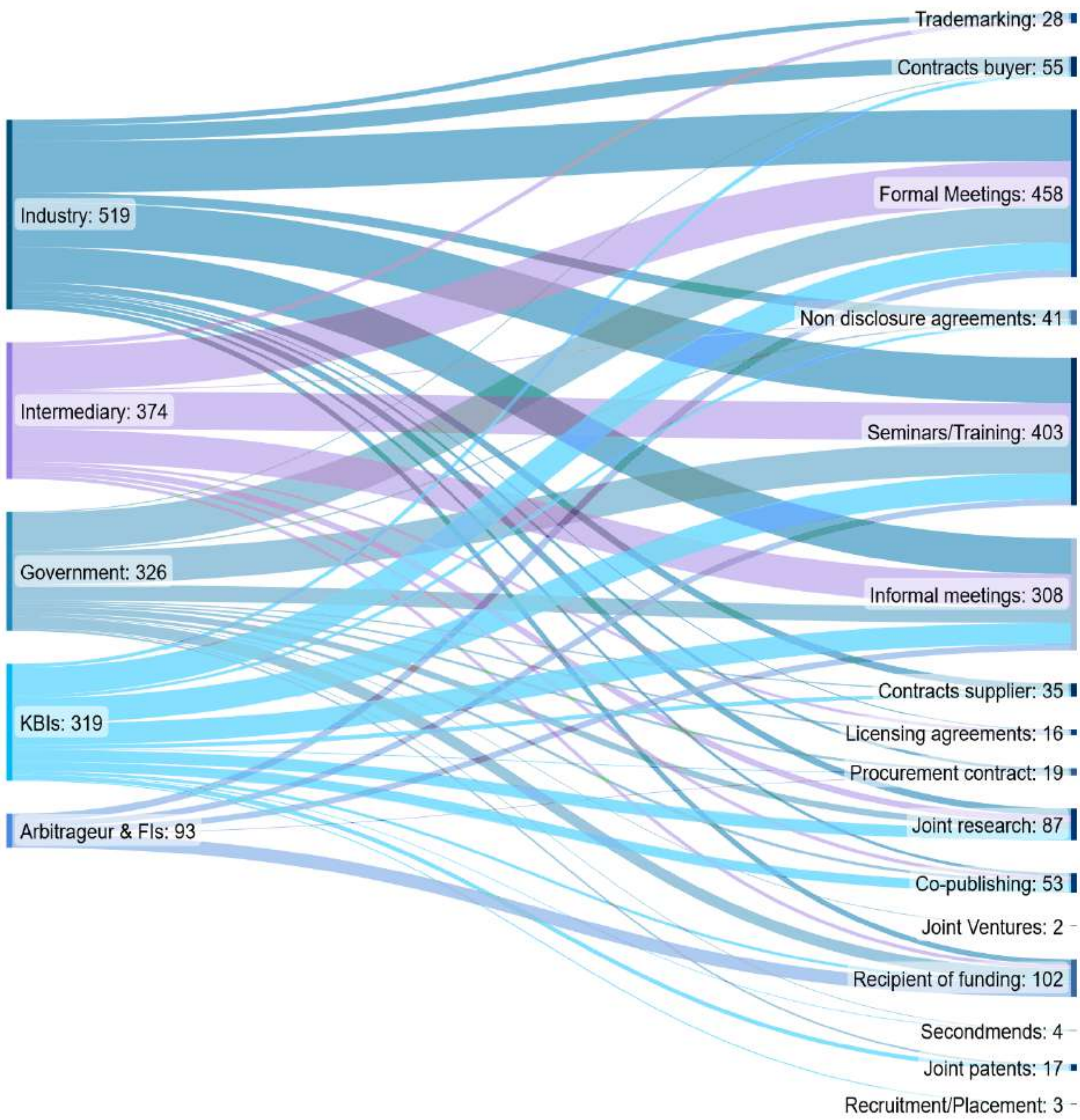
An example of a government funded initiative with an intermediary is the technology innovation platform "TechNovuus". TechNovuus was established under the aegis of the MHI by the ARAI as a collaborative ecosystem for enabling indigenous technology, innovation and solution development focused on Indian mobility CASE (connected and shared, affordable, safe, environment friendly and towards energy independence). The platform has initiated a programme called "UpTech" which provides technology up-levelling support to startups, MSMEs and innovators. In addition, within the framework of TechNovuus, a Mobility Hackathon was launched with 10 problem statements with the theme of: 'Safe, Sustainable, and Smart Mobility Solutions for Aatmanirbhar Bharat'.

Funds flow is between intermediaries and arbitrageurs as evidenced by platforms such as the "Atal Innovation Mission of NITI Aayog". It provides INR 10 crore grants for established incubation centres. Tacit knowledge exchange between the two actors is in the form of formal meetings, informal meetings and seminars/trainings, highlighted in the relationship between the Enterprise Incubation Centre (EIC) of premier B-school IIM Lucknow's Noida and the HDFC Bank, who have signed an MoU to help startups with mentoring, training, product acceleration, and banking services

[80] Sourced from: https://auto.economictimes.indiatimes.com/news/auto-components/acma-unveils-center-of-excellence-in-sonipat/71836724

[81] Sourced from: https://auto.economictimes.indiatimes.com/news/auto-technology/icat-signs-mou-with-northcap-university-for-emerging-technologies/93885411?redirect=1

FIGURE 27: **Intermediary relationships**



BOX 1: The ACMA Centre of Excellence in Partnership with IIT Delhi (INT - KBI Linkage)

Objective

The ACMA Centre of Excellence (ACoE) SAKSHAM is a state-of-the-art training centre for disseminating futuristic technology and know-how to the automotive industry, primarily aimed at facilitating Tier 2 and Tier 3 firms in designing and developing new products and thereby improving their productivity and competitiveness through advanced capacity-building programmes.

Approach

The Automotive Component Manufacturers Association of India (ACMA), the apex body representing the Indian auto-component industry, established the ACoE at the Sonipat campus of the Indian Institute of Technology, New Delhi (IIT-D) to offer world-class skilling and training to students as well as industry professionals working in the automotive industry.

- The Design lab at the ACoE offers software-based simulations to enable practical learning of design engineers in process engineering, product design, styling, systems, modelling, layout, simulations and project management.
- A high-end 3-D scanner with high accuracy scans components of sizes up to 2 meters, for inspection and learning.
- The mechatronics lab at the ACoE is a state-of-the-art facility offering practical learning and opportunities for live demonstrations, that are made possible by an array of plug-and-play mechatronic gadgets and tools for training on advance pneumatics, hydraulics, electro-pneumatics, servo motor drive systems with linear drives and sensors, and a robotics station.
- As a shared resources centre of the auto-component industry, the ACoE offers various training programmes to meet the key skilling needs of firms to stay competitive, thus targeting both technical and soft skill enhancements. The key thematic areas of training include: zero defect quality with traceability and advance metrology, simulations of design, development and testing of components, automation and robotics, digitisation of manufacturing, and on tools for cost and productivity competitiveness.

Outcomes

- Since its founding in 2019, to date more than 300 companies have participated in the training programme, such that 20,000 people have attended the trainings.
- The ACoE SAKSHAM expanded its domain to foster cooperation and collaboration with other institutions and universities, and is now working with IIT Palakkad, Kerala to introduce industry electives as a core subject in their curriculum to adapt the syllabus with industry requirements.
- The collaboration is also exploring incubation centres to be set-up in IIT Palakkad.

6.2.5 Arbitrageurs and financial institutions

Figure 28 highlights the arbitrageur and financial institution intra- and inter-linkages.

Intra-relationships

The main intra-linkages reported are formal and informal meetings, seminars and training and as recipients of funding.

Information flow is crucial in order for arbitrageurs and financial institutions to effectively stay on track with the market and assess risk. Investor Conclave was hosted as a platform for assessing regulatory scenarios and high-end networking among the private equity (PE) or venture capital (VC) investors by the Indian Venture Capital Association. The Indian Private Equity & Venture Capital Association (IVCA)[82] is one of the platforms for investment funds to interact with each other and develop the ecosystem of India's PE/VC industry.

With respect to the recipients of funding, the IDBI Bank's "Fund Scheme for NBFCs"[83] is an example which provides

[82] Sourced from: https://ivca.in/mission-vision/
[83] Sourced from: https://www.idbibank.in/lending-to-nbfc-hfc.aspx

financial assistance in the form of working capital limit and term loans to Non-Banking Finance Companies (NBFCs), including Housing Finance Companies (HFCs), Infrastructure Finance Companies (IFCs) and Asset Finance Companies (AFCs).

Inter-relationships

With respect to inter-relationships, once again formal and informal channels of communication are prominent, followed by knowledge dissemination activities in the form of seminars and training, followed by non-disclosure agreements (NDAs).

Formal and informal communication between arbitrageurs and financial institutions and government generally orient around investment policies. For example, the 4th "Roundtable with Global Venture Capital Funds", was organised by the Department for Promotion of Industry and Internal Trade (DPIIT), Ministry of Commerce and Industry in January 2022 to explore new sectors for investing, to promote and protect the intellectual property created by young Indian entrepreneurs and provide expertise to scale-up and explore greater capital infusion, including risk capital.

For decades, banks were frontrunners in automation, but now, large parts of their once cutting-edge technologies have turned into legacy systems that hinder innovation. While banks are grappling with legacy systems and regulatory pressure, lean and agile FinTech startups are homing in on their customers. It is crucial that banks introduce future-proof technologies and processes to keep up with their competitors. Knowledge dissemination is crucial to the process. An example of this is A. C. Patil College of Engineering, Mumbai & IDBI Intech (subsidiary of IDBI Bank) joint workshop on artificial intelligence and machine learning.

In the case of the government interacting with arbitrageurs and financial institutions with respect to the recipient of funding outcomes, the "India Automotive Component Manufacturers Private Equity Fund"[84], set-up by IFCI Venture Capital Funds Ltd. (GoI), raised a corpus of INR 190 crore from various financial institutions like the IDBI, LIC, etc. It invested in Indian companies engaged in, amongst others, the automotive parts and components manufacturing sector in order to generate high returns for its investors.

An example of tacit knowledge transfer coupled with recipients of funding in the case of arbitrageurs and financial institutions with knowledge-based institutions, which is involved in the ideation to market process, is IIT Madras and RBI Innovation Hub (RBIH)[85], a wholly owned subsidiary of the Reserve Bank of India. They have signed an MoU to work together in developing the ecosystem necessary to support and scale FinTech startups in India.

With respect to arbitrageurs and intermediaries and recipients of funding, Yes Bank invested an undisclosed amount in venture catalysts group funds called "Venture Catalysts", an integrated incubator that helps startup founders across all stages of their businesses[86]. NDAs indicate the confidentiality policy of banks for the determination of materiality and disclosure of events/information with the industry or startups, as is exemplified by SIDBI's disclosure policy for MSMEs.

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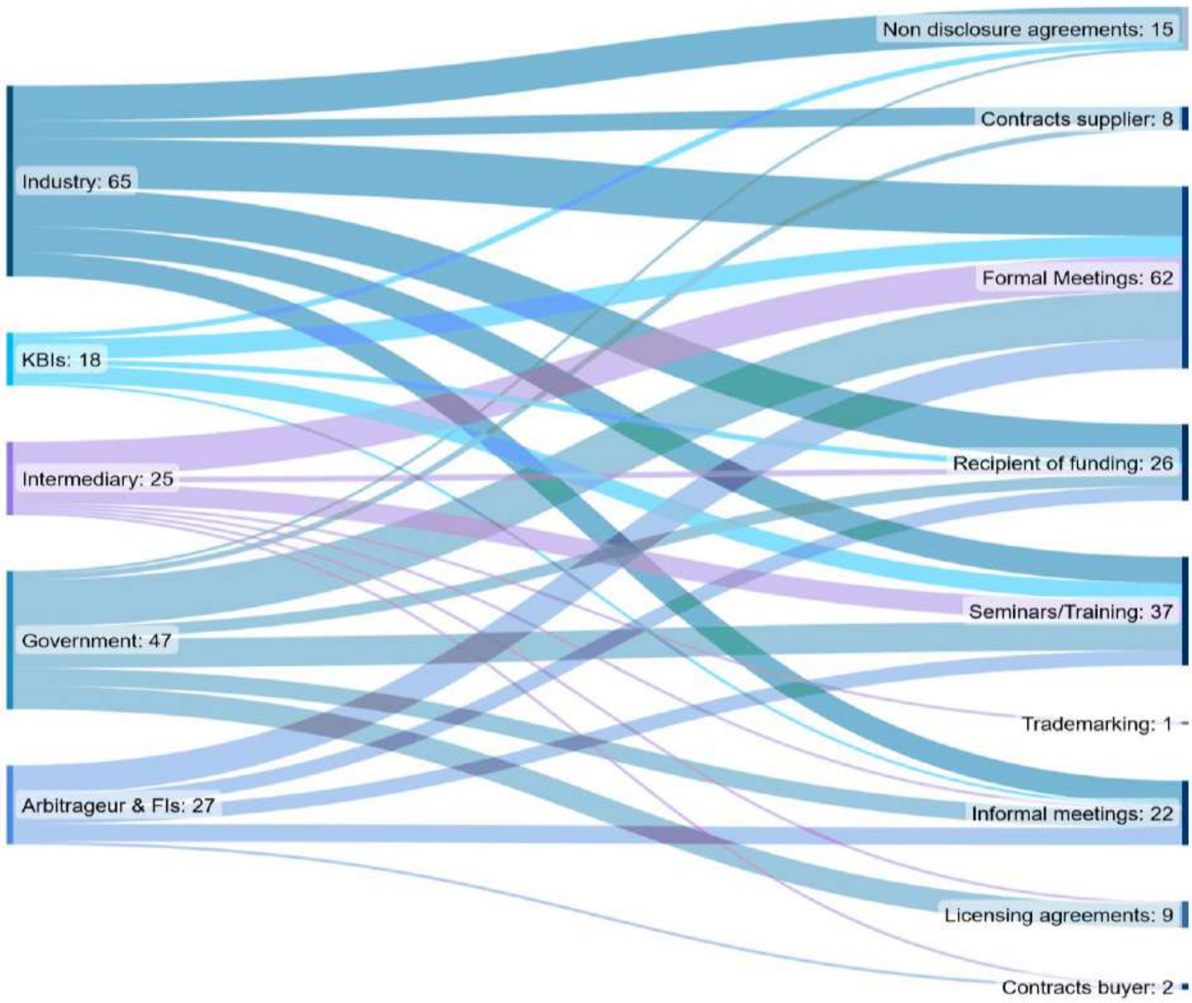
[84] Sourced from: https://www.ifciventure.com/funds-india-automotive-component-manufacturers

[85] Sourced from: https://economictimes.indiatimes.com/news/company/corporate-trends/tata-power-iit-madras-ink-mou-to-collaborate-on-rd-training-tech-solutions/articleshow/88120388.cms?from=mdr

[86] Sourced from: https://www.financialexpress.com/industry/banking-finance/yes-bank-invests-in-startup-incubator-venture-catalysts/2633937/#:~:text=Yes%20Bank%20on%20Wednesday%20announced,and%209%20Unicorns%20accelerator%20fund.

FIGURE 28: Arbitrageur and financial institution relationships



In the relationships presented above, there are some interactions which are robust, however what emerges is the need to bolster certain truncated relationships in order to facilitate knowledge and resource flows within and between the actors, hence fostering innovation. According to the literature, the scope and intensity of these interactions between the actors are reflected in varying institutional arrangements, referred to as Triple Helix Type I, II, and III (TH-Type I, II and III) (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2003b, 2008; Ranga and Etzkowitz, 2013). In the specific case of the automotive sector, we observe TH Type II transitioning to TH Type III. TH Type II refers to mechanisms of communication between the actors that are strongly influenced by the market and technological innovations and the point of control is at the interfaces where consequently new codes of communication are developed. The role of the government is primarily to limit cases of market failure. It can be considered a 'laissez-faire' model of interaction "in which actors are expected to act competitively rather than cooperatively in their relations with each other". However, in TH-Type III, the actors assume each other's roles in the institutional spheres as well as the performance of their traditional functions. With the emergence of TH Type III, a complex network of organizational ties has developed, both formal and informal, among the overlapping spheres of operations. Hence, universities take on entrepreneurial tasks such as marketing knowledge and creating companies as a result of both internal and external influences.

Based on this, the inter and intra interactions that need attention are:

- Industry relations with KBIs in the form of secondments and recruitment need to be bolstered for the tacit exchange of knowledge.
- Industry intra-linkages with other industry actors in terms of joint research are missing and need to be bolstered because such linkages are known to reduce costs, minimise risks, promote knowledge and

technology transfer and improve market access (Edwards-Schachter et. al, 2012).

- Intra-linkages between KBIs in the form of joint research need to be strengthened as they can result in the bolstering of direct support to industry. Research collaborations between universities, and public and private research institutions are excellent sources of research data. Therefore, its successful management can generate firm level benefits leading to innovative ideas and impulses and the provision of support for technological development (Steel et al., 2018 and Broström & Mckelvey, 2015).

6.3 Barriers to Innovations

The focus of this chapter is the elucidation of the barriers that exist within the automotive system of innovation. It is crucial to understand which barriers to innovation are significant for the automotive sector in order to critically understand where resources need to be applied to bolster the system of innovation and boost innovation for the sector.

To this end, factor analysis is used to indicate the underlying factors that significantly influence barriers to innovation, which enables evidence-based policy design to be targeted specifically and accurately to overcome the highest barriers to innovation in prioritised sequencing. Factor analysis condenses observed variables into factors in a pattern matrix (clusters of inter-correlated variables) with 'mutual interdependence' (Gaur, 1997). The factors represent the underlying structure that is responsible for the variation of variables in the data and thus the population (Kim Jae-On and Mueller 1978). The next section aims to articulate this both from the system perspective, as well as from the level of each individual actor.

Description of Table Structure

The column 'Factor Number' indicates the descending rank order (by importance) of the factor, which influences the sets of barriers to innovation variables. The column 'Factor Name' provides a description for the grouped variables influenced by the factor and enables meaningful policy discussion about the barriers to innovation. The factor names are assigned based on the factor loading of the variables, taking the higher loading variables into consideration as well as the judicious use of empirical evidence and theory in the literature on the System of Innovation (SI). The naming of factors therefore reflects the variables that are most influenced by the underlying factor. Furthermore, the column 'Factor Loading' indicates the correlation between factors and variables, i.e., the extent to which the factor influences the variable. The column 'Cronbach's Alpha' indicates the internal consistency and reliability of the factor, and hence the cohesion of variables as a group. The dominant heuristic, or commonly accepted rule of thumb for describing internal consistency and reliability using Cronbach's Alpha, is indicated in Table 6 (George and Mallery, 2003; Kline, 1999; Cortina, 1993).

For the purpose of policy analysis, factors influencing groups of variables with Cronbach's Alpha below 0.7 are deemed inconsistent and unreliable and are rejected for policy purposes. The factors enable economy-wide policy prescriptions, as well as actor- and sector-specific policy prescriptions to be carefully and accurately designed.

The column 'Total Variance Explained' (TVE) indicates the amount of variance (variation) of the groups of variables in the data sample and population, which is accounted for by the factor. It is an indication of the extent or power of the influence of the factor. The column 'Kaiser-Meyer-Olkin' (KMO) is a measure of sampling adequacy. It indicates the robustness of the sample in terms of the distinct and reliable factors extracted (Kim Jae-On and Mueller, 1978). The Bartlett's Test of Sphericity (BTS) indicates the significant confidence level regarding the coherence of factors, reproducibility and generalisability of the results (Kaiser, 1974; Dziuban and Shirkey, 1974, p.359; Kim and Mueller 1978, p.54; Rummel, 1970) (see Table 7).

TABLE 6: Internal consistency of factor

Cronbach's Alpha	Internal Consistency/ Reliability
a ≥ 0.9	Excellent
0.9 > a ≥ 0.8	Good
0.8 > a ≥ 0.7	Acceptable
0.7 > a ≥ 0.6	Questionable
0.6 > a ≥ 0.5	Poor
a < 0.5	Unacceptable

TABLE 7: Kaiser-Meyer-Olkin (KMO)

Internal consistency of factor	
KMO = 1	Perfect
KMO > 0.9	Marvellous
0.9 > KMO > 0.8	Meritorious
0.8 > KMO > 0.7	Middling
0.7 > KMO > 0.6	Mediocre
0.6 > KMO > 0.5	Miserable
KMO < 0.5	Unacceptable

Source: Kim Jae-On and Mueller, 1978

From the analysis of all actors (see Table 8) four factors emerge which account for 42.75% of the total variance explained (TVE), namely, '**Industry 4.0', 'Policy Function', 'Market' and ´Human Capital`**.

Factor 1- '**Industry 4.0**' is the most significant factor barrier to innovation and accounts for 22.98% of the TVE within the sample, hence the population. The variables that load on the factor are: 'Lack of access to I4.0 technologies', 'Lack of understanding of I4.0 technologies', 'Cost of I4.0 technologies' and 'Lack of infrastructure for I4.0' with a 'Good' Cronbach's Alpha value (Tabachnick and Fidell, 2007).

Industry 4.0 or the Fourth Industrial Revolution (4IR) consists of a set of complex, interrelated and advanced digital production (ADP) technologies that have changed the face of global manufacturing. The key technology pillars of 4IR include: the Internet of Things (IoT), big data, artificial intelligence, robotics, additive manufacturing, cloud computing, augmented reality, virtual reality, cyber-physical systems, system integration and simulation. These exponential technologies are impacting and revolutionising the automotive value chain throughout. 4IR technologies have increased the productivity of firms, especially through connected factories and the integration of the entire automotive value chain through the Industrial IoT (ASDC, 2022). The complexity of 4IR technologies demands high interdependency of competences and technological complementarity among system actors (Dalenogare et al., 2018; Reischauer, 2018; Rübmann et al., 2015).

Implementation of 4IR technologies at a broader organizational level is required for a measurable impact of digital transformation. Transforming factories from being manual and labour-intensive to being automated and highly digitised requires enhanced capabilities, not limited to investment in technologies. Firms require a vast set of capabilities to digitally transform their entire operating model using 4IR technologies (Boer et. al, 2021). Such capabilities are hard to be found in a single technology provider, especially in the case of small and micro enterprises (SMEs) (APO, 2019).

The first step towards 4IR implementation is a clear understanding of I4.0 technologies. There still exists a lack of understanding of the value, goals and needs of 4IR technology among many firms (Bai et al., 2020). Robust evaluation mechanisms and decision support tools can help manufacturing firms understand the impact of 4IR technologies and effectively implement them. A clear understanding of 4IR technologies, their benefits and impact can help firms develop an organization-wide 4IR strategy and set implementation targets. Educating the workforce on 4IR technologies and upskilling them is key to its effective implementation. A well-functioning innovation ecosystem can allow collaborations between system actors for knowledge sharing and awareness building. It will enable firms to integrate resources and co-create 4IR solutions (Grant Thornton & CII, 2017).

BOX 2: Implementation of Industry 4.0 in Sona Comstar

Objective

Improved production processes using Industry 4.0 applications where digitalisation has been a critical move.

Approach

Sona Comstar, an Indian multinational company, is a leading manufacturer in drivetrain for automotives and electric vehicles. With 3,555 employees across its nine manufacturing facilities in India, the USA, China and Mexico, it spends 20% of its total revenue on in-house R&D. Digitalisation at its core and in the value chain has been a critical move to improve efficiency, compliance and asset utilisation, especially after its diversification into new products and international markets.

The company focused on reducing human-errors using advanced digital production solutions such as the image-based autonomous inspection systems resulting in high productivity improvements with zero-defect outflow. Manual interventions were eliminated by using digital gauges with automatic wear offset for correction in CNC machines that resulted in zero-rejection/rework and have achieved 100% fault-ride throughs (FRTs), with a process capability greater than 1.67. Digital data loggers for collecting and transmitting real-time data have resulted in tremendous productivity improvements such that immediate responses during digital and multi-gauge inspections at the final quality gates have resulted in zero defect outflows with 100% FRTs. Simple interventions in deploying sensors to measure critical parameters such as temperature, vibrations, oil-levels and flow, among others have tremendously impacted the availability and reliability of machineries and also reduced preventive maintenance. Real-time data monitoring using Industry 4.0 solutions in connected production machines not only automated real-time data production but has also been critical to improving overall equipment efficiency (OEE) through quick action based on 16 losses.

Outcomes

Advanced digitalisation over the years at Sona Comstar has been pivotal in achieving improved operations efficiency; Improved competitiveness in global markets measured in terms of new customers, increasing the share of business with customers and improving the profitability of customer accounts, primarily driven by customer experience and responsiveness; High impacts on on-time delivery to commit, production cycle time and customer quality metrics. The company also strongly emphasises the role of Industry4.0 connectivity, from shop floor to boardroom and vice-versa, and establishing a common agenda for digitalisation in production, and in people engagement across regions. This includes impacting and improving leadership decision making, organizational learning and development, and acquiring skills and competencies.

Factor 2 – '**Policy Function'** which is a key foundation to an effective system of innovation (Reiljan and Paltser, 2015), accounts for 7.72% of the TVE with 'Lack of legal framework', 'Lack of clear national innovation strategy', 'Restrictive public/ govt regulations' and 'Lack of explicit policy support' loading on it. The internal consistency is considered 'Acceptable'.

It is generally recognised that the public sector has an important role in promoting innovation – its task is to support the development, diffusion and implementation of innovation (Edquist 2006, p.182) through the creation of effective incentives and disincentives. Public sector intervention in the economy is usually justified by the need to overcome market and system failures. With the support from national regulations (laws, standards and norms) and public sector institutions, the task of policy is to integrate both formal and informal institutions (social, political, economic, educational, scientific, etc.) of the society in order to create and develop a conducive environment which guides economic agents to innovate and increase their competitive performance. The government sector directly guides the innovation processes through various support activities such as public procurement, tax breaks, subsidies, and so on. The activities and effectiveness of economic units in their innovation processes is largely dependent on the smooth functioning of the innovation system, including the effectiveness and coordination of innovation policy measures (Reiljan and Paltser, 2015).

Factor 3- '**Market**' shows its importance in driving innovation through demanding customers and innovative customers[87], as well as distinct 'rules of the game' articulated through higher resolution regulations. The TVE, amounts to 6.33%, and the associated variables are 'Lack of innovative customers' and 'Lack of demanding customers' with a Cronbach's Alpha value categorised as 'Acceptable'. Market dynamism can be described by rapid changes in technologies, changes in market structure, the instability of market demand, intense fluctuations in supply of materials, and the probability of market shocks (Nguyen & Harrison 2019; Jansen, Van Den Bosch and Volberda 2006; Sirmon, Hitt and Ireland RD, 2007). For instance, the shift from internal combustion engines to electric vehicles is a market disruptor. Volatility and unpredictability characterises market dynamism (Miller and Friesen, 1983), therefore a high level of it restricts the ability to distinguish the market boundaries, develop clear successful business models, and identify market participants such as competitors, customers, and suppliers and their respective needs (Eisenhardt and Martin, 2000).

Consequently, this leads to external uncertainty thus making it more difficult to predict future market situations, plan and organise their resources, and respond with their own knowledge and related processes. Therefore, firms are required to continuously improve and modify their products and services with innovation to meet customers' needs. Less dynamic markets, in contrast to highly dynamic markets, present not so frequent changes that market players can usually anticipate or regular changes that occur periodically and are hence predictable. In less dynamic market environments, there is better clarity on market boundaries, the market participants (e.g., firms, customers and suppliers) know each other well and customer demand is relatively stable. Hence, firms do not feel the need to innovate or modify their products or business processes (Eisenhardt and Martin, 2000; Schilke, 2014).

In light of the above, in order to promote innovation, a dynamic market is required. "Regulations which encourage market dynamism, innovation and competitiveness improve economic performance. The aim of regulatory reform is to increase efficiency and effectiveness and to have a better balance in delivering social and economic policies over time" (OECD, 2011 p.4). Poorly designed or weakly applied regulations can hamper business responsiveness, divert resources away from productive investments, hinder entry into markets, reduce job creation and generally discourage entrepreneurship. Hence, there is the need for administrative simplification (OECD, 2009) with the provision of clear, consistent, and coherent rules for dynamic markets to function well and long-term planning is an important consideration in this process.

Factor 4- '**Human Capital**' underscores the question of how firms can effectively identify, mobilise and deploy human capital (Lippman and Rumelt, 2003; Sirmon et al., 2007; Wang et al., 2011). This is a crucial issue particularly with the paradigm shift caused by digital transformation and the 4IR.

The TVE of the factor amounts to 5.71%, and the variables loading on the factor are ´Lack of technically trained manpower´ and ´Quality of technically trained manpower´ with an internal consistency categorised as 'Good'. Innovation is the driving force of the global economy, especially in the manufacturing sector (Xin et al., 2010). To innovate, firms need to receive inputs and make effective use of many types of resources, among which human capital is critical (Barney, 1991).

Human capital is a collective resource that emerges from the knowledge, skills, and abilities of employees (Wang et al., 2011). For example, training helps employees maintain state-of-the-art skills and enables them to use the skills in innovation (Lau and Ngo, 2004). With the advent of the 4IR, it is evident that a number of changes in human skills and tasks are being observed with a shift in direction and the need for learning and reskilling (da Silva, 2018).

Digital transformation and the 4IR have led to a wave of change from the economy to society. In the Indian context the industry is predominantly dependent on legacy technology for example the internal combustion engine and transmission. In newer automotive models these are either diminished or absent. A shift is being seen in the direction of connected cars and electric vehicles (ASDC, 2022).

In general, exponential technologies impact every aspect of the automotive value chain, dramatically increasing productivity. In India, big data, AI, sensors, advanced robotics, and the Industrial IoT have had the strongest impact (FES, 2019). Consequently, there is a consensus that human labour requirements will change at two levels. Firstly, within manufacturing 4IR will lead to a significant decrease in low-skill activities and an increase in activities requiring specialised knowledge for the management of exponential technologies including planning, control and information technology (IT) tasks (Bonekamp and Sure, 2015). This will lead to a rise in the complexity of many professional profiles and will necessitate a more intensive and time-consuming process of learning, training and continuous self-improvement. (Ligarski et al., 2021).

[87] The concept of innovative customers challenges traditional thinking about usability of products and services and signals the need to go deeper when evaluating the needs, desires and realities of their customers and looking at innovative demand requirments. Business owners should learn how customers use a product or service in their day to day lives. Listening to the customer is key to driving innovations in the existing product or bringing out new innovative products.

Secondly, at the service level (dealership) there will also be a shift in skills requirements, particularly with the workforce needing to be aware of the nuances of emerging technologies such as connected cars and the IoT, as well as how to personalise the customers purchasing journey. This is becoming ever more important with the change in consumer demographics (ASDC, 2022).

The automotive sector will continue to hire at a rate of 2–2.5% YOY against the historical growth rate of 3–3.5% to reach 14.3 million in FY 2022. Around 60–65% of the jobs in the sector will require new skill sets by FY 2022 (EY, 2017).

The current workforce in the automotive sector in India lacks the necessary skills to absorb these technological shifts. With the public sector in the background and private sector as the key player who has just started taking initiatives, there is still a lack of the desire to invest in skilling and human resource training (FES, 2019). Dependency on the government is huge for training and skilling, while many companies outsource it. Some OEMs have in-built learning factories with their Tier-1 suppliers, (in some cases, known as "Dojo centres") which facilitate the development of abilities to learn and experiment. However, such facilities are absent in many firms.

Factors 2, 3 and 4 are significant but collectively only account for 19.77% of the TVE. Factor 1 ranks as the most important factor as it contributes close to 22.98% of the TVE and should be the main focus of system-oriented policies. Once again this expounds the importance of I4.0 technologies, particularly as a driver for innovation for the automotive sector. However, it is crucial to note that since the data collection period of FY 2017-18 to FY 2019-20, the impact of COVID-19 has had a profound impact on the automotive sector, particularly with respect to the adoption of I4.0 technologies. It has been the mainstay of large firms in the areas of automation and robotics and in the case of MSMEs for predictive maintenance like the use of sensors for monitoring equipment. However, there is still room for improvement as there is a level of hesitation amongst two thirds of manufacturing firms. The reason being challenges in the field of technical standards, regulatory framework, high investment costs and the lack of skilled personnel (Holtkamp (and Anandi Iyer, 2017).

The overall implications for policy emerging from the analysis of barriers to innovation is that resources should be used on two levels. Firstly, at the level of the system through more overarching interventions, and secondly at the individual actor level in order to address their specific needs. Each of these will be articulated in the "Recommendations" chapter. A structured dialogue between stakeholders is required to orient which policies can be most effectively used to address these barriers and challenges. Policies and their targets should not be unattainable or out of reach but issues need to be addressed from a realistic perspective.

TABLE 8: System-wide barriers to innovation

Barriers to innovation faced by all actors in the Food sector (N = 553)									
Factor Number	Name of Factor	Variables	Factor loading	Cronbach's Alpha	Total Variance Explained (TVE)	KMO	Bartlett's Test of Sphericity		
							Chi squared	Df	Sig.
1	Industry 4.0	Lack of access to I4.0 technologies	0.836	0.857	22.98%	0.831	4463.117	351	0
		Lack of understanding of I4.0 technologies	0.831						
		Cost of I4.0 Technologies	0.79						
		Lack of infrastructure for I4.0	0.755						
2	Policy Function	Lack of legal framework	0.748	0.701	7.72%				
		Lack of clear national innovation strategy	0.678						
		Restrictive public / governmental regulations	0.677						
		Lack of explicit policy support (government)	0.587						
3	Market	Lack of Innovative customers	0.808	0.7	6.33%				
		Lack of demanding customers	0.764						
4	Human Capital	Lack of technically trained manpower	0.866	0.792	5.71%				
		Quality of technically trained manpower	0.844						
Cumulative Total Variance Explained						**42.75%**			

The determinant of the R matrix should be greater than 0.00001; if it is less than this value, look through the correlation matrix for variables that correlate very highly (R>.8) and consider eliminating one of the variables (or more depending on the extent of the problem) before proceeding[88].

6.4 Success of Policy Instruments

Having understood barriers to innovation, both at the actor and system level, it is important to ascertain how actors perceive various policies, and consequently, an understanding of whether or not they are effectively calibrated and configured to reach their intended target's needs. To begin with, it is important to understand what public policy instruments are. They can be defined as "a set of techniques by which governmental authorities wield their power in attempting to ensure, support and effect (or prevent) social change" (Borras and Edquist, 2013., pg.1515). Unsurprisingly, the objectives of innovation policy have to do with the different national traditions and forms of state-market-society relations, not to mention the orientation of governmental ideology.

Generally speaking, there are three main categories of policy instruments: i) Regulatory frameworks [89]; ii) Economic and financial instruments[90]; and iii) Soft instruments.[91] Phrased differently, these can be considered as "sticks", "carrots" and "sermons". In this vein, the respective perceived success or failure of national policies is reviewed grouping them as per the aforementioned classifications.

An alternative way to classify innovation policy is in terms of supply-side measures and demand-side measures (see Figure 29). Supply-side policies are seen to create a supply push to innovate (Voß and Simons, 2014); whereas "demand-side innovation policies are defined as all public measures to induce innovations and/or speed up diffusion of innovations through increasing the demand for innovations, defining new functional requirement for products and services or better articulating demand" (Edler and Georghiou, 2007., pg. 953). Supply-side measures can be further split into the grouping of finance (equity support, fiscal measures, support for public research, support for training and mobility, and grants for industrial R&D) and services (information and brokerage support and networking measures).

Demand-side policies can be presented in four main groupings: systemic policies, regulation, public procurement, and stimulation of private demand (Edler and Georghiou, 2007).

Using this classification to order policy instruments of the Indian manufacturing sector, the following groupings emerge: i) Supply-side finance policies include – research grants, subsidised loans, government-backed venture capital, and donor funds; ii) Supply-side services include – ICT access and focused skills development initiatives; iii) Demand-side measures include – tax breaks, spatial policies, government procurement, standards setting, regulation and labour mobility (laws and incentives). The system as a whole, as well as the views of each of the individual actors will be reviewed to understand how successful policy is through the aforementioned lens.

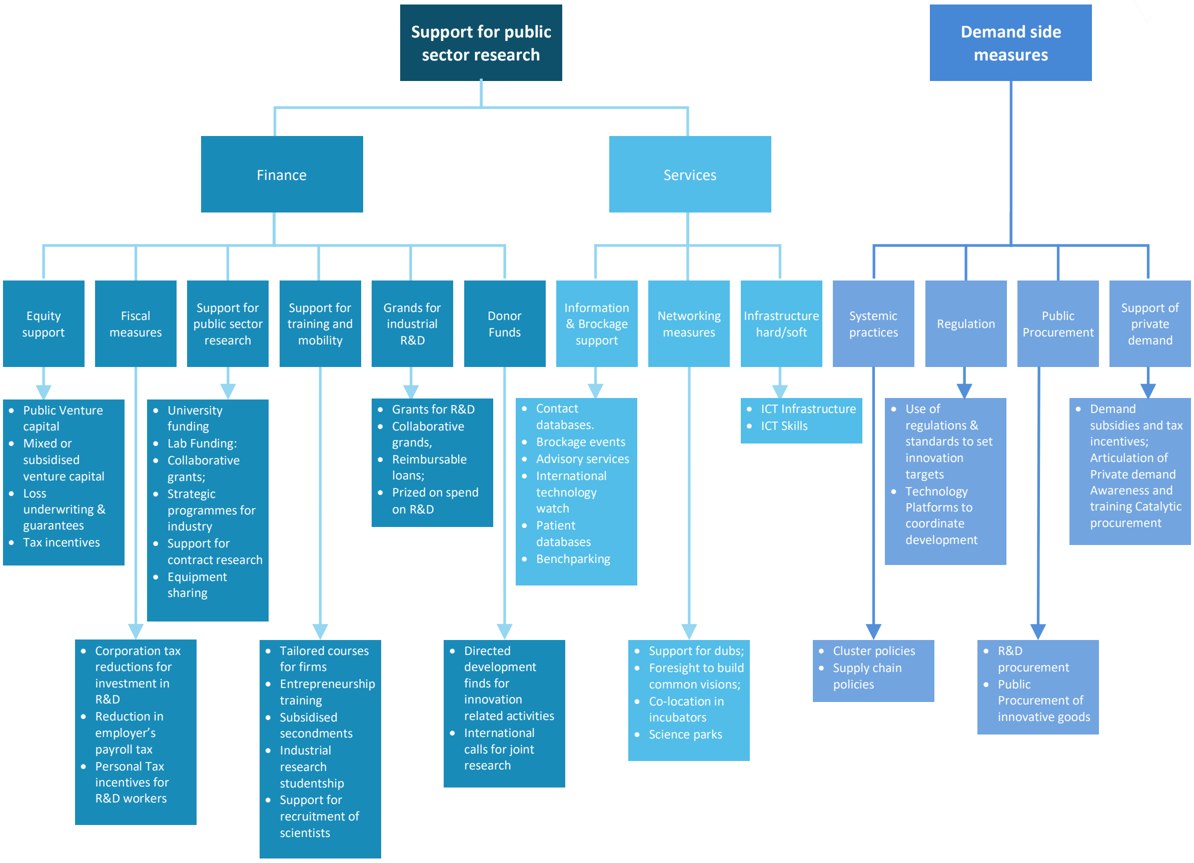
[88] Sourced from: http://users.sussex.ac.uk/~andyf/factor.pdf

[89] "The first type, regulatory instruments, use legal tools for the regulation of social and market interactions. The logic behind this type of instrument is the willingness from the government to define the frameworks of the interactions taking place in society and in the economy. Naturally there are many different types, but common for them all is that these regulatory instruments (laws, rules, directives, etc.) are obligatory in nature, meaning that actors are obliged to act within some clearly defined boundaries of what is allowed and what is not allowed. Obligatory measures are typically backed by threats of sanctions in cases of non-compliance. These sanctions can be very different in nature (fines and other economic sanctions, or temporary withdrawal of rights), depending on the content of the regulation and the definition of legal responsibility. Some authors believe that sanctioning is the most crucial property of regulatory instruments (focusing on the imposition and hierarchical side of regulation). Others see the normative authority of governments as the most important feature of these instruments (hence focusing on the normative-positive side of obligatory regulation). From the point of view of innovation policy, regulatory instruments are often used for the definition of market conditions for innovative products and processes" Borras and Edquist, 2013., pg.1516

[90] "Economic and financial instruments provide specific pecuniary incentives (or disincentives) and support specific social and economic activities. Generally speaking, they can involve economic means in cash or kind, and they can be based on positive incentives (encouraging, promoting, certain activities) or on disincentives (discouraging, restraining, certain activities)" Borras and Edquist, 2013., pg.1516.

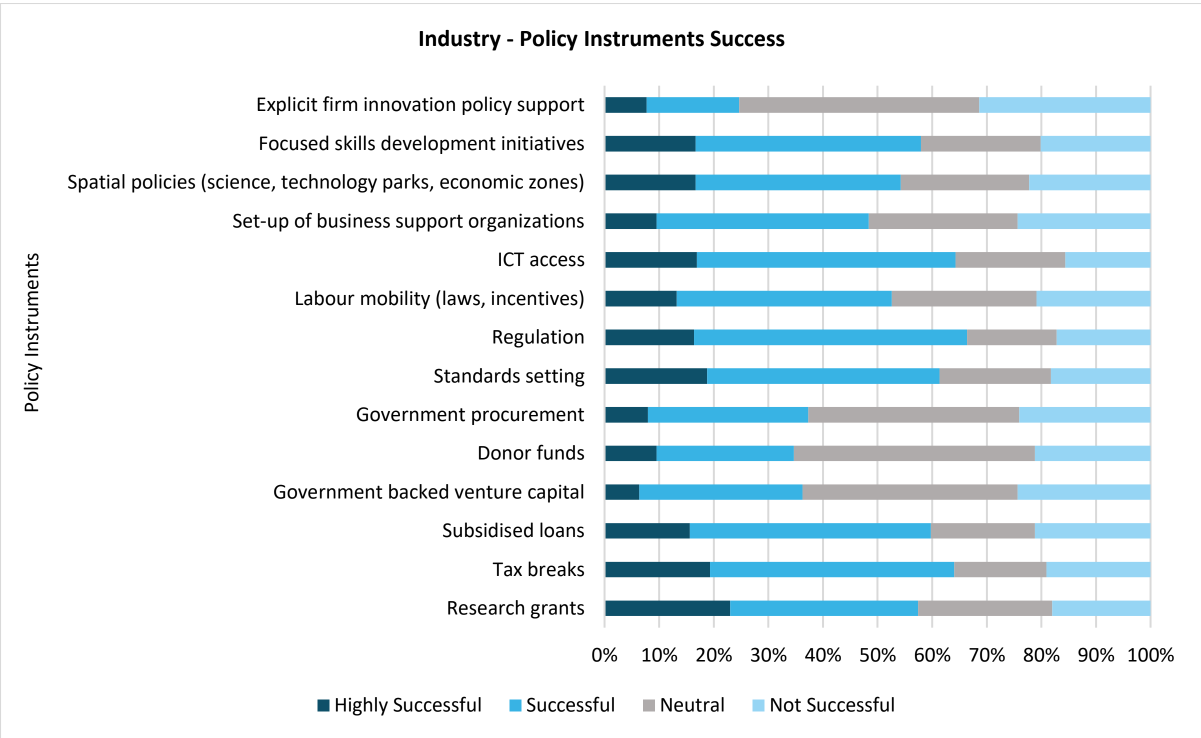
[91] "Soft instruments are characterised by being voluntary and non-coercive. With soft instruments, those who are 'governed' are not subjected to obligatory measures, sanctions or direct incentives or disincentives by the government or its public agencies. Instead, the soft instruments provide recommendations, make normative appeals or offer voluntary or contractual agreements. Examples of these instruments are campaigns, codes of conduct, recommendations, voluntary agreements and contractual relations, and public and private partnerships.

FIGURE 29: Policy taxonomy



6.4.1 Industry

FIGURE 30: Success of policy instruments – Industry



From the perspective of industry respondents (see Figure 30 above), in general, all policy instruments are deemed to be successful and highly successful, except for the 'Explicit firm innovation policy support' instrument, which has been reported as 'Not successful' by 31% of industry respondents. 'Set-up of business support organizations', 'Government-backed venture capital' and 'Government. procurement' have also been reported as 'Not successful' by 24% of respondents. In contrast, the most successful policy instruments (reported by more than 60% of respondents) are demand-side policies, namely, 'Regulation' (66%) and 'Tax breaks' (64%) as well as the supply-side services, 'ICT access' (64%). They are followed by a demand-side measure of 'Standards setting' (61%) and the supply-side financial measure, namely, 'Subsidised loans' (60%).

Regulations can both enhance and constrain business activity. Improvements in firm entry regulation are associated with higher productivity (GII 2020). Amirapu and Gechter (2019) find that restrictive labour regulation in India is associated with a 35% increase in firms' unit labour costs. The NITI Aayog Innovation Index 2021 underscores this by articulating that "governments that enact and enforce open and fair procedures, regulate markets efficiently, protect property rights, and lower the burden of regulations are more likely to see higher levels of innovative entrepreneurial activity". In real terms, the Doing Business Index of the World Bank highlights that India is among the 10 economies improving the most after implementing regulatory reforms focused on the areas of starting a business, dealing with construction permits, trading across borders and resolving insolvency (World Bank, 2020).

Industry respondents also report 'Tax breaks' as successful. The importance of tax breaks is recognised by NITI Aayog as a means to promote business sector R&D. Furthermore, the government could focus on specific areas under which top R&D-intensive domestic firms are eligible for tax incentives (NITI Aayog 2021). This is echoed in the draft "STIP 2020" which stipulates that in order to incentivise investments in STI, there is a need to boost "fiscal incentives for industries investing in STI through incremental R&D-based tax incentives, tax credit for investing in facilities for commercialisation, tax holidays, tax waivers, target-based tax incentive for specific domains, tax deduction, expatriate tax regimes, remodeling of patent box regime, etc" (DST, 2020: p.21). Similarly, the draft "National Automotive Policy 2018" articulates that weighted tax deduction on R&D expenditure needs to be retained by defining "applicable R&D expenditure heads and mandate audits by statutory auditors to verify R&D expenditure for companies to qualify for exemption". From the above, it is clear that the overall orientation of policy with respect to 'Tax breaks' are markers of success in meeting their targets.

The success of 'Subsidised loans' for the automotive sector is exemplified at the national level by schemes and policies of different ministries and further supported at the state level by specific initiatives which include a concessional rate of interest on loans and investment subsidies/tax incentives. The draft NAP 2018 highlights the need to offer fiscal incentives for green mobility by facilitating changes in the banking norms to ease loans and financing for green vehicles[92]. However, the OECD reports that India is one of the countries which provides the least subsidies for the automotive sector in comparison to other major markets. Hence, it could be a challenge for India to achieve its goal of manufacturing nearly 7 million electric vehicles by 2030 (ILO Consulting, 2020).

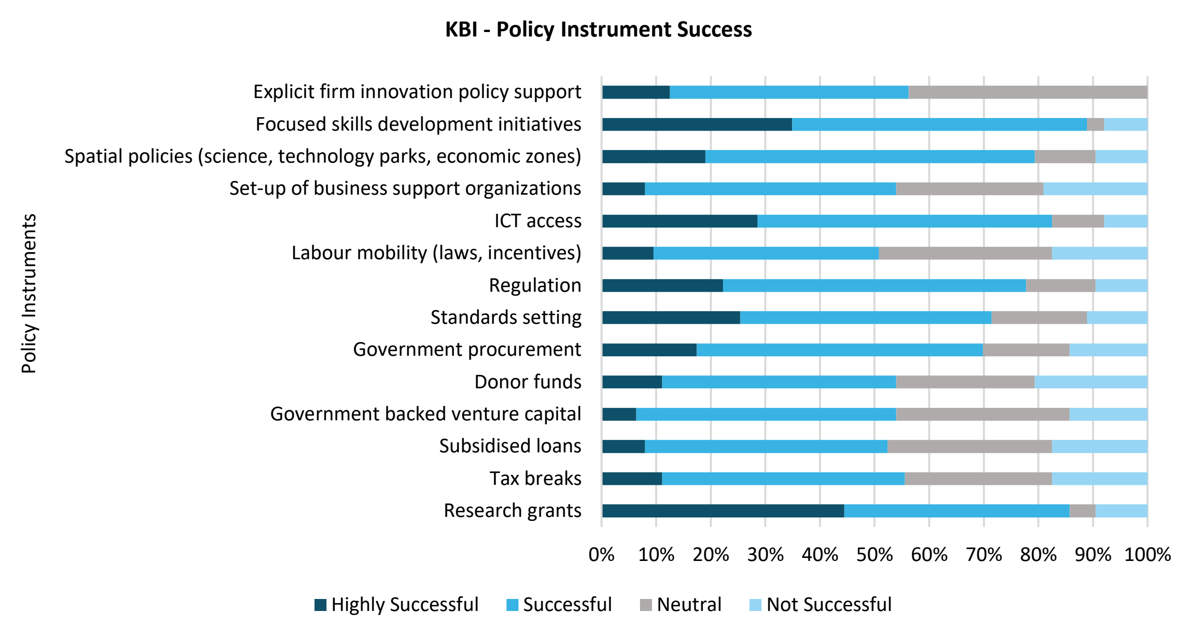
With regards to 'ICT access', the strategies of the "National Policy on Information Technology 2012" highlight the need "to enable long-term partnership with industry for: i. use of ICT in cutting-edge technology; ii. driving development of new ICT technologies through strategic sectors; iii. facilitate growth of IT SMEs and use of IT across all SMEs" (MEITY, 2012:7). The policy outlines the need to intervene and "promote use of IT in key economic sectors such as Construction, Textiles, Pharmaceuticals, Banking, Finance, Retail, Energy, Automobiles, Healthcare, Education, Agriculture, Engineering Services, Transport and Logistics for improved efficiency and productivity" (MEITY, 2012: 7). Contrary to this, it is important to highlight that in accordance with the Global Innovation Index (GII), while India has been ranked 46th out of 132 economies, the country's ICT access ranking declined from 108 in 2012 to 111 in 2021. More specifically, with respect to the automotive sector, the draft NAP 2018 makes no reference to ICT or 4IR.

It is important to note that the first key area of intervention within the government's draft "National Automotive Policy 2018" is oriented towards innovation and R&D. However, during the dissemination process, the policy and its implications need to be clearly transmitted to industry and other system stakeholders. A means to achieve this would be through the government working closely with industry associations in terms of outreach.

[92] STIP 2020 indicates the need to enhance financial support to industry, especially for MSMEs, for pursuing research through innovation support schemes such as matching grants, small business innovation grants (under fast-track mode), innovation vouchers (SMEs), direct innovation grants, risk guarantees, with special focus on high-risk projects, revenue-based financing, seed grants, loans, research subsidies, equity, research and IPR credits, open innovation scheme, etc.

6.4.2 Knowledge-based institutions

FIGURE 31: Success of policy instruments - Knowledge-based Institutions



From the view of knowledge-based institution respondents (see Figure 31 above), it is evident that in general, the majority of respondents view all policy instruments as 'Highly Successful' and 'Successful', except for 'Donor funds' with 21% of respondents reporting it as unsuccessful.

In terms of policy success, supply-side service measures such as 'Focused skills development initiatives' (89%) and 'ICT access' (83%) are deemed to be the most successful, along with the supply-side financial policy measure 'Research grants' (86%).

This is convergent with the draft National Automotive Policy 2018 which indicates "the rolling out of a comprehensive long-term (10 year) roadmap which will enable the industry and support agencies to define skill development, improve the skill development and training ecosystem, increase the accountability of the Automotive Skills Development Council (ASDC) through performance-based funding linked to metrics such as incremental employment generated, level of employment, curriculum coverage, industry feedback, etc." (DST, 2018). The NAP 2018 also outlines the importance of establishing shared training and testing facilities in these clusters for technology improvement and skill development as part of the "Skill India" programme.

Furthermore, the "National Education Policy 2020" indicates the need for a flexible and multidisciplinary approach for education with stronger linkages to industry in order to allow graduates access to industry. As part of holistic education, internships with local industry, businesses, etc., have been encouraged so that students may actively engage with the practical side of their learning and, as a by-product, further improve their employability.

The success of 'Research grants' as a policy instrument can be attributed to the funds received from the government.

Finally, KBI respondents view the demand-side measures: 'Regulation', 'Standards setting' and 'Spatial policies' as 'Successful', although not as much as supply-side financial and supply-side service measures. In terms of 'Regulation', the response of KBIs is convergent with that of industry and has been explained in the previous section.

'Standards setting' has been reported by KBIs as a 'Successful 'policy instrument. It is a driver for innovation and stimulates firms to change their behavioural patterns and enables them to be more technologically adaptive, leading to overall increased productivity and competitiveness. Standards in the automotive sector in India range from India 2000, which was based on Euro I standards, to the currently ongoing Bharat Stage-VI (BS-VI) norms. The "Auto Fuel Policy 2025" has laid down the emission and fuel roadmap up to 2025 which envisaged the implementation of BS-IV emission norms in India by 2017, BS-V norms in 2020/2021 and BS-VI from 2024. However, due to increased pollution levels in the NCR, the government leapfrogged to BS-VI emission norms in 2020. The government has also set the requirement of corporate average fuel consumption standards for passenger vehicles. Moreover, the draft NAP 2018 outlines the rollout of a comprehensive long-term (10 year) roadmap that will define the emission standards applicable after BS-VI with a target of harmonising with the most stringent global standards by 2028, across all vehicle segments.[93]

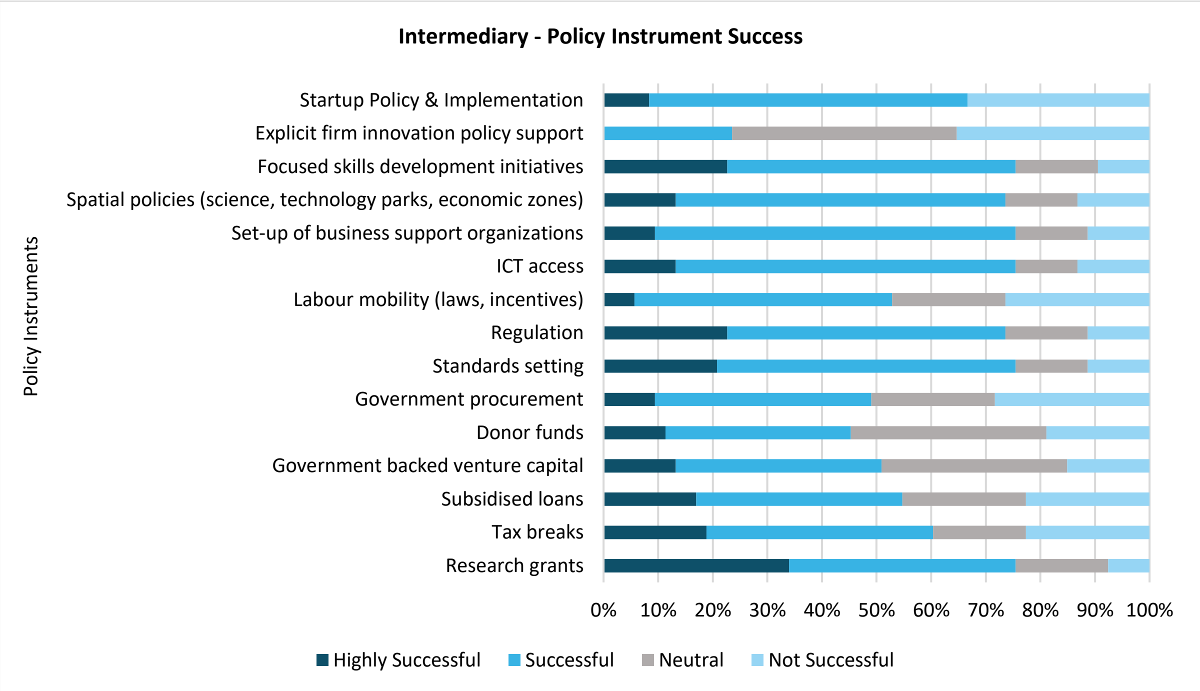
In India, vehicle technology has evolved to meet the safety regulations notified as per the Safety Roadmap adopted by the Central Motor Vehicle Rules - Technical Standing Committee (CMVR-TSC). Today the vehicle technology in India is at par with the international benchmarks as Indian safety standards are being aligned with Global Technical Regulations (GTR) and UN Regulations. The government is currently working towards the implementation of the “Bharat New Vehicle Safety Assessment Program” (BNVSAP).

Several ministries such as the Ministry of New and Renewable Energy (MNRE) and the Ministry of Heavy Industries (MHI) have championed response to these standards. This has led to increased collaborations and focused R&D programmes within the knowledgebase in areas such as new and renewable energy technologies including hydrogen and fuel cells. For instance, the ARAI is working on the development of Hydrogen PEM Fuel Cell with the industry. There is also the emergence of new technological solutions such as the Digital Twin Spark ignition (DTSi) and the increased use of electronic control units to monitor and manage the increasing complexity in the engine and the rest of the vehicle (Krishnan, 2016).

Proximity is an important dimension of the effectiveness and efficiency of a system of innovation in terms of connectedness and linkages which facilitate the flow of knowledge and resources between the actors. This can be achieved through spatial policy instruments such as special economic zones (SEZs), cluster development and aggregation, as well as industrial and technology parks. For example, a cluster approach to manufacturing can assist firms in achieving competitive advantage by promoting their common interests, identifying the most promising opportunities to encourage further innovation, developing worker skills, and addressing issues that affect productivity. Firms will have improved access to suppliers of raw materials, parts and components, machinery, skills and technology as well as other supporting services that can enable them to enhance competitiveness.

6.4.3 Intermediary

FIGURE 32: Success of policy instruments – Intermediary



[93] Define a roadmap for harmonising key standards and testing methods with global benchmarks. Agencies like the ARAI and NATRiP should be upgraded in line with the harmonisation plan, to develop capabilities which are at par with global testing and certification agencies. Also evaluate accession to the UNECE WP.29 1958 Agreement within the next 5 years, which will eliminate a major technical barrier to trade. Harmonise AIS and BIS standards on safety critical parts over next 3 years, with the eventual target of single standards.

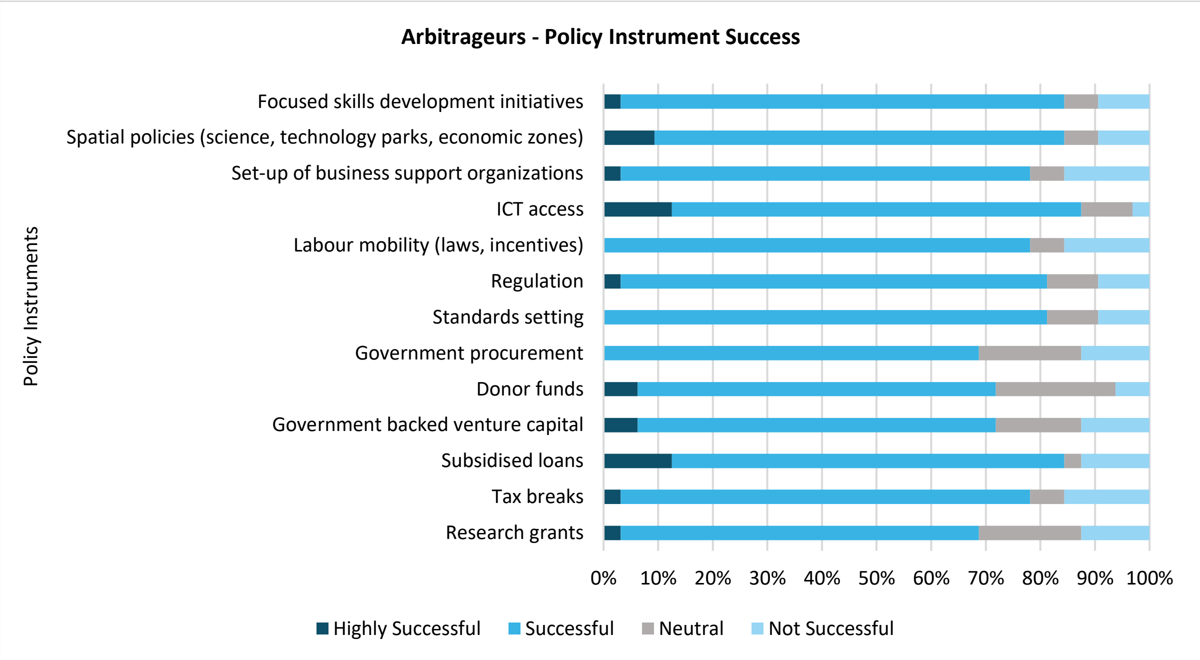
Intermediaries report all policy instruments as 'Highly Successful' and 'Successful' (see Figure 32 above), except for 'Explicit firm innovation policy support'. The most successful demand-side measures reported are 'Standards setting', 'Regulation' and 'Spatial policies'. This mirrors the view of KBIs and that of industry in the case of 'Regulation'. Supply-side service measures such as 'ICT access' and 'Focused skills development initiatives' are also deemed to be 'Successful'. The supply-side financial measure 'Research grants' is also considered a 'Successful' instrument by intermediaries. Explanations have been covered in the previous sections.

One of the roles of industry associations is to liaise with the government in advocating solutions for the challenges faced by industry. They work closely with the government on policy issues, interfacing with thought leaders, and enhancing efficiency, competitiveness and business opportunities for industry through a range of specialised services and strategic global linkages. It also provides a platform for consensus-building and networking on key issues (CII, 2022).

Similarly, institutions supporting technical change (ISTCs) collaborate with the government for setting standards and designing policies and regulations. In the automotive sector in India, the Automotive Research Association of India (ARAI) is a leading institution supporting technical change and is an autonomous body affiliated to the Ministry of Heavy Industries (MHI). The ISTC has been assisting the government in formulating automotive standards and regulations (ARAI, 2022). The ARAI undertakes research and development programmes for developing indigenous technologies and solutions for the mobility sector. These are in addition to the various assignments executed by the ARAI for the industry with regards to certification, testing, validation, optimisation and developmental work.

6.4.4 Arbitrageurs

FIGURE 33: Success of policy instruments – Arbitrageurs



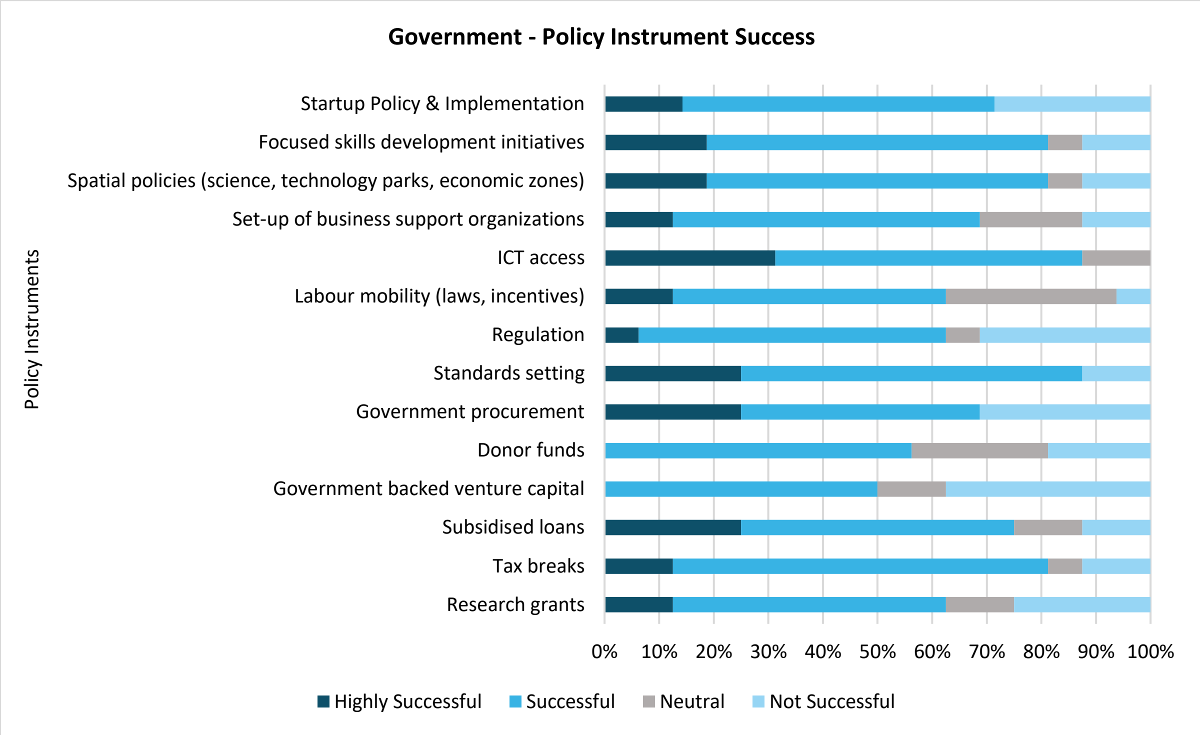
The next actor perspective on the relative success of policy instruments is that of arbitrageurs (Figure 33 above). Again, most of the policy instruments are reported as 'Highly Successful' and 'Successful', except for 'Labour mobility laws and incentives' and 'Set-up of business support organizations. These observations converge with that of industry and KBIs in terms of 'Labour mobility laws and incentives' and with KBIs, with regards to 'Set-up of business support organizations and the explanations for the same have been provided in previous sections.

It is clear that the majority of the respondents (88%) report the supply-side services 'ICT accesses and the demand-side measure 'Standards setting' as most successful, closely followed by 'Focused skill development initiatives', 'Spatial policies' and 'Tax breaks' at 81% each ('Highly Successful' and 'Successful' combined). The success of 'ICT access', 'Standards setting' and 'Focused skill development initiatives' with respect to the automotive sector has been explained above. In the case of 'Spatial policies', it is clear that the high concentration of arbitrageurs can be seen within the financial hub of Maharashtra. The role of proximity is crucial within the venture capital industry (Zook, 2004).

Venture capital plays a huge role in the commercialisation of scientific findings and facilitation of the emergence of high-growth businesses. They add value to the innovation ecosystem by fostering the generation, diffusion and absorption of new knowledge (Pierrakis & Saridakis, 2017). However, the presence of finance-related barriers signals room for improvement

6.4.5 Government

FIGURE 34: Success of policy instruments – Government



The last actor's perspective on the relative success of policy instruments is that of the government (Figure 34 above). Again, most of the policy instruments are reported as 'Highly Successful' and 'Successful', except for 'Government-backed venture capital', for which their response is divided with 50% respondents reporting it 'Successful', 38% reporting it 'Not Successful' and 12% staying 'Neutral'. Government policies understand that there is a need for "avenues for entrepreneurship development through incubators and accelerators to support the scaling-up and commercialisation of grassroots innovations" (STIP 2020, p.32). This process requires a vibrant venture capital landscape that not only provides access to funding in the process of ideation to market but also business support services. Within the Indian context, the majority of venture capital funds are private sector owned[94]

According to Venture Intelligence data, in the first six months of 2021, private equity-venture capital investments in India grew by 33% (Shaik, 2021). As per ETAuto's research, automotive startups attracted a whopping US$ 354 billion in investments globally in 2019. Automotive startup investments in India stood at US$ 1.7 billion. According to KPMG's Venture Pulse study, VC investment in India fell sharply in the first quarter of 2020, due to the economic and political uncertainties generated by the COVID-19 pandemic (Priya, 2020). Though there are government-driven funding mechanisms such as the National Research Foundation (NEP 2020) and the Technology Acquisition Fund (NAP 2018) that focus on indigenous R&D and technology acquisition through public private partnerships and the Hybrid Annuity Model, it is still recognised that the absence of venture capital investment thwarts innovation in India (NITI Aayog 2021).

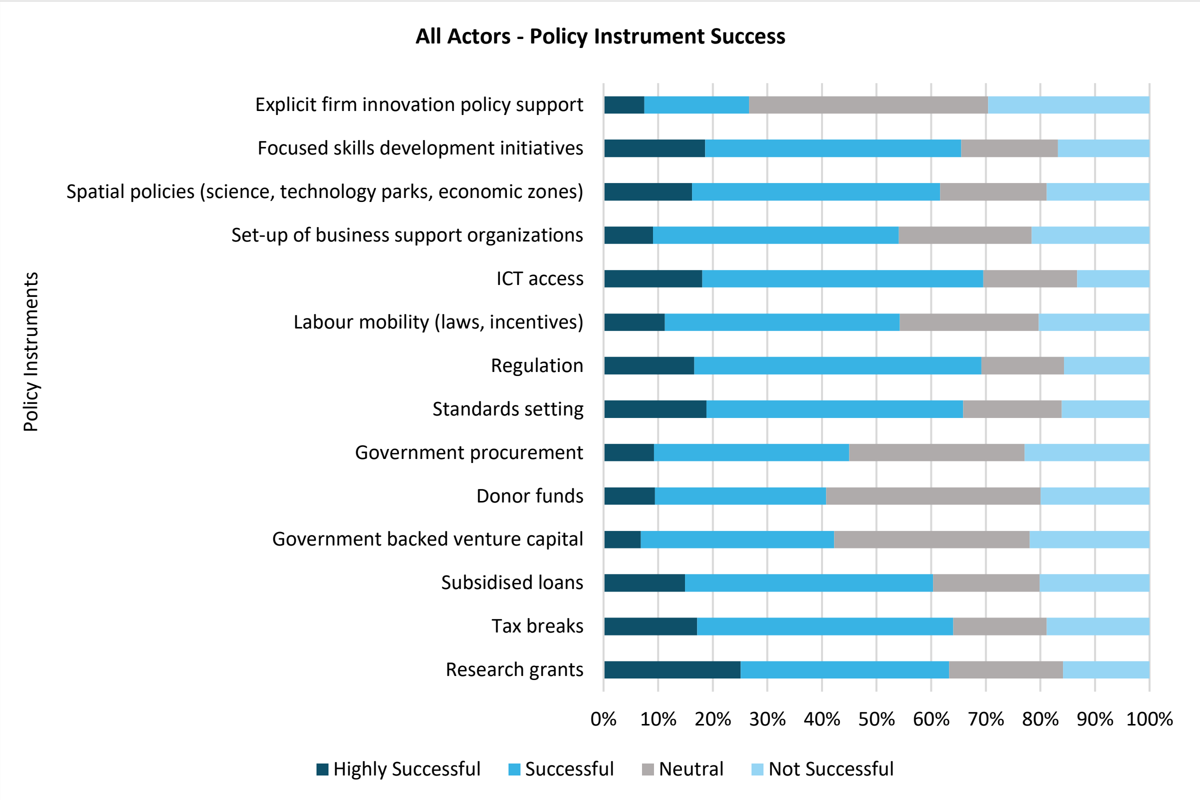
[94] Government-backed venture capital funds include: SBI Capital Markets Ltd. (SBICAP), Canbank Venture Capital Fund Ltd. (CVCFL), IFCI Venture Capital Funds Ltd. (IFCI Venture), and SIDBI Venture Capital Limited (SVCL): https://www.indianweb2.com/2015/01/13-govt-venture-capital-firms-for_14.html

Government procurement is the second most unsuccessful policy instrument reported by 31% of government respondents. In the case of the Indian automotive sector, in line with the "Make in India" initiative, the government has mandated preference to be given to domestically manufactured vehicles with minimum 65% local content in the public procurement of automobiles (PTI, 2018). However, India is lagging in several indicators related to the assessment of the state of procurement practices (OECD, 2019) namely: "strategic leadership, efficiency, the procurement process's openness, and the legislative framework in place, including subordinate legislation, model documents, and general contract conditions" (Nair, 2021: p.1). There is a lack of a comprehensive central legislation solely governing public procurement in India. Rather, the current public procurement regime comprises a framework of overlapping administrative rules and regulations, sector-specific guidelines and state-specific legislation (BTG Legal, 2021). The Government of India (GoI) implemented the General Financial Rules (GFR) as its core procurement framework in 1947 which was only updated in 2017. The absence of a central procurement regulation enabling procuring authorities with scope to tweak guidelines and contract formats, leads to confusion on the one hand and rigidity on the other. Consequently, different agencies may even prescribe varying qualification criteria, financial terms, selection procedures, etc., for similar public sector work. Furthermore, the government has been making efforts to ensure transparency and fairness in the public procurement system. In 2012, the GoI introduced the Public Procurement Bill. Introduction of a new legislation to govern how the government buys goods and services from the private sector is one of the proposed solutions to public procurement problems (Roy and Uday, 2020). Minister of Finance, Mr Arun Jaitley, in his 2015-16 budget speech advocated the same and stated, "Malfeasance in public procurement can perhaps be contained by having a procurement law and an institutional structure consistent with the UNCITRAL model. I believe Parliament needs to take a view soon on whether we need a procurement law, and if so, what shape it should take." (Paragraph 72). The present government is yet to introduce the bill.

Regulation is the third most unsuccessful policy instrument according to 31% of government respondents and the explanation for the same has been provided in previous sections.

6.4.6 All Actors

FIGURE 35: Success of policy instruments - All actors



Summarising the above results, the most successful policy instruments reported by all actors in the automotive sector are 'ICT accesses at 70% including 52% 'Successful' and 18% 'Highly Successful', followed by 'Regulation' at 69% including 52% 'Successful' and 17% 'Highly Successful' and 'Standards setting' at 66% including 47% 'Successful' and 19% 'Highly Successful'. The most unsuccessful policy instrument reported by all actors is 'Explicit firm innovation policy support' at 30%. This is reflective of the barriers reported by all actors under the policy function (see Table 7: System-wide barriers to innovation). However, it is interesting to note that regulation is deemed successful by respondents from all actor groups, while the presence of 'restrictive public/ governmental regulations' has been reported as a prominent barrier to innovation by the same set of actors in the automotive sector (see Table 8: System-wide barriers to innovation). This can be explained by the fact that regulations which encourage innovation and competitiveness are deemed successful whereas those that are poorly designed or weakly applied hamper economic performance and pose a significant barrier to innovation (OECD, 2011 p.4).

7.

Recommendations

Recommendations

Literature on innovation policy draws attention to the complex and heterogeneous nature of the policy instruments at hand. It captures the growing interest in understanding the effects that different policy instruments have on innovation performance, how (combinations of) individual instruments interact with market mechanisms and the overlapping or complementary effects that can be associated with different policy instruments within systems of innovation (Borrás and Edquist 2013; Izsák, Markianidou, and Radošević 2013; Mohnen and Röller 2001). This diversity reflects the complexity of innovation systems which entail a series of elements or subsystems that can reinforce, but also block each other (Hekkert et al. 2007; Kuhlmann and Arnold 2001). The underlying innovation-related policy objectives or policy domains subject to specific policy interventions can be grouped around one or more of the following objectives (Borrás and Edquist 2015):

- Support investment in research and innovation
- Enhance innovation competences of firms.
- Increase adoption of Industry 4.0 through digital transformation in the automotive sector
- Support services for innovating firms
- Competence building through individual/ organizational learning, involving formal/informal education and training.
- Demand-side activities involving the creation of new markets.
- Provision of constituents or supporting the development of agents within the system
- Enable integration of automotive into GVCs
- Strengthen linkages within innovation systems.

This list is not exhaustive but helps to illustrate the ramifications of the policy decision tree around innovation and industrialisation. Addressing these policy problems calls for a portfolio approach in which a combination of instruments simultaneously targets several objectives and groups of policy problems (Izsák, Markianidou, and Radošević 2013; Nauwelaers 2009).

Policy instruments result from policies aimed at facilitating different forms of innovation, including products or services, which denote the acquisition/ development of new proprietary technologies protected by patents or other forms of intellectual property rights (IPRs); yet some others are closer to business process innovations in the form of changes in operations (manufacturing techniques, optimisation of workflows and process re-engineering), product development, business process development, marketing and sales, procurement, logistics and distribution, as well as organizational innovation through changes in administration and management. Whereas some policies aim to support forms of innovation with clear and rapid market potential, some others aim at addressing more upstream issues with no immediate commercial value.

The possibility of combining policy instruments is what makes innovation policy systemic (Borrás and Edquist 2013). However, finding 'optimal models' for the combination of instruments, otherwise interpreted as one-size-fits-all solutions, is problematic; significant differences result from framework conditions but also from the 'quality' of implementation (Flanagan, Uyarra, and Laranja 2011), the degree of maturity reached by certain agents or the innovation system (Izsák, Markianidou, and Radošević 2013), and even the particular governance structures around innovation (Dutrénit et al., 2010). Moreover, identifying the impacts of individual innovation policy interventions on social and economic outcomes is extremely difficult. There is a complex chain of direct and indirect, vertical and horizontal effects, and the ultimate results may only be perceptible many years after implementation (Padilla-Pérez and Gaudin, 2014; Santiago and Natera, 2014).

Finding an optimal innovation policy mix is not a one-off exercise, but a continuous process that adjusts to the dynamics of an innovation system. The formulation of effective policy is therefore a highly complex affair. Table 9 highlights short-, medium- and long-term recommendations based on the analysis conducted.

TABLE 9: Policy recommendations

Observation	Implication	Recommendations
Fragmented system-wide actor information	Better access to public goods in order to have an up-to-date understanding of who's who and who's where in the IASSI. Robustness and credibility of data shared at the system level.	Need to integrate and standardise national actor databases with respect to the IASSI. • Review and consolidation of existing data. • Regularly update centralised sectorial database. • Purpose driven Platform to be developed in PPP approach (beyond search engine, for example Start-up India, IRCTC - Indigo). • To be owned by government and managed by institutions with access by all major institutions (market driven). • Integrated feedback mechanism for improvement (stakeholders at all levels).
Need to improve target response rate, especially in the case of Government actor group	Better clarity in systems analysis for evidence-based policy craft incorporating longitudinal benefits of data collection	• Institutionalise the IASSI Survey within a national institution with top-down mandate. • Make the IASSI Survey a mandatory census (4 years) and linked to the national database. • Targeted promotion strategy (including use of multimedia and social media, dissemination of value information, creation of ownership, multiple level campaign). • Actor or entity (state level, district level etc.) level competition for response rate. • Incentivization through a sense of belongingness, continuity and follow-up. • Acknowledging and lauding of contributions by leading institutions - creation of champions. • Data collection driven regional outreach initiatives. • National level agencies to be coordinated and partnered with - ISIs, • Planning and onboarding to make utility of champions. • Upstream driven sensitization approach.
Need for better institutional coordination between regions / clusters.	Ease of skills and knowledge flow between and sharing of best practises between actors.	• Commonly agreed structured framework for joint activities • Creation and transmission of information using contemporary multimedia resources. • Sharing of failures and lesson learning. • Regular meetings in person; quarterly webinars. • Virtual dissemination of Data Information Statistics and Knowledge (DISK). • Creating champions for systematic coaching of the sectors taking into account equally successes and failures. • Make use of middle-level executives. For example, LinkedIn creator accelerator programme (CAP).
Better awareness of policy terminology (SSI) across system actors	Across the board understanding	Have a standard definition in all documentation. • Present definition in national government bulletin. • Standardization of terminology used in policy/national documentation. • Outreach to industry via industry associations. • Development of impact driven byte size content dealing with core terminology and widely disseminated using multimedia in multi languages (30 sec short).
Lack of understanding by actors of each other's role within the IASSI	On clear understanding of actor roles and responsibilities within a system there is the increased ability for them to reach out to each other. With the focus being impact on the directionality of actor relationships to become more bi-directional.	• SSI should be an integrated component of national events, i.e., ACMA Southern Regional Events. • National innovation event (every 2 years bringing together users, producers, and service providers for innovation). It can be linked to National Science Week (10 best projects). • An integrated platform linking institutions and their services. • Developing actor level content using multimedia - easily accessible and easily digestible. For example, fail fast fail safe (moral of the story). • Learn, un-learn, and thinkers and be future relevant. • Culture of innovation (create a mascot). • Promotion in adoption of ISO 56002 (2019). • Incorporation of Theory of Inventive Problem Solving (TRIZ) within the sector. • Creation of an innovation indicator assessment scheme for all contributing actors. Participation and access to assessment score can be used to leverage benefits. Catching them young (tinkering labs, start-up kits).
Industry modes of interaction that require attention: **Intra:** Despite user-producer relationship between IND actors there are few	Tacit exchange of knowledge can help reduce costs, minimize risks, promote knowledge and technology transfer, and improve market access.	**Intra** Encourage partner-based collaborations for building capabilities and up-skilling the managerial and labour force. • Organize brainstorming sessions in system level understanding & vendor capabilities development. • Forums for Cross-Industry Best Practices.

linkages in terms of tacit knowledge transfer & joint research activities **Inter:** **IND - GOV** Poor public financing for the automotive sector. **IND - KBI** Low conversion of joint research activities into innovation outputs. **IND-INT** Less joint research & trademarking/standards **IND-ARB** Few linkages in terms of formal meetings, informal meetings & seminar/trainings	Low innovation activity in the automotive sector due to lack of public funds for industry	• Consortia work for undertaking pre-competitive work. Working towards identifying the common problem, for example Size India – ergonomics, body dimensions, road profile data acquisition etc. • Standardization of communication protocols for connected vehicles. • Promotion of solutions towards Net Zero. • Make use of middle level executives, for example LinkedIn creator accelerator programme (CAP). • Boost technical tie-ups linked with measurable outcomes. **IND-INT** • In coordination with ISTCs, promote standardization for circularity for example end of life protocols (battery, engines, entire vehicle). • Provision of affordable, centralised research and testing facilities for MSMEs and start-ups. **IND-KBI** • Internship programme on the Technology Innovation Platform under the aegis of MHI and National Apprenticeship Promotion Scheme to be scaled up. • Development of centralised resources for internship programme spearheaded by ACMA, ARAI and SIAM. Link this to NIRF ranking. • Improving the employability index of higher education institutions. • Customisation of Quality Packs for the automotive sector addressing emerging technologies (e.g., CASE, ADAS, cyber security, functional safety). • Reskilling and upskilling of industry professionals (e.g., from ICE vehicles to EVs). • Evaluation of existing online courses and ranking of the same in line with industry relevance and assigning an industry champion to promote them. **IND-ARB** • Educating financial institutions and their assessors in line with new technological trends. For example, ARAI training insurers in emerging automotive topics. • Open Innovation Programmes with Corporate Venture Capitalists (VCs).
Knowledge-based institutions modes of interaction that require attention: **Intra:** Few linkages in the form of joint research & joint patents **Inter:** **KBI-IND** Few linkages through joint research, co-publishing, and recipient of funding. **KBI-INT** Few joint research & co-publishing activities. **KBI-ARB** Few seminars/training activities.	KBIs are working in silos. Impacts generation of applied research	**Intra** • Create forums where KBIs (higher education institutions) come together on a regular basis. • Create forums for joint research, meetings, seminars, and recruitment activities with respect to the automotive sector. • Better coordination between departments and specialised centres within the institution. • Change in management outlook to better facilitate coordination. • Credit transfer between institutions should be allowed. • Research scholar exchange programmes should be initiated. • Replication of CSIR's Theme Directorate model for the automotive sector. • Initiate Capacity Building & Investment in Technology Research. • Uptake recycling-based research projects to enhance sustainable manufacturing practices. • Multi-pronged approach to develop agile workforce having both technical & business acumen. **KBI-IND** • Replicate the FITT Foundation for Information and Technology Transfer (IIT-D) model in other tertiary education institutions. • Providing adequate resources for functional spaces like dean of corporate relations for higher educational institutes. • Facilitating publishing of industrial research from the point of view of IPR and other legalities. • Globally competitive packages to be made available to students graduating from core branches of engineering. • Involving industry in content and design of curriculum. • Introduction of convergence of disciplines at the beginning of post grad level. • Technological Partnership in emerging areas like intelligent transportation systems & automatic transmissions. **KBI-INT** • Replication of models, such as Robert Bosch Technology Centre, Warwick Manufacturing Group, Fraunhofer institute – Industry-specific centres where you have representation of various intermediaries, fostering an aggregated approach to research. • Creation of good programme managers with a helicopter view of the sector.

		• Intermediaries can bridge between KBIs and industry and be a facilitator of training and upskilling. • Utilising intermediaries for increasing visibility and outreach of research being done by Indian KBIs to help facilitate demand for upskilling. Intermediaries can be conduit for assessing needs, quality and demand of skills required by industry.
Intermediary modes of interaction that require attention: **Intra:** Limited joint research and co-publishing activities. **Inter:** **INT-IND** Few joint research and co-publishing activities. **INT-KBI** Few linkages as secondments, recipient of funding & user-producer relationships **INTER-ARB** Limited Joint Research Activities	Future proofing trends in the automotive sector Lack of codification of knowledge together with industry	• Working collectively and collaboratively. • Creation of a joint forum across intermediaries to discuss the topic of “Beyond Regulations”. Utilising technology foresight model. **Intra** • Scale up joint research activities between intermediaries (e.g., ACMA, SIAM, ARAI) in line with the finding of technology foresight exercise. • Widening the scope of actor inclusion in such exercises. For example, new members and new institutions (CII, FICCI, NASSCOM) due to lateral application interdisciplinarity. • Research Partnerships with Inter-Sector Associations like Software Engineering to leverage Industry 4.0. **INT-IND** • Take into consideration the value addition of stakeholders in the formulation of new projects/ activities, (not as a second thought but from the onset). • All avenues of dissemination of information and knowledge must be leveraged, in line with the target audience. • Leveraging the CSR funds of industries to address topics related to circular economy, net zero, recycling, etc. • Creation of global standardization platforms with international regulatory institutions. **INT-KBI** • Scale-up programs like ‘Train the Trainer’ bolstering on resource efficiency & circular economy. • Promote more technical know-how programs on design & embedded engineering services. • Establish a dedicated taskforce for fostering research & stakeholder connectivity with global bodies & International Purchase Offices (IPOs).
Arbitrageurs’ modes of interaction that require attention: **Intra:** Few interactions through recipient of funding. **Inter:** Overall, there are few linkages with other actors. **ARB-KBI** Less recipient of funding **ARB-INTER** Less recipient of funding & no joint research activities.	Low reporting of Linkages by ARB Arbitrageurs are isolated as actors, and they can’t perceive the importance of their own role and responsibilities in the automotive sector. Arbitrageurs need to readjust their focus away from services to the manufacturing sector.	**Intra** • Have regular fora addressing the areas of future technology trends skills and with inclusion of other system actors. • Creating a pool of funds to support studies and activities pertaining to future technology trends and transformation of the automotive sector. Thus, enabling them to better assess the risk and returns of the future of investment in the sector. • Promotion of corporate venture capital funds led by the leaders of the automotive sector. Following the lead of CVCs in other sectors (e.g., TATA STEEL and MARICO). **ARB-KBI** • Institutionalize an easy project financing model for Electric Vehicles. • Establish summer internship or post-doctoral research policy with Banks on business-relevant projects. • Enable Specialist Research Wings & Incentivize for sector-specific investigative studies.
Latent barriers - All Actors • Industry 4.0 (Lack of access to I4.0 technologies; lack of understanding of I4.0 technologies; cost of I4.0 technologies; and lack of infrastructure for I4.0) • Policy Function (Lack of legal framework; lack of clear national innovation strategy; restrictive public / governmental regulations; and lack of explicit policy support) • Market (Lack of Innovative customers; and lack of demanding customers) • Human capital (Lack of technically trained manpower; and quality of technically trained manpower)		**Industry 4.0** • Initiate ‘Booster Incentives’ to encourage enterprises for investing in Industry 4.0. • Strengthening of policy landscape for alternative fuels. • Incentivizing for phasing out & scrapping of ICE vehicles. • Re-orient skill development initiatives & align with digital culture. **Policy Function** • Specific-policy interventions in emerging white spaces in electrification for strengthening Indian suppliers. • Regulatory measures for penetrating innovation in automotive-adjacent sectors (Railway, Farm & construction Equipment & Defense). • Robust strategy to provide education & knowledge resources on Industry 4.0 **Market** • Holistic Development Approach for Auto-Electronics Market. **Human capital**

		• Scaling up of C4I4, PSG College of Technology, SAMARTH Udyog Centre. • SIAM, ACMA to join forces with SAMARTH Udyog Centre to disseminate to the automotive sector. • Increasing outreach of ASDC skilling programme. • Application of readiness index and benchmarking indices for I4.0. • Offering mandatory I4.0 module in automotive engineering. • Competitive compensation packages to be offered. • Aim for creation of surplus skilled human capital. • Proficiency assessment programmes to be created and applied. • Transition towards gig economy approach (learn-unlearn-reskill). • Staying relevant and agile through, leadership and culture strategy development, leadership assessment, drive behaviour changes, changing behaviour and developing the capabilities of managers within the sectors. • Adopting model of IT sector creating skilled human capital pipeline and bench. • Adoption of crowdsourcing and co-creation as a problem-solving tool.
Unsuccessful policy instruments from the perspective of Industry: • Explicit firm innovation policy support • Govt. backed Venture Capital • Government Procurement	Strengthen and focus delivery of policy to address specific gaps	• Establish a National Network of Industry 4.0 to accelerate manufacturing innovations. • Setting-up Skill Development Infrastructure Funds for up-grading ITI's. • Build awareness of government-backed funding • Creating awareness of best practices and successes of already implemented government procurement platforms (GEM portal). • Structuring, filtering, and dissemination of information related to government procurement and demand-side policy incentives.
Unsuccessful policy instruments from the perspective of KBI: • Donor funds • Set-up of business support organizations • Subsidized loans	Strengthen and focus delivery of policy to address specific gaps	• Establish investment funds to accelerate innovation in ACES (Autonomous vehicles, Connectivity, EVs and Shared Mobility). • Increase the number of critical testing facilities across the country. • Establish a strategic network between KBI & MSME tool rooms for up gradation, development, and supply of advanced technologies.
Unsuccessful policy instruments from the perspective of Intermediary: • Government procurement • Labour mobility laws and incentives • Subsidized loans	Strengthen and focus delivery of policy to address specific gaps	• Streamline Nation-level, State-Level & City-Level procurement system to enhance interoperability. • Effective measures to standardize competency wages. • Create databases on the impact of and beneficial effects of start-up subsidies. • Creating a mechanism to establish linkage/interplay between public subsidies and private financing. Development of a bridging fund. • Cascade follow-on financing from subsidised loans.
Unsuccessful policy instruments from the perspective of Arbitrageurs: • Tax breaks • Labour mobility laws and incentives • Set-up of business support organizations	Strengthen and focus delivery of policy to address specific gaps	• Tax Rebates & Non-fiscal measures to push domestic manufacturing of Electric Vehicles. • Promote Intrapreneurship schemes for employees and increase employee retention. • Joint Venture Initiatives with banks for building charging & battery swapping infrastructure. • Incentivise VC's/angel investors to collaborate with regional incubators for investor readiness training programmes and creating local angel networks.

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9. Annexes

Annexes

9.1 Annex 1 – Sample size calculation

- **Overall sample sizes** for both firm level and sectorial system of innovation surveys are determined by the degree of stratification of the sample. The overall sample size depends on the decision of the sample size for each level of stratification.
- **Determining the desired sample size**: Desired sample size from a particular state, which will represent the population (total production units), is calculated through the formula developed by Cochran (1963).

  $$SS = \frac{Z^2 * p * (1 - p)}{e^2}$$

  Where:

  Z = Z value (e.g., 1.96 for 95% confidence level)
  p = percentage picking a choice, expressed as decimal (.5 used for sample size needed)
  e = margin of error, expressed as decimal (e.g.,.05 = ± 5%)

- **Margin of Error** – It is defined as the range of values below and above the sample statistic in a confidence interval. It is a measure of the variability of sample statistics, and it is used to indicate the level of precision of the sample estimate. It is typically expressed as a percentage of the total sample size and is calculated by taking the standard deviation of the sample and dividing it by the square root of the sample size. Margin of error for the sectorial survey sampling is ± 5%.
- **Confidence Level** – It is the proportion of sample, which will represent the population, given the level of precision or confidence interval. A 95% level of confidence has been taken, which shows that 95 out of every 100 samples will have true population value within the level of precision.
- **Correction for Finite Population**: If the population is small then the sample size can be reduced slightly. This is because a given sample size provides proportionately more information for a small population than for a large population. The sample size obtained for different states is based on the formula –

  $$New\ SS = \frac{SS}{1 + \frac{SS - 1}{pop}}$$

  Where: pop = is the number of production units in a state (finite population)

A convenient sample was chosen for each actor category and contact details were verified through the ASI and CMIE databases.

9.2 Annex 2 – NIC code classification

NIC 2008 Codes & Its Description (Divisions and Groups)	
Division 29	**Manufacture of motor vehicles, trailers, and semi-trailers**
Group 291	Manufacture of motor vehicles
Group 292	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers
Group 293	Manufacture of parts and accessories for motor vehicles

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Vienna International Centre
Wagramerstr. 5, P.O. Box 300,
A-1400 Vienna, Austria

+43 1 260-0

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