DG REFORM

Integrated policymaking in the area of RDI

Call for tenders under REFORM/2021/OP/0006 Lot 1

RFS ID: TSIC-RoC-19598

4 December 2024 – Vertical pilot Automotive technologies in Slovakia

Technical Support Instrument

Supporting reforms in 27 Member States

VAIA RESEARCH AND INNOVATION AUTHORITY

Funded by the European Union

This document was produced with the financial assistance of the European Union. Its content is the sole responsibility of the author(s). The views expressed herein can in no way be taken to reflect the official opinion of the European Union.

The project is funded by the European Union via the Technical Support Instrument, managed by the European Commission Directorate-General for Structural Reform Support.

This report has been delivered in November 2024, under the EC Contract No. TSIC-RoC-19598. It has been delivered as part of the project "Integrated policymaking in the area of RDI".

© European Union, *[year]*

The Commission's reuse policy is implemented by Commission Decision 2011/833/EU of 12 December 2011 on the reuse of Commission documents (OJ L 330, 14.12.2011, p. 39 – https://eur-lex.europa.eu/eli/dec/2011/833/oj).

Unless otherwise noted, the reuse of this document is authorised under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence (https://creativecommons.org/licenses/by/4.0/). This means that reuse is allowed, provided that appropriate credit is given and any changes are indicated.

Directorate-General for Structural Reform Support
REFORM@ec.europa.eu
+32 2 299 11 11 (Commission switchboard)
European Commission
Rue de la Loi 170 / Wetstraat 170
1049 Brussels, Belgium

CONTENTS

Table of Tables

Table of Figures

1. Introduction

1.1. Overall purpose of the report

This updated report is submitted under the DG REFORM call for tender REFIRM/2021/OP/0006 Lot 1 "Integrated policymaking in the area of RDI" project, specifically under Deliverable 3 – Vertical Pilot Report on the Automotive Industry. It offers an analysis and insights into the fraction of the Slovak automotive ecosystem, focusing on cutting-edge technologies.

The structure of this report is as follows:

- Introduction (Chapter 1)
- Summary of key findings (Chapter 2)
- Megatrends analysis of cutting-edge technologies in the automotive industry (Chapter 3)
- Analysis of the Slovak companies in cutting-edge automotive technologies (Chapter 4)
- Analysis of Slovak researchers involved in cutting-edge automotive technology research (Chapter 5)
- Annex 1: Desk research and literature review (Chapter 6)
- Annex 2: Technology list creation
- Annex 3: Excel file with Slovak cutting-edge automotive companies

1.2. Methodology overview

This methodology overview outlines the initial steps of creating a roadmap, namely the industrial performance assessment and megatrends analysis.

Creation of technology lists. The process of scoping the automotive industry involved developing a comprehensive list of cutting-edge technologies. Initially, the study team utilised ChatGPT to generate a preliminary list. Following this, a systematic literature review was conducted to refine and validate the list. This review involved analysing academic papers, industry reports, and market analyses to identify prevailing trends and innovations within the automotive sector (see Annex 1 for the full list of reviewed reports).

The technologies were then evaluated based on the available data. Following this initial assessment, and after incorporating feedback from an external validation event, the list was re-evaluated and updated using the previously outlined steps. Technologies were subsequently selected based on stricter criteria, which included companies that produce, manufacture, design, develop, or research the technology, or possess in-house expertise in technological management. Based on these criteria, a revised list of technologies was created, including:

- Electric vehicles and battery technology
- Digitally controlled micro-precision manufacturing
- Additive manufacturing (3D Printing)
- Smart mobility solutions
- Intelligent transportation systems

Megatrends analysis involves the systematic assessment and evaluation of large-scale, transformative forces that significantly impact societies, economies, industries, and individuals over extended periods, often spanning decades. These megatrends are overarching, pervasive, and have far-reaching consequences, shaping various aspects of human life and the business environment. Recognising the dynamic nature of the business landscape, megatrends analysis becomes paramount for identifying emerging trends wherein Slovak companies can not only add value but also position themselves strategically for future opportunities. European Commission officially identifies 14 key megatrends[1]. The most important megatrends for developing Slovakia's automotive industry are climate change, scarcity of resources, growing consumption, rapid technology development, an ageing population, urbanisation, and shifts in consumer demands.

Company analysis. After keywords were validated using desk research, they were entered into the Milda.ai database, which produced company lists for each technology. By utilising advanced technologies like Large Language Models (LLMs) and Natural Language Processing (NLP), Milda.ai aggregates and validates information from multiple inputs, including social media (LinkedIn, Facebook, Twitter), company websites, and patent databases (PATSTAT). The system processes these data points to create structured profiles, covering variables such as company name, activities, location, patents, and industry, ensuring comprehensive and reliable insights for users.

Benchmarking. The analysis includes benchmarking Slovak companies against companies in other Visegrád countries (Poland, Czechia, and Hungary). The Visegrád region is selected as the benchmark for comparison due to its relevance and similarity to the target area. For the overview of the Visegrád region's cutting-edge automotive technologies, we have analysed a dataset of 862 unique companies. Company analysis included the total number of companies per technology, per country and companies by age, industry and company size.

Researchers' analysis. The researchers' analysis involved collecting data on Slovak researchers, their affiliated institutions, and their publications from the OpenAlex database. Stringent criteria were applied to ensure the inclusion of only active researchers with recent publications relevant to the selected technologies (matching the chosen keywords). Applied filters included:

- Researchers must have at least one publication within the last five years (2019 onwards).
- Researchers must have at least five publications related to the specified technological terms.

Moreover, the analysis focused on the applied sciences universities in Slovakia, such as the Technical University of Košice, the Slovak University of Technology in Bratislava, and the University of Žilina. After applying these filters, the study team compiled a dataset of 244 unique researchers affiliated with 15 research and educational facilities.

Overall positioning of Slovak cutting-edge technology ecosystem: To categorise and analyse the technologies, an arbitrary classification system was employed, dividing them into three distinct groups:

- LEAD: Technologies with a high number of both companies and researchers.
- GROW: Technologies with a high number of either companies or researchers, but not both.
- LAG: Technologies with low numbers in both companies and researchers.

[1] https://knowledge4policy.ec.europa.eu/foresight/tool/megatrends-hub_en#explore

The analysis is visually represented using scatter plots created with the ggplot2 package in the R programme. The technologies were placed into four quadrants based on relative involvement:

- Top-left: Low number of companies, high number of researchers (GROW).
- Bottom-right: High number of companies, low number of researchers (GROW).
- Bottom-left: Low number of both companies and researchers (LAG).
- Top-right: High number of both companies and researchers (LEAD).

This categorisation helps identify areas of strength and potential growth or lag in terms of commercial and research involvement. Additionally, the size of the bubbles on the scatter plot indicates the ratio of companies to researchers:

- Larger bubbles: Represent sectors with a higher concentration of companies relative to researchers, suggesting a more commercially driven area.
- Smaller bubbles: Indicate a stronger focus on research and development, with fewer companies involved.

This visualisation method also facilitates the evaluation of niche technologies, which might naturally fall into the GROW or LAG quadrants due to their smaller scale. The relative positioning and bubble sizes provide insights into the balanced or imbalanced contributions of these technologies to industry and research.

Data limitations. Recognising potential limitations within the dataset, it is acknowledged that while approximately 90% of the data sourced from Milda.ai is considered valid, instances of incompleteness or diminished relevance may still occur. To mitigate these issues, various filters were applied during the data cleaning process, including exclusions based on industry sectors and value chain positioning (key operational activities of companies). Additionally, researchers manually evaluated the quality and relevance of the data and edited the company lists as necessary.

Lessons learned:

- Allowing **buffer time** for evaluating compiled datasets is essential to ensure adequate opportunity for **manual and qualitative assessment of data** quality and validity. This practice enhances the overall quality of the data and ensures its legitimacy. In the context of this project, there was effort needed to clean data from related but not directly relevant companies within automotive industry, such as car rentals, insurance companies, body shops and other enterprises focusing on automotive services.
- An **iterative approach** is essential when working with data derived from assumptions about technological presence in the market and research. It is advisable to evaluate not only the technology lists but also the relevance and profiles of the companies involved. This can be achieved through feedback from national experts and external validation events. Incorporating this feedback early in the project allows for updates to the technology lists, enhances the strategy for company searches, and may even reveal entirely new companies based on revised criteria and/or emerging needs.
    - In addition to excluding irrelevant companies, the target profile was refined to focus on Slovak firms engaged in the design, development, production, or manufacturing of technologies directly related to the automotive sector or with significant potential for automotive applications. Additionally, the focus extended to IT hubs, software development companies, and consulting firms contributing to

new mobility solutions, including embedded software development (e.g., blockchain for automotive, backend systems, V2X, smart and electric mobility).
    - Utilising digital tools like Milda.ai can expedite preliminary company scraping, facilitating more effective extraction once confidence in the selected technologies has been established.
    - Subsidiary companies were integrated into the general list if they had a Slovak domain, while notable companies without Slovak domains, such as MAGNA INTERNATIONAL, were also added to the dataset to provide a more comprehensive overview of robotics companies operating in Slovakia.
- An **agile/creative approach** is essential when comparing technologies and innovations, ranging from specific to general. When conducting comparative assessments, it is important to recognise that not all technologies can be compared on a like-for-like basis. Therefore, adjustments to the quantitative analysis and contextualisation of the acquired data are crucial. For instance, certain technological applications may exhibit a significant commercial presence with limited research involvement, and vice versa. This can be entirely expected based on their characteristics.
- The purpose of benchmarking with Visegrád countries was to provide context for the Slovak data, rather than to deliver precise rankings or establish a clear market positioning. Given the differences in country and technology sizes, the goal was not to claim full coverage but to offer a comparative framework for understanding the data. As such, the results should be interpreted with caution.

2. Summary of key findings

Overview of Slovak companies in automotive technologies

The analysis identified **108 unique firms** involved in cutting-edge automotive technologies in Slovakia across five technological categories. Electric Vehicles and Battery Technology comprises 32 companies, Digital Controlled Micro-Precision Manufacturing includes 30 companies, Additive Manufacturing (3D printing) has 19 companies, while Smart Mobility Solutions and Intelligent Transportation Systems account for 18 and 11 companies, respectively.

A significant portion of these companies, approximately 78%, are well-established, having operated for over ten years, indicating a **mature market**. The representation of young companies, including startups, is minimal, with only 7% identified. This **limited presence of new entrants** suggests potential barriers to entry in the sector, such as high capital requirements and strong competition from established firms. In terms of size, 37% of the firms employ between 10-49 employees, while 28% have fewer than ten employees, and 20% employ between 50-249. Additionally, 60% of the companies report a turnover under EUR 4.9 million, reflecting a **predominance of small and medium-sized enterprises (SMEs)** that play a critical role in the national economy.

The companies are primarily **concentrated in the Automotive sector**, with 31 companies in this category, followed by 19 companies in Computer/IT Services and 16 companies in Electronics and Machinery. Traditional industries, such as Mining and Metals and Energy, also contribute to the technological landscape, illustrating a blend of innovation and established industrial strengths. In terms of value chain positioning, the largest share of companies, 57%, is engaged in Manufacturing and Assembly, followed by 40% in Machinery, Hardware, and Components and 32% in Software and IT Solutions. **Both R&D and Design and Engineering account for 31% of the companies**, highlighting that a significant share of companies focuses on innovation and technical design.

Zooming in on technology-specific categories, **48% of companies in Electric Vehicles and Battery Technology are engaged in R&D**, highlighting a strong commitment to innovation within this sector. This emphasis on R&D is vital for advancing EV technology, enhancing battery efficiency, and facilitating the transition toward sustainable transportation solutions. Similarly, **47% of companies in Additive Manufacturing are involved in R&D**. This ongoing research is crucial for improving materials, processes, and applications, enabling the development of new products and solutions that meet evolving market demands.

Overview of the Slovak positioning within the cutting-edge technologies

The following overview is based on the arbitrary categorisation of technologies into three groups: *LEAD*, characterised by a high number of companies and researchers; *GROW*, defined by either a high number of companies and a low number of researchers or vice versa; and *LAG*, marked by low numbers in both areas. For enhanced visualisation, the analysis utilises scatter plots that accordingly position technologies within quadrants. Moreover, the size of the bubbles on the scatterplot represents the ratio of companies to researchers. A larger bubble size could indicate a sector with a higher concentration of companies relative to researchers, suggesting a more commercially driven area. Conversely, smaller bubbles might signify a stronger focus on research and development, with fewer companies involved. This method also allows for evaluating more niche technologies, which are placed in the GROW or LAG quadrants due to naturally small sizes, in terms of their balanced/imbalanced contribution to industry and research.

Overall, the analysis identified a total of 108 unique companies and 284 unique researchers involved in cutting-edge automotive technologies in Slovakia (Table 1).

TABLE 1. OVERALL POSITIONING OF SLOVAK ECOSYSTEM IN THE CUTTING-EDGE AUTOMOTIVE TECHNOLOGIES

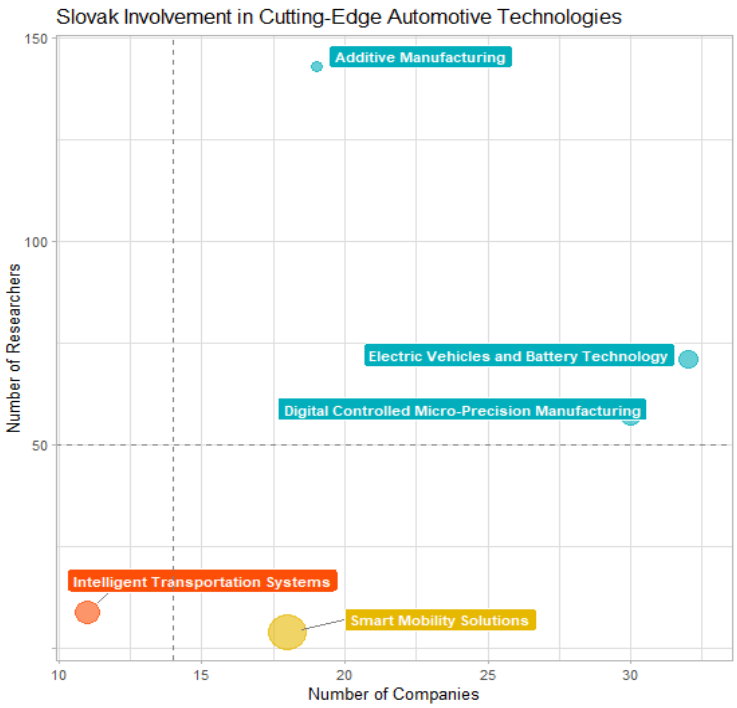
CUTTING-EDGE TECHNOLOGY	NO OF SLOVAK COMPANIES	NO OF SLOVAK RESEARCHERS
Electric Vehicles and Battery Technology	32	71
Digital controlled micro-precision manufacturing	30	57
Additive Manufacturing (3D printing)	19	143
Smart Mobility Solutions	18	4
Intelligent Transportation Systems	11	9
Total	**110 (108 unique companies)**	**284 (244 unique researchers)**

Source: compiled by the study team.

Zooming in on technological positioning, **Additive Manufacturing leads** in both the number of researchers and companies, followed by **Electric Vehicles and Battery Technology** and **Digitally Controlled Micro-Precision Manufacturing** (

FIGURE **1**). These three categories are positioned in the LEAD group, reflecting a strong presence of both industrial and academic activity. In contrast, Smart Mobility Solutions falls under the GROW category, as the number of researchers does not meet the threshold to elevate it into the LEAD group, despite a relatively robust industry presence. Meanwhile, Intelligent Transportation Systems (ITS) is classified in the LAG category, given the few researchers and companies in this field.

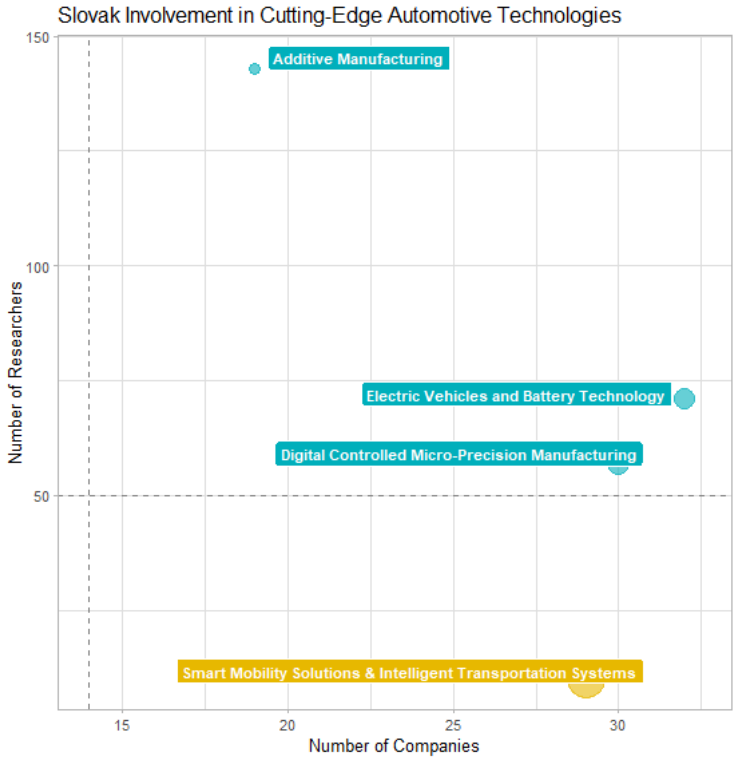
FIGURE 1. SLOVAK POSITIONING IN CUTTING-EDGE AUTOMOTIVE TECHNOLOGIES (A)



Source: compiled by the study team. Note: The scatterplot is arbitrarily divided into four quadrants and colour-coded according to Slovak positioning, as follows: LEAD - ●, GROW - ●, & LAG - ●. ** Note: The size of the bubbles corresponds to the companies-per-researchers ratio.*

However, it is important to note that Smart Mobility Solutions and ITS are overlapping domains where companies and researchers often share goals, values, processes, and methodologies (Figure 2). They may also draw from a common knowledge base, further blurring the distinction between them. For this reason, combining these categories for the purpose of visualisation is justifiable. When merged, this unified category would more appropriately fall under the GROW group, which better reflects its importance and potential.

FIGURE 2. SLOVAK POSITIONING IN CUTTING-EDGE AUTOMOTIVE TECHNOLOGIES (B)



Source: compiled by the study team.

** Note: The scatterplot is arbitrarily divided into four quadrants and colour-coded according to Slovak positioning, as follows: LEAD - ●, GROW - ●, & LAG - ●.*

*** Note: The size of the bubbles corresponds to the companies-per-researchers ratio.*

3. Megatrends analysis of cutting-edge technologies in the automotive industry

Pivotal global events and key megatrends deeply influence the automotive industry's transformation towards sustainability and enhanced/diversified mobility. The transformation of the automotive industry has escalated due to the rapid evolution of technology, particularly within the framework of Industry 4.0[2], which is reshaping vehicle design, manufacturing, and functionality. Increasing consumption and the expanding influence of consumers are driving demand for more personalised, efficient, and sustainable mobility solutions. The ageing global population necessitates diversifying and adapting mobility modes to enhance accessibility and safety. Moreover, growing concerns over climate change and increasing scarcity of resources are propelling the industry toward greener, more energy-efficient and sustainable solutions, necessitating the urgency for the industry's innovation.

The automotive value chain is undergoing transformative changes driven by the push towards sustainability, influenced by consumer demand, governmental regulations, and international commitments like the Paris Agreement and the European Green Deal[3]. These forces are prompting innovations in sustainable practices, such as improved manufacturing methods such as *Additive Manufacturing (3D printing)* and *Precision Engineering*[4]. 3D printing technology enables more efficient production, reducing material waste and supporting on-demand, localised manufacturing[5]. Precision manufacturing allows for the development of high-quality, customised parts with minimal tolerances, enhancing performance and reducing resource consumption. The European Green Deal's comprehensive approach impacts various sectors, promoting a clean, circular economy to minimise waste and enhance resource efficiency in the vehicles' product value chain.

Furthermore, the automotive industry is shifting from traditional investments in product range to IT software solutions to foster innovation. Companies that reallocate their R&D budgets towards software solutions are experiencing more robust growth. The automotive sector is becoming increasingly attractive to new entrants from the software industry, leading to the integration of new partners into the automotive value chain[6]. Artificial Intelligence (AI) is propelling advancements in both software and hardware as it is used to streamline and make more efficient manufacturing processes, as well as to create innovative products and features[7]. Ultimately, the industry faces a redistribution of markets and revenue pools towards new business models and technologies crucial for the future of electric, autonomous, and connected mobility[8].

[2] Industry 4.0, also known as the Fourth Industrial Revolution, refers to the integration of advanced digital technologies into manufacturing and industrial practices. It encompasses the use of the Internet of Things (IoT), big data analytics, artificial intelligence (AI), robotics, cloud computing, and cybersecurity to create smart, automated factories.

[3] De Pinaga, C. B., & Van Eweyk, A. R. (2023). A Review of Green Technology and its Effects in the Auto Industry.

[4] Alami, A. H., Olabi, A. G., Alashkar, A., Alasad, S., Aljaghoub, H., Rezk, H., & Abdelkareem, M. A. (2023). Additive manufacturing in the aerospace and automotive industries: Recent trends and role in achieving sustainable development goals. *Ain Shams Engineering Journal*, *14*(11), 102516.

[5] Nash, M. (2024, March 5). Additive manufacturing: Supporting sustainable production. Automotive Manufacturing Solutions. https://www.automotivemanufacturingsolutions.com/sustainable-production/additive-manufacturing-supporting-sustainable-production/45315.article

[6] PwC. (2017). Eascy - The five dimensions of automotive transformation. Retrieved from https://www.pwc.com/gx/en/industries/automotive/publications/eascy.html

[7] European Commission, Executive Agency for Small and Medium-sized Enterprises, (2020). Artificial intelligence : critical industrial applications : report on market analysis of prioritised value chains, the most critical AI applications and the conditions for AI rollout, Publications Office. https://data.europa.eu/doi/10.2826/838431

[8] Papadimitriou, D., & Duysinx, P. (2022). FUTURE MOVE: A review of the main trends in the automotive sector at horizon 2030 in the Great Region.

The trend toward Electric Vehicles (EVs) is becoming increasingly evident, as demonstrated by recent data from European and global markets. In the European Union, the car market saw an 18% increase from January to May 2023, with a notable rise in the market share of Battery Electric Vehicles (BEVs) from 9.6% to 13.8%[9]. Moreover, a rising share of consumers view a brand's commitment to sustainability as necessary, particularly in developing markets, with 56% of Indian consumers and 32% of Chinese consumers considering it very important[10]. Backed by policies like the European Union's 2035 zero-emission vehicle mandate, the growing market share and global push towards EVs suggest an accelerating shift likely to transform the automotive landscape significantly[11]. Moreover, Hydrogen Fuel Cells (HFCs), which complement BEVs by offering greater energy storage and faster refuelling, are becoming viable for heavy-duty and long-range vehicles. The cost of ownership for BEVs and HFCs is expected to converge within the next decade, challenging traditional internal combustion engines[12].

The modes of mobility are being transformed and diversified due to technological advancements, rising consumer demand, and a growing, ageing population. This shift is marked by the rise of smarter, more connected transport systems. At the forefront are *Intelligent Transportation Systems (ITS)* and *Smart Mobility Solutions*, which integrate advanced communication technologies, IoT, and data analytics to optimise networks. The demand is growing for personal and public mobility that prioritises safety, reduces congestion, and improves accessibility[13,14]. Additionally, consumers are increasingly seeking digital features that enhance connectivity and convenience, such as in-car apps, real-time navigation, and vehicle-to-vehicle and vehicle-to-everything communication. These technologies support maintenance updates, vehicle health monitoring, traffic alerts, and optimised route suggestions, reflecting a growing demand for smarter, more integrated mobility solutions[15].

Below is a table summarising the key technologies and megatrends influencing the automotive industry selected for this project:

TABLE 2. CUTTING-EDGE AUTOMOTIVE TECHNOLOGIES MAPPING TO MEGATRENDS

TECHNOLOGY	ASSOCIATED MEGATRENDS	DEVELOPMENT DESCRIPTION
Electric Vehicles & Battery Technology	Climate change, Scarcity of resources, Growing consumption	The rise in EVs and advancements in battery technology is driven by the need to reduce emissions and meet growing consumer demand for sustainable transport solutions.
Digital Controlled Micro-Precision Manufacturing	Rapid technology development, Consumer demand, Globalisation	This technology allows for highly accurate, automated production processes, meeting the demands of mass customisation, precision, and efficiency in global supply chains.

[9] Richert, M., & Dudek, M. (2023). Selected Problems of the Automotive Industry—Material and Economic Risk. Journal of Risk and Financial Management, 16(8), 368.

[10] Deloitte US. (2024). 2024 Global Automotive Consumer Study: Tracking consumer trends in the automotive industry. Deloitte. https://www2.deloitte.com/us/en/pages/consumer-business/articles/global-automotive-consumer-study.html

[11] Richert, M., & Dudek, M. (2023). Selected Problems of the Automotive Industry—Material and Economic Risk. Journal of Risk and Financial Management, 16(8), 368.

[12] McKinsey & Company. (2017). Hydrogen: The next wave for electric vehicles? Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/hydrogen-the-next-wave-for-electric-vehicles

[13] McKinsey & Company. (2019). Autonomous driving's future: Convenient and connected. Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected

[14] PwC. (2017). Eascy - The five dimensions of automotive transformation. Retrieved from https://www.pwc.com/gx/en/industries/automotive/publications/eascy.html

[15] Deloitte US. (2024). 2024 Global Automotive Consumer Study: Tracking consumer trends in the automotive industry. Deloitte. https://www2.deloitte.com/us/en/pages/consumer-business/articles/global-automotive-consumer-study.html

Additive Manufacturing (3D Printing)	Scarcity of resources, Rapid technology development, Growing consumption	Additive manufacturing enables resource-efficient production methods, reducing material waste and allowing for on-demand, localised production to meet growing consumer needs.
Smart Mobility* Solutions	Urbanisation, Consumer demand, Climate change	Focused on individual and commercial mobility, this includes shared, electric, and autonomous vehicles and app-based solutions that provide seamless and sustainable transport options for consumers.
Intelligent Transportation Systems (ITS)	Urbanisation, Rapid technological development, Ageing society	A broader infrastructure-based ecosystem that integrates communication technologies, IoT, and data analytics to manage traffic flow, enhance safety, and optimise transport networks at the city or regional level.

Source: compiled by the study team.

** The distinction between Smart Mobility Solutions and Intelligent Transportation Systems (ITS) is somewhat arbitrary, as both companies and researchers often share overlapping goals and techniques. However, this loose distinction has been made to capture the focus on individual or consumer-driven mobility versus infrastructure/ecosystem, respectively.*

4. Analysis of the Slovak companies in cutting-edge automotive technologies

4.1. Overview of Slovak companies involved in cutting-edge automotive technologies

The analysis of Slovak companies involved in cutting-edge automotive technologies identified **108 unique firms** (TABLE 3). Electric Vehicles and Battery Technology represent the largest category, with 32 companies, followed closely by Digital Controlled Micro-Precision Manufacturing, with 30 companies. Additive Manufacturing (3D printing) includes 19 companies, while Smart Mobility Solutions and Intelligent Transportation Systems account for 18 and 11 companies, respectively.

TABLE 3. COUNT OF SLOVAK COMPANIES ACROSS CUTTING-EDGE AUTOMOTIVE TECHNOLOGIES*

TECHNOLOGY	COUNT OF COMPANIES
Electric Vehicles and Battery Technology	32
Digital Controlled Micro-Precision Manufacturing	30
Additive Manufacturing (3D printing)	19
Smart Mobility Solutions	18
Intelligent Transportation Systems	11
Grand Total	110 (108 unique companies)

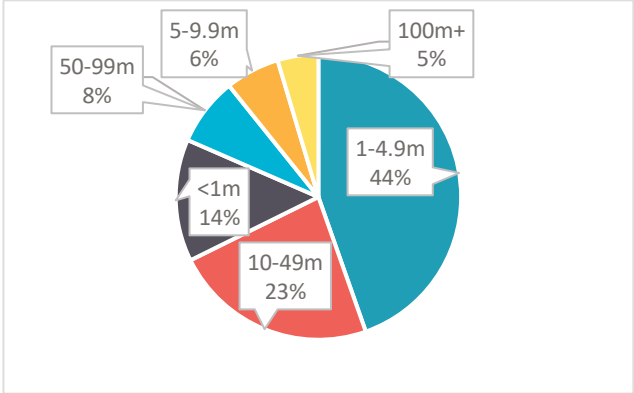
Source: compiled by the study team.
**Some companies were categorised under more than one technology.*

Most Slovak companies (78%) in the cutting-edge technology sector are **well-established**, having been in operation for over ten years (Figure 3). This indicates a **mature market** with many players possessing longstanding experience in the industry. The small percentage of early growth companies including startups is small with only 7%, suggesting **potential barriers for young companies entering the market**. Most companies in the sector are small and medium-sized enterprises (SMEs), with 37% having 10-49 employees, 28% having fewer than 10 employees, and 20% employing between 50 and 249 people (Figure 3). A significant portion (60%) of the companies report a turnover under EUR 4.9 million, which aligns with the prevalence of small to medium-sized firms (Figure 5). Additionally, 15% of companies have over 250 employees, indicating a considerable presence of larger firms in the market.

FIGURE 3. & FIGURE 4. DISTRIBUTION OF SLOVAK COMPANIES BY AGE (N=98) AND SIZE (N=86)

Source: compiled by the study team.

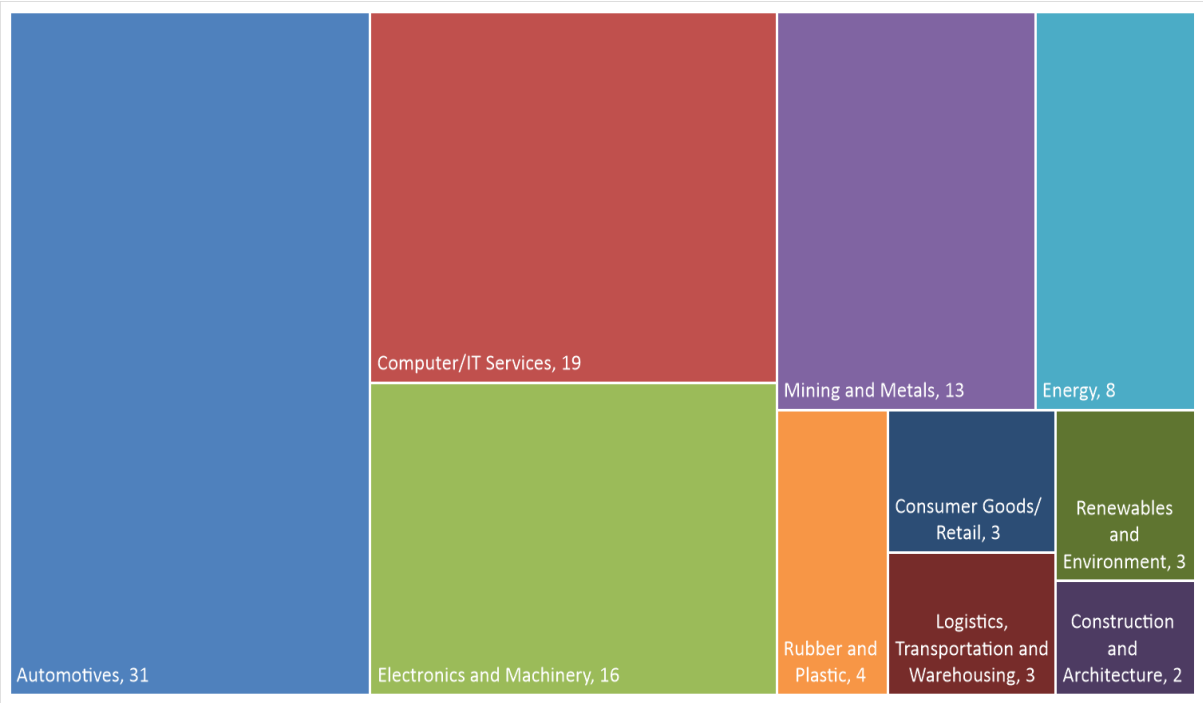
FIGURE 5. DISTRIBUTION OF SLOVAK COMPANIES BY TURNOVER (N=65)*



Source: compiled by the study team.
**Noteworthy that turnover was not available for 40% of companies.*

The analysed companies are **primarily concentrated in the Automotive industry**, which represents the largest share with 31 companies (Figure 6). This is followed by Computer/IT Services (19 companies) and Electronics and Machinery (16 companies), indicating a significant focus on digitalisation and engineering. Traditional industries like Mining and Metals (13 companies) and Energy (8 companies) also play a key role, reflecting Slovakia's historical industrial strengths, with some potential shift towards innovative technologies. Smaller industries, including Rubber and Plastic, Consumer Goods/Retail, Logistics, Transportation and Warehousing, Renewables and Environment, and Construction and Architecture, have a more limited presence but still contribute to the broader technological landscape.

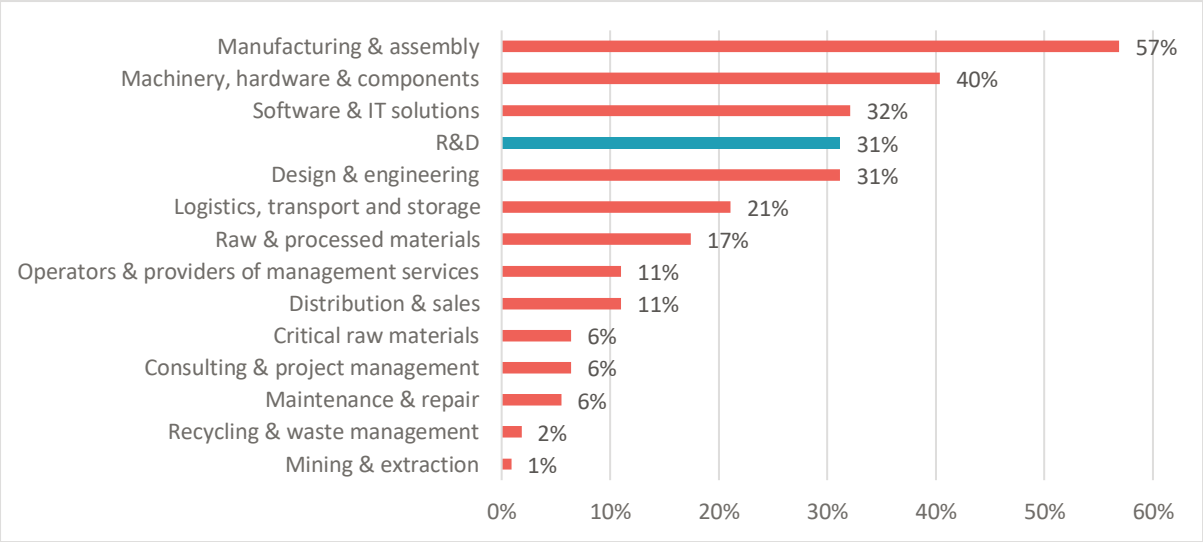
FIGURE 6. DISTRIBUTION OF ANALYSED SLOVAK COMPANIES ACROSS THE TOP 10 INDUSTRIES



Source: compiled by the study team.

Regarding **Value Chain Positioning, the largest share of companies (57%) is engaged in Manufacturing & assembly**, indicating a strong emphasis on production activities (Figure 7). This is followed by Machinery, hardware & components at 40%, showcasing a significant focus on the hardware and machinery aspect of technology development. Software & IT solutions account for 32%, reflecting the importance of digital services and innovation. **R&D and Design & engineering both account for 31%**, suggesting that a substantial portion of companies is also heavily involved in innovation and technical design. Other activities like Logistics, Transport and Storage (17%) and Raw & Processed Materials (11%) highlight the importance of supply chain and material processing in the sector. Smaller segments such as Consulting & Project Management, Critical Raw Materials, and Recycling & Waste Management (all 6% or less) indicate niche operational roles, while Mining & Extraction represents the smallest share (1%).

FIGURE 7. SHARES OF SLOVAK COMPANIES INVOLVED IN SPECIFIC KEY OPERATIONAL ACTIVITIES (VALUE CHAIN POSITIONING)*



Source: compiled by the study team.
**Each company can be involved in more than one operational activity, so shares will not amount to 100%.*

This section provides a closer look at the involvement of Slovak companies in key operational activities across various cutting-edge technology categories (Figure 8). Rather than covering the entire value chain, the focus is on activities that are highly relevant to cutting-edge technology companies. These include **Manufacturing & assembly**, **R&D**, **Design & Engineering**, **Software & IT solutions**, **Machinery, hardware & components**, and **Consulting & project management**. The analysis examines how companies are positioned in each of these operational areas within specific technology categories, highlighting their contributions to innovation, production, and technical services.

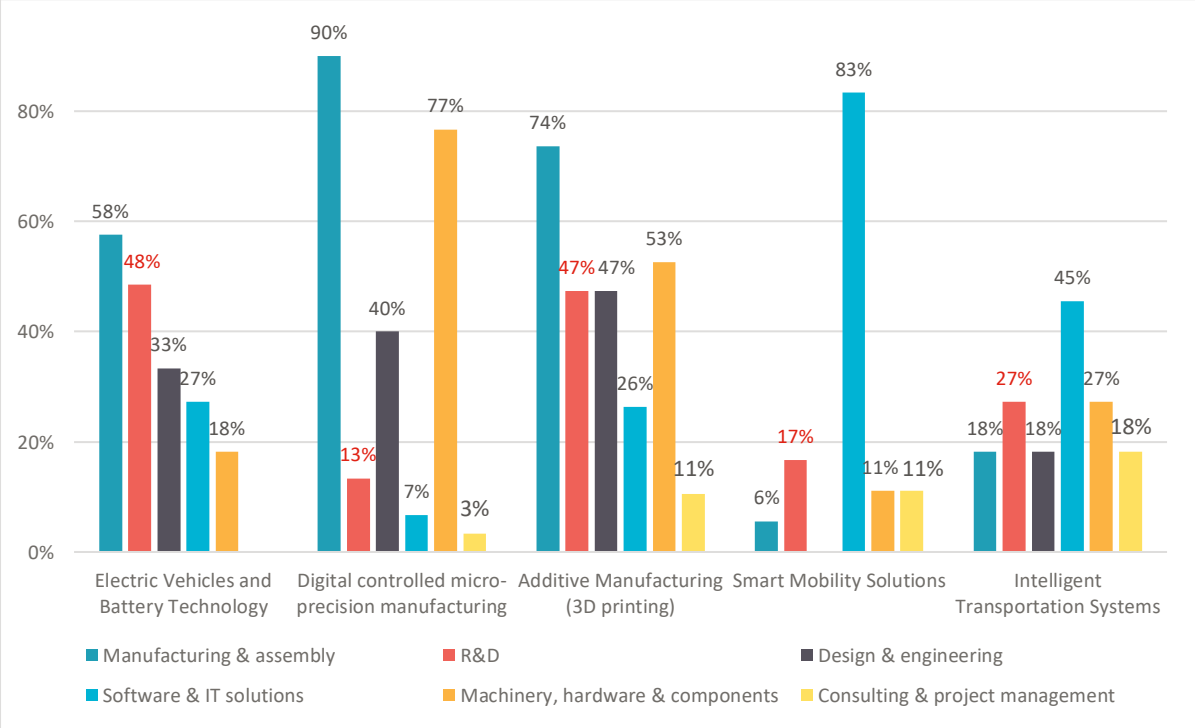
- Most **Electric Vehicles and Battery Technology companies (58%) are focused on Manufacturing & assembly**, reflecting the strong production emphasis in this sector. A significant portion (48%) is involved in R&D, indicating active innovation. Software & IT solutions (33%) and Design & engineering (27%) also play notable roles, demonstrating the integration of digital technologies and engineering expertise in developing electric vehicles and battery systems.
- The **Digital Controlled Micro-Precision Manufacturing companies are dominated by Manufacturing & assembly (90%)** and Machinery, hardware & components (77%), highlighting a production-focused approach with significant reliance on technical hardware. R&D (13%) and

Design & engineering (7%) are less prominent, suggesting that while innovation exists, the core activities remain heavily centred on precision manufacturing.

- A large share of **Additive Manufacturing (3D printing) companies (74%) are involved in Manufacturing & assembly**, underscoring the production-oriented nature of 3D printing. R&D and Design & engineering both account for 47%, indicating strong engagement in innovation and technical design, critical for the growth and application of 3D printing technologies. Machinery, hardware & components (26%) are also relevant but less dominant.
- Most of the **Smart Mobility Solutions companies (83%) are involved in Manufacturing & assembly operations**, reflecting the production-heavy nature of this sector. Smaller but equal shares (11% each) are involved in R&D, Design & Engineering, and Software & IT Solutions, suggesting that while innovation and technical design are necessary, the primary focus is on manufacturing smart mobility systems.
- This **Intelligent Transportation Systems sector shows a more balanced distribution, with 45% of companies involved in Manufacturing & assembly**. R&D and Design & engineering (27% each) are equally significant, reflecting the need for innovation and technical development. Software & IT solutions and Consulting & project management (18% each) play essential roles, pointing to the diverse range of expertise required for intelligent transportation technologies.

Overall, while **Manufacturing & assembly is a dominant activity across all sectors**, companies are also highly engaged in multiple other activities, particularly **R&D**, **Design & Engineering**, and **Software & IT Solutions**, depending on the technology. This diversity in operational activities shows that many Slovak companies involved in cutting-edge technologies are versatile and capable of handling multiple stages of the value chain, from production to innovation and technical services.

FIGURE 8. SHARES OF COMPANIES BY TECHNOLOGY INVOLVED IN KEY OPERATIONAL ACTIVITIES OF MOST INTEREST (VALUE CHAIN POSITIONING) *



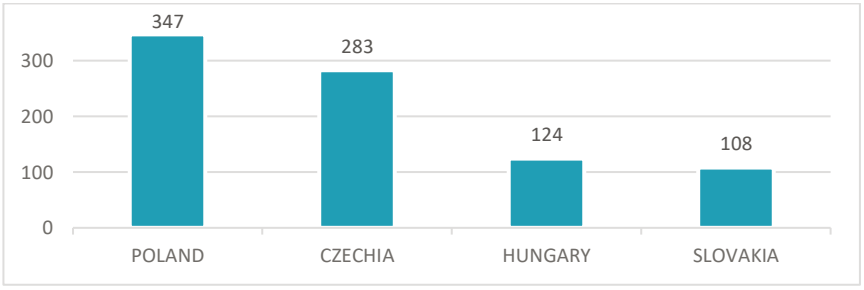
Source: compiled by the study team.

**Each company can be involved in more than one operational activity, so shares will not amount to 100%.*

4.2. Overview of Visegrád companies involved in cutting-edge automotive technologies

For Visegrád benchmarking, we analysed a total of 862 unique companies in the automotive industry. Unsurprisingly, due to differences in economy and population size, Poland ranks first with 347 companies, followed by Czechia with 283, Hungary with 124, and Slovakia with 108 companies (Figure 9).

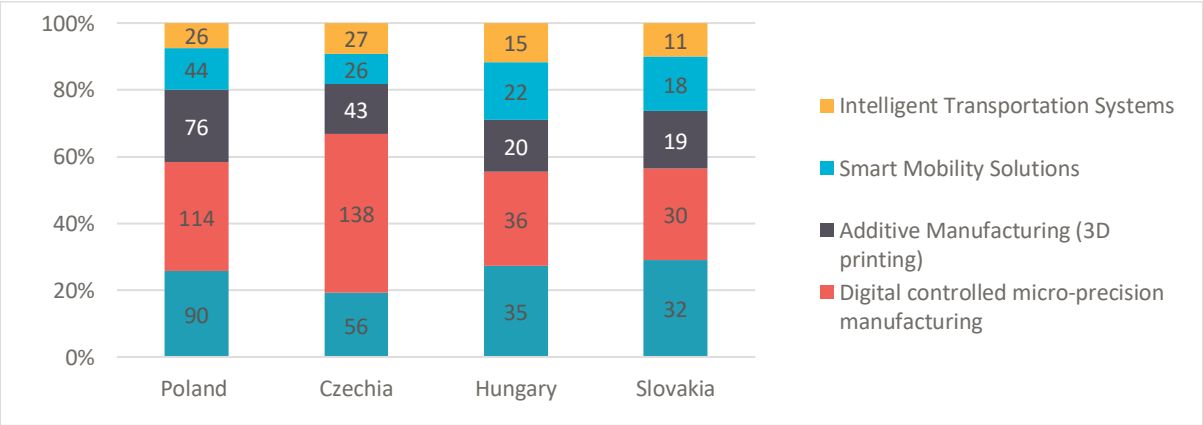
FIGURE 9. NUMBER OF VISEGRÁD CUTTING-EDGE AUTOMOTIVE COMPANIES



Source: produced by the study team.

The distribution of companies in **cutting-edge automotive technologies** across the Visegrád region shows notable similarities (Figure 10). Electric Vehicles and Battery Technology lead, with Slovakia (29%), Hungary (27%), and Poland (26%) having substantial shares. Digital Controlled Micro-Precision Manufacturing follows, dominated by Czechia at 48%, with Poland (33%), Hungary (28%), and Slovakia (27%) trailing. Additive Manufacturing ranks third, particularly strong in Poland (22%), with Slovakia at 17%. Smart Mobility Solutions and Intelligent Transportation Systems account for smaller shares, with Hungary leading in both categories at 17% and 12%, respectively.

FIGURE 10. DISTRIBUTION OF VISEGRÁD CUTTING-EDGE AUTOMOTIVE COMPANIES BY TECHNOLOGY

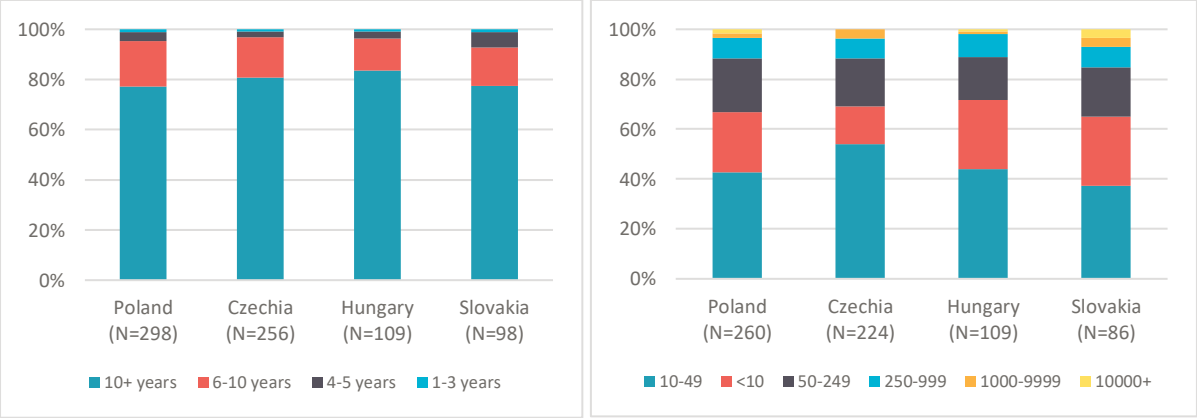


Source: produced by the study team.

The Visegrád region's company profile shows a significant similarity, with over **80% of businesses being more than 10 years old** (Figure 11 & 12). **Most of these firms are classified as SMEs**. The number of younger companies is very low; those aged between 1 and 3 years represent just 1% of all regional firms. Early-growth companies aged 4 to 5 years make up about 4%. This lack of younger startups is concerning in sectors that thrive on innovation, as a mix of established and emerging firms is essential

for a competitive economy. The dominance of older companies may point to challenges that new ventures face, such as regulatory hurdles, limited funding, and market saturation. To cultivate a more dynamic economy, there needs to be a stronger focus on supporting startups and encouraging entrepreneurship. This could include improving access to financing, offering mentorship, and establishing incubators for new businesses.

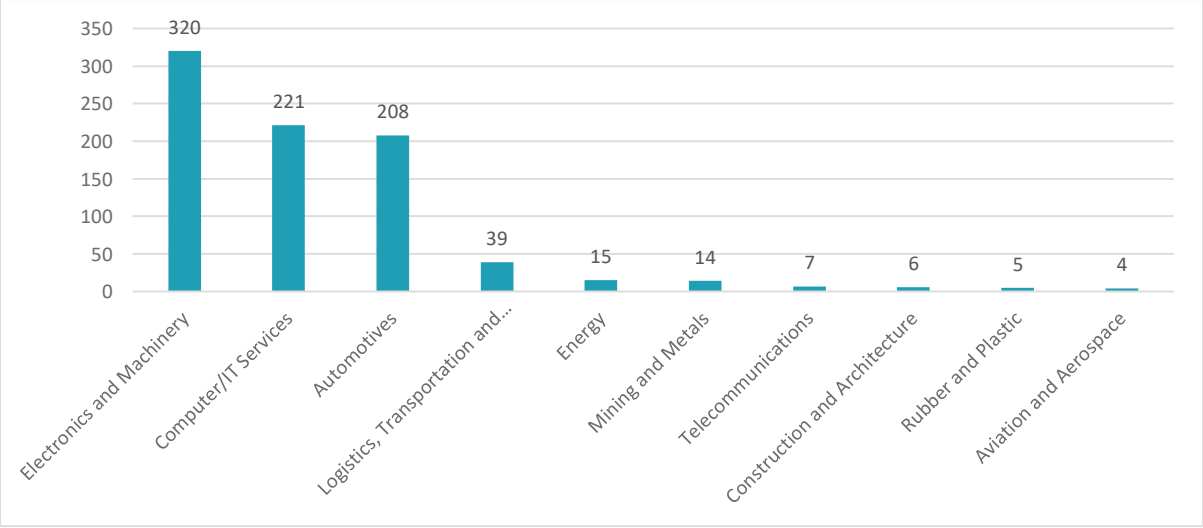
FIGURE 11. & FIGURE 12. DISTRIBUTION OF VISEGRÁD CUTTING-EDGE AUTOMOTIVE COMPANIES BY AGE AND SIZE



Source: produced by the study team.

Regarding **Industrial Distribution** within the Visegrád region, **the largest industry is Electronics and Machinery**, comprising 320 companies (Figure 13). This is followed by Computer and IT Services with 221 companies and the Automotive industry, which has 208 companies. Unsurprisingly, Logistics, Transportation and Warehousing ranks fourth among the largest industries. This distribution highlights the significant role that electronics and machinery play in the regional economy, reflecting a robust industrial base that supports various sectors, including automotive manufacturing and IT services. The presence of a well-developed logistics sector further underscores the interconnectedness of these industries, facilitating the movement of goods and services throughout the region.

FIGURE 13. DISTRIBUTION OF VISEGRÁD CUTTING-EDGE AUTOMOTIVE COMPANIES ACROSS TOP 10 INDUSTRIES



Source: produced by the study team.

Regarding Value Chain Positioning, Visegrád companies participate similarly in a range of operational activities, with key activities being Manufacturing & assembly, Machinery, hardware & components and Software & IT solutions (Figure 14). Notably, Czechia has the largest share of companies involved in Manufacturing & assembly at 67%, as well as 59% in Machinery, hardware & components. Hungary stands out with the highest proportion of companies in Software & IT services at 44%. Additionally, it's worth noting that approximately one-third of all Visegrád companies are in Design & engineering and R&D activities.

FIGURE 14. SHARES OF VISEGRÁD COMPANIES INVOLVED IN SPECIFIC KEY OPERATIONAL ACTIVITIES (VALUE CHAIN POSITIONING) *

VALUE CHAIN POSITIONING	POLAND	CZECHIA	HUNGARY	SLOVAKIA
Manufacturing & assembly	59%	67%	56%	57%
Machinery, hardware & components	48%	59%	48%	41%
Software & IT solutions	39%	31%	44%	32%
Design & engineering	32%	28%	30%	31%
R&D	31%	34%	32%	31%
Logistics, transport and storage	17%	15%	22%	21%
Raw & processed materials	14%	19%	6%	18%
Distribution & sales	13%	10%	8%	11%
Operators & providers of management services	10%	14%	15%	11%
Maintenance & repair	9%	10%	11%	6%
Consulting & project management	4%	7%	6%	6%
Critical raw materials	2%	3%	1%	6%
Recycling & waste management	2%	2%	2%	2%
Mining & extraction	0%	0%	0%	1%

Source: compiled by the study team.
**Each company can be involved in more than one operational activity, so shares will not amount to 100%.*

4.3. Examples of Slovak companies involved in cutting-edge automotive technologies

Electric Vehicles and Battery Technology

Electric Vehicles and Battery Technology companies encompass a variety of sectors, all contributing to the growth of the Slovak EV ecosystem. Some focus on creating and managing **charging networks** and ensuring efficient power access for EVs. Others are involved in the **design and production of EVs**, from passenger cars to commercial vehicles. Key players in **energy solutions** develop advanced batteries and storage systems to enhance range and efficiency. Additionally, firms are innovating **digital tools** to improve EV performance and integrate these vehicles into broader infrastructures, while others specialise in **essential components**, enabling the smooth operation of EV systems. Below are a few prominent examples.

InoBat is an innovative company focused on developing and manufacturing **electric batteries** for various sectors, including automotive, commercial vehicles, motorsport, and aerospace. The company leverages cutting-edge lithium-ion technology to deliver high-performance, lightweight battery solutions that enhance vehicle design flexibility and efficiency.

InoBat's strong **R&D** capabilities enable close collaboration with original equipment manufacturers, prioritising energy density and charging efficiency. This allows for creating specialised battery solutions tailored to diverse EV projects, resulting in uniquely designed systems that enhance performance and safety. Their approach supports modular and scalable designs that meet the specific needs of the evolving EV market.

AgeVolt Slovakia s.r.o. is an innovative company specialising in **EV charging solutions** for commercial, domestic, and public applications. Their offerings include the development and supply of EV chargers and intelligent energy management systems that predict long-term occupancy and electricity consumption. AgeVolt's smart charging system integrates EV chargers with building energy management systems, enabling real-time optimisation based on current capacity and demand.

An additional aspect of the company's **R&D** efforts involves the development of a blockchain-based digital ecosystem that connects drivers and charger owners, integrating EV charging with loyalty and marketing systems. This platform enhances user experience by offering benefits such as reduced charging costs for customers of participating businesses, thereby further encouraging efficient and sustainable transportation.

GreenWay Infrastructure s.r.o. is a company committed to advancing the EV landscape by **constructing and managing EV charging infrastructure**, offering a range of solutions including fast and ultra-fast chargers, roaming services, and smart technologies.

Their **R&D** focuses on enhancing electromobility through improved charging systems and user-friendly applications. GreenWay has also participated in European initiatives, securing funding from the European Commission and INEA for projects like NCE-FastEVNet and NCE-AdvancedEVNet, which aim to reduce oil dependence and environmental impacts while supporting long-distance EV travel. They have also implemented the iSTORMY project under Horizon 2020, contributing to the design of an innovative and interoperable hybrid energy storage system.

Digital Controlled Micro-Precision Manufacturing

Digital Controlled Micro-Precision Manufacturing encompasses various companies that leverage advanced technologies to produce precision components and systems. This category focuses on digital and CNC machining processes that ensure high accuracy and efficiency in manufacturing. Key activities include 3D printing, CNC machining, metal casting, laser welding and cutting, and automation solutions, which are critical for industries such as automotive, aerospace, and electronics.

IMC Slovakia, s.r.o. is a **mechanical engineering** firm that manufactures **components and complex machinery** for industries such as automotive, food, steel, textile, ventilation, and construction.

Their services include sheet metal processing, metalworking, welding, surface treatments, and assembly, leveraging advanced laser technologies, CNC (Computer Numerical Control) lines, and robotic welding systems for high-precision work. The company also offers surface treatments like sandblasting and powder coating, supported by a dedicated test facility and design department for prototype development.

IMC Slovakia's **R&D** division focuses on innovative solutions based on customer needs, improving productivity and quality. It places particular emphasis on sustainable advancements under the Green Programme.

The Matador Group is a leading system supplier of both automotive and non-automotive solutions. **Matador Industries, a.s.,** focuses on **general engineering**, providing extensive machining services, including drilling, milling, and turning. The company excels in developing and **assembling custom single-purpose equipment** for various industries, including serial production for the automotive sector.

Their CNC milling capabilities are enhanced by advanced tools that handle materials such as aluminium, steel, Inconel, and plastics. Matador Industries also offers both manual and automated welding services, employing MIG, MAG, and TIG techniques.

AOKI Slovakia s.r.o. is a **precision engineering firm** specialising in producing **components for the automotive sector**. The company utilises advanced robotic CNC lathes and grinders, ensuring high accuracy and product security. It focuses on manufacturing high-quality shafts for turbo diesel and gasoline engines.

Additive Manufacturing (3D printing)

The **Additive Manufacturing** category consists of companies leveraging 3D printing technologies for layer-by-layer fabrication of parts and products. This includes firms specialising in rapid prototyping and custom product development, offering tailored solutions for unique client needs. Other companies focus on material synthesis and research, innovating new materials for various applications. Additionally, some businesses provide specialised 3D printing services that integrate design and manufacturing. Industrial automation firms also play a vital role by optimising production processes and incorporating 3D printing into manufacturing workflows, enhancing overall efficiency and innovation within the industry.

3D SYSTEMS SK s.r.o. is an **additive manufacturing** company specialising in **3D printing** technologies that enable the production of complex parts and prototypes from digital models. The company's extensive range of 3D printing solutions includes FDM (Fused Deposition Modelling), SLS (Selective Laser Sintering), and MJF (Multi

Jet Fusion) technologies, each suited for different material requirements and precision levels.

Additionally, 3D SYSTEMS provides **reverse engineering** services, where physical products are digitally scanned and reconstructed into CAD models, allowing for modifications or replication. This combination of 3D printing technologies and design capabilities supports industries like automotive, architecture, and industrial design, helping engineers quickly iterate and test new concepts.

HALÁS - KOVOOBRÁBANIE s.r.o. is an **engineering company** specialising in the precision production of CNC parts through milling and turning, primarily for the automotive industry. The company focuses on serial production while also excelling in small series and prototype manufacturing, particularly for gears, injection moulds, and complex mechanical components.

Using traditional **CNC machining and advanced 3D printing technologies**, HALÁS can rapidly transform concepts into functional prototypes, especially for intricate measuring devices. The company's integration of additive manufacturing enables flexibility and efficiency, offering customised solutions using ABS or PLA materials in the prototyping phase.

CADtech s.r.o. is an **engineering company** focusing on **mechatronics and pneumatic machinery**. It employs advanced technologies in its design and development processes. The firm specialises in creating mechanical components, fixtures, and bespoke machines through the application of CAD (Computer-Aided Design), CAM (Computer-Aided Manufacturing), and CNC (Computer Numerical Control) methodologies.

Additionally, CADtech integrates 3D scanning and printing technologies into its prototyping services, allowing for efficient digitisation and modelling of existing components.

Smart Mobility Solutions

The **Smart Mobility Solutions** category focuses on improving transportation experiences through user-centric technologies. Many of these solutions are app-based and designed for personal or commercial use in areas like vehicle tracking, fleet management, and smart parking. These tools help optimise vehicle operations, enhance convenience, and streamline transportation processes. While Intelligent Transportation Systems (see further) target broader infrastructure and traffic management, smart mobility emphasises the direct interaction of individuals and businesses with their vehicles and transport systems, making everyday mobility smarter and more efficient.

Fleximodo is an innovative company specialising in IoT technology, focusing on developing **smart parking solutions**. Their expertise spans miniaturisation, long-distance communication, and space-qualified

electronics, all of which contribute to their high-precision, cost-effective parking management systems.

They offer high-precision, cost-effective tools for **digitising parking infrastructure**, providing data creation, monitoring, and protection for parking slots. Their technology not only streamlines parking but also enables cities and businesses to optimise revenue through congestion pricing while offering enforcement tools for cities and towing companies. Fleximodo's modular IoT-based systems support efficient parking management, contributing to sustainable urban mobility.

Camasys is a technology company that offers **cloud-based solutions for car rental and fleet management**. It offers an all-in-one management system that addresses key industry challenges, such as digitalisation, sustainability, and operational efficiency. The system's key features include dynamic pricing, e-documentation, fleet management, online reservations, and damage control.

The Camasys system is accessible via a website, enabling customers to check vehicle availability and make real-time bookings, enhancing the user experience and driving sales. The Camasys Mobile Drop-In/Off application further streamlines the vehicle delivery and return process, allowing users to efficiently document vehicle conditions for smoother transitions and easy access to vehicle history.

IoMobility Solutions s.r.o. is a technology company focused on creating innovative **digital solutions that enhance urban mobility**. They specialise in smart mobility systems, offering an ecosystem designed to streamline transportation through modern infrastructure, IoT devices, and digital platforms. Their Internet of Mobility (IoM) Ecosystem integrates various aspects of urban transport such as traffic flow, shared mobility, and e-mobility, providing tools for monitoring, analysis, and management. By focusing on user experience, convenience, and sustainability, IoMobility helps municipalities and businesses improve mobility services, reduce congestion, and optimise urban transportation for smoother, more efficient travel.

Intelligent Transportation Systems

The **Intelligent Transportation Systems** category includes companies that develop technologies and services designed to enhance transportation efficiency, safety, responsiveness, integration, and sustainability. These companies focus on traffic management and urban parking solutions, providing tools to optimise transportation infrastructure and decision-making processes for municipalities. Additionally, firms offer advisory services, data collection, and management solutions that help streamline operations for public and private transport entities. The industry also emphasises safety through advanced monitoring systems, emergency response devices, and the integration of AI for energy management and operational efficiency.

BETAMONT s.r.o. operates within the **Intelligent Transport Systems** sector, focusing on the development and **integration of advanced technologies for road and rail** transport. The company's work includes traffic management systems that enhance vehicle flow and safety, toll systems designed for interoperability, and analytics for traffic forecasting and infrastructure planning.

A central component of BETAMONT's offerings is the Measure-in-Motion® modular platform, which serves multiple functions, including vehicle diagnostics and enforcement mechanisms for various transportation modes.

The company engages in **R&D** in key areas such as sensor technology for transport and industry, virtual intelligent spaces, Edge Computing, Cloud computing, Big Data, IoT, and deep data analysis. Their projects are driven by market needs and national transportation initiatives, including the development of real-time traffic monitoring systems, enhancement of highway information systems, implementation of a weighing-in-motion system for vehicles, establishment of a Telematics Systems Research Centre, and design of systems for free-flow vehicle weighing.

NOPE, a.s. is an intelligent transport systems company specialising in the design and implementation of comprehensive **transport management solutions**. The company provides critical information and control systems that enhance the safety, efficiency, and reliability of transport infrastructures.

A notable innovation from NOPE is the MIRSA application, developed to monitor road surface conditions and optimise winter maintenance operations. This application integrates data from various sources, including weather stations and vehicular inputs, facilitating effective decision-making for transport authorities. Furthermore, NOPE's expertise encompasses a range of technologies, including variable traffic signs, emergency telephones, and advanced road meteorology systems, all designed to improve transport safety and efficiency.

TransData s.r.o. is a provider of comprehensive hardware and software solutions for **public transport management and passenger handling**. The company's information systems offer real-time visual and acoustic updates regarding vehicle routes, trip durations, and announcements through various information panels, including features for the visually impaired. These systems integrate seamlessly with central dispatch operations, enabling transport operators to relay real-time traffic conditions, delays, and updates to passengers.

Among their offerings, TRANSFLEET facilitates real-time vehicle management, aiming to reduce operating costs, enhance transport quality, and improve passenger satisfaction while providing analytical insights for more efficient traffic management. TRANSOFFICE delivers an integrated overview of public transport business processes,

encompassing passenger transport planning, sales device management, employee records, and personalised traffic card management.

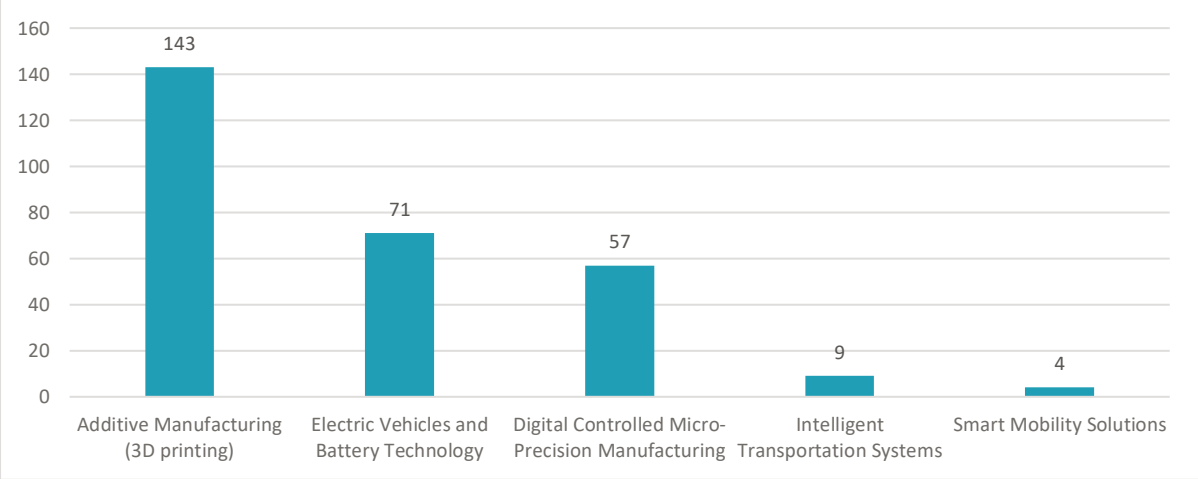
5. Analysis of Slovak researchers involved in cutting-edge automotive technology research

To evaluate the Slovak commercial presence in cutting-edge automotive technologies relative to its research base, we analysed the academic contributions of Slovak authors in relevant fields. The sample for this analysis includes **244 unique researchers affiliated with 15 research and educational facilities**[16].

Nevertheless, in terms of absolute numbers, **the largest group of researchers is engaged in Additive Manufacturing,** with 143 researchers (Figure 15). This is followed by those working on Electric Vehicles and Battery Technology (71) and Digital Controlled Micro-Precision Manufacturing (57). ITS and Smart Mobility Solutions rank lower, with only 9 and 4 researchers, respectively.

It is essential to note that some domains, particularly Intelligent Transport Systems (ITS) and smart mobility solutions, represent practical applications spanning diverse sectors. Therefore, it is expected that specific examples of research in these areas may be limited. This observation does not suggest a lack of research in these fields; rather, it highlights that these applications often rely on foundational research in areas such as IoT, AI, Big Data analytics, etc.

FIGURE 15. COUNT OF RESEARCHERS ACROSS CUTTING-EDGE TECHNOLOGIES*



Source: produced by the study team.

** The same researcher can be responsible for more than one technology.*

In terms of institutional distribution, **most researchers in the automotive sector are affiliated with the three leading Slovak institutions: the Technical University of Košice (78), the University of Žilina (76), and the Slovak University of Technology in Bratislava (52).** Specifically, for Electric Vehicles and Battery Technology, most researchers are based at the University of Žilina, while nearly half of the researchers in additive manufacturing come from the Technical University of Košice (

[16] The initial available sample included 3,198 researchers across 126 institutions. However, several filters have been applied, namely 1) researchers with their last known institution in Slovakia (ensures focus on national research capabilities), 2) researchers with at least one publication since 2019 (assumed to be active researchers), and 3) researchers with at least five term-related publications (to help identify researchers focusing on applied research).

Table 4).

TABLE 4. AUTHORS RELATED TO AUTOMOTIVE INDUSTRY AND SHARE OF AUTHORS PER INSTITUTION*

CENTER	TECHNICAL UNIVERSITY OF KOŠICE	UNIVERSITY OF ŽILINA	SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA	OTHER[17]	TOTAL
Electric Vehicles and Battery Technology	9 (13%)	43 (61%)	15 (21%)	4 (6%)	71 (100%)
Digital Controlled Micro-Precision Manufacturing	15 (26%)	11 (19%)	13 (23%)	18 (32%)	57 (100%)
Additive Manufacturing (3D printing)	67 (47%)	26 (18%)	32 (22%)	18 (13%)	143 (100%)
Smart Mobility Solutions		4 (100%)			4 (100%)
Intelligent Transportation Systems		8 (89%)		1 (11%)	9 (100%)

Source: produced by the study team.

** The same researcher can be responsible for more than one technology.*

[17] *OTHER institutions* include Comenius University Bratislava, Institute of Electrical Engineering, Trencianska Univerzita Alexandra Dubceka V Trencine, Institute of Materials Research, Institute of Informatics, Institute of Inorganic Chemistry, Institute of Materials and Machine Mechanics, Slovak Academy of Sciences, Technical University of Zvolen, University of Pavol Jozef Šafárik, Centre of Excellence for Advanced Materials Application, Institute of Experimental Physics, and Selye János University.

6. Annex 1: Desk research and literature review

1. Alami, A. H., Olabi, A. G., Alashkar, A., Alasad, S., Aljaghoub, H., Rezk, H., & Abdelkareem, M. A. (2023). Additive manufacturing in the aerospace and automotive industries: Recent trends and role in achieving sustainable development goals. *Ain Shams Engineering Journal*, *14*(11), 102516.
2. De Pinaga, C. B., & Van Eweyk, A. R. (2023). A Review of Green Technology and its Effects in the Auto Industry.
3. Deloitte US. (2024). 2024 Global Automotive Consumer Study: Tracking consumer trends in the automotive industry. Deloitte. https://www2.deloitte.com/us/en/pages/consumer-business/articles/global-automotive-consumer-study.html
4. European Commission, Executive Agency for Small and Medium-sized Enterprises, (2020). Artificial intelligence : critical industrial applications: report on market analysis of prioritised value chains, the most critical AI applications and the conditions for AI rollout, Publications Office. https://data.europa.eu/doi/10.2826/838431
5. Fekri, M., Jafari, M., & Mahdavi Mazdeh, M. (2022). The impact of Industry 4.0 on the automotive business models: A successful transition through an integrated system-engineering and strategic perspective. *Available at SSRN 4181782*.
6. McKinsey & Company. (2017). Hydrogen: The next wave for electric vehicles? Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/hydrogen-the-next-wave-for-electric-vehicles
7. McKinsey & Company. (2019). Autonomous driving's future: Convenient and connected. Retrieved from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/autonomous-drivings-future-convenient-and-connected
8. Nash, M. (2024). Additive manufacturing: Supporting sustainable production. Automotive Manufacturing Solutions. https://www.automotivemanufacturingsolutions.com/sustainable-production/additive-manufacturing-supporting-sustainable-production/45315.article
9. Papadimitriou, D., & Duysinx, P. (2022). FUTURE MOVE: A review of the main trends in the automotive sector at Horizon 2030 in the Great Region.
10. Papulová, Z., Gažová, A., & Šufliarský, Ľ. (2022). Implementation of automation technologies of industry 4.0 in automotive manufacturing companies. *Procedia Computer Science*, *200*, 1488-1497.
11. Pichler, M., Krenmayr, N., Schneider, E., & Brand, U. (2021). EU industrial policy: Between modernization and transformation of the automotive industry. *Environmental Innovation and Societal Transitions*, *38*, 140-152.
12. PwC. (2017). Eascy - The five dimensions of automotive transformation. Retrieved from https://www.pwc.com/gx/en/industries/automotive/publications/eascy.html
13. Richert, M., & Dudek, M. (2023). Selected Problems of the Automotive Industry—Material and Economic Risk. Journal of Risk and Financial Management, 16(8), 368.
14. SpecialChem. (2020). Emerging Trends and Developments in Thermoplastic Elastomers. https://omnexus.specialchem.com/tech-library/article/emerging-trends-and-developments-in-thermoplastic-elastomers
15. Sütőová, A., Šooš, Ľ., & Kóča, F. (2020). Learning needs determination for industry 4.0 maturity development in automotive organisations in Slovakia. *Quality Innovation Prosperity*, *24*(3), 122-139.
16. Valaskova, K., Nagy, M., Zabojnik, S., & Lăzăroiu, G. (2022). Industry 4.0 wireless networks and cyber-physical smart manufacturing systems as accelerators of value-added growth in Slovak exports. *Mathematics*, *10*(14), 2452.

7. Annex 2: Technology lists creation

The scoping process for the automotive sector involved compiling a comprehensive list of advanced technologies. This was approached methodically, combining the use of ChatGPT with traditional desk research and literature review. The research team used ChatGPT to generate: 1) a list of advanced technologies relevant to the automotive sector; 2) a list of established (non-advanced) automotive technologies. PPMI consulted ChatGPT to gain preliminary insights on significant technologies, establishing a foundation for research and helping to shape focal points for the study by producing relevant lists. These lists were then validated through desk research and review of the latest industry trends.

To further develop and verify the list of advanced automotive technologies, a systematic literature review was conducted. This included sourcing and analysing academic papers, industry reports, and market analyses to identify current trends and innovations in the automotive sector (see Annex 1 for the full list of reviewed sources). The breadth and diversity of sources provided a well-rounded view of the current technological landscape. After completing the desk research, identified technologies were grouped into five categories, namely Intelligent Transportation Systems, Smart Mobility Solutions, Electric Mobility and Battery Technology, Additive Manufacturing (3D printing), and Digital Controlled Micro-Precision Manufacturing. This stage was followed by the creation of a detailed list, including brief descriptions of each technology, highlighting their relevance and potential advantages.

As a result of the abovementioned methodological steps – desk research and the Chat GPT search – we have created a list of the most recent and impactful cutting-edge technologies in the automotive sector:

1. ***Intelligent Transport Systems:*** *Integrated technology systems used to enhance transport infrastructure and improve efficiency, safety, and sustainability. ITS includes real-time traffic management, vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, and smart traffic signals.*
2. ***Smart Mobility Solutions:*** *Innovative solutions that optimise transport systems for urban environments. This includes ride-sharing platforms, micro-mobility options (like e-scooters), multimodal trip planning, and technologies aimed at reducing congestion and improving access to various transport modes.*
3. ***Electric Mobility and Battery Technology:*** *Technologies focused on electric vehicles (EVs) and advancements in battery storage, performance, and sustainability. This includes lithium-ion batteries, fast-charging infrastructure, and efforts towards solid-state and next-generation battery technologies.*
4. ***Additive Manufacturing (3D Printing):*** *A process that creates three-dimensional objects by layering materials based on digital models, offering benefits in design flexibility and material efficiency. Used in automotive, aerospace, healthcare, and more, this technology enables on-demand production and rapid prototyping.*
5. ***Digitally Controlled Micro-Precision Manufacturing:*** *Manufacturing techniques using digital controls to achieve extreme precision in the creation of small and complex components. Essential in industries like electronics and medical devices, this includes CNC (Computer Numerical Control) machines, laser machining, and micro-milling technologies to achieve high accuracy and repeatability.*

After keywords validation using desk research, the keywords were entered into Milda.ai, which produced company lists for each technology. Below we provide specific keywords for automotive technology company search in Milda.ai.

TABLE 5. LIST OF KEYWORDS USED FOR EACH CUTTING-EDGE TECHNOLOGY AUTOMOTIVE SECTOR

TECHNOLOGY	KEYWORDS
Intelligent Transportation Systems	Toll system development OR intelligent traffic management software OR smart road traffic control systems OR software-integrated parking regulation solutions OR intelligent transportation systems OR traffic control system software OR real-time traffic data analysis OR urban smart traffic management solutions OR advanced smart transportation systems OR connected transport infrastructure solutions OR vehicle-to-infrastructure
Smart Mobility Solutions	real-time fleet tracking OR real-time vehicle tracking OR mileage tracking OR digital driver identification OR smart parking solutions OR real-time vehicle performance analysis OR real-time vehicle alerts OR real-time car monitoring OR real-time vehicle monitoring OR automatic drive book generation OR smart urban mobility OR smart mobility data analysis OR smart mobility OR smart mobility applications OR shared mobility applications OR car-sharing applications OR Fleet Management Software OR real-time vehicle location data OR real-time vehicle monitoring data OR GPS vehicle monitoring applications OR innovative mobile application OR smart parking app OR real-time car monitoring
Electric Mobility and Battery Technology	electric mobility OR electric vehicle production OR electric vehicle battery supply OR EV battery production OR electromobility solutions OR electric motor production OR electric vehicle charging OR smart EV charging solutions OR EV charging stations OR electric vehicle infrastructure OR electric vehicle integration OR electric vehicle design OR electric vehicle technology OR hydrogen-powered vehicles OR zero-emission bus development OR electric vehicle charging network OR electric car charging solutions OR vehicle electrification OR powerline communication for electric vehicles OR shared electric mobility OR electric motor manufacturing OR hydrogen mobility solutions
Additive Manufacturing (3D printing)	3D printing OR rapid prototyping OR custom part production OR metal additive manufacturing OR composite materials OR ceramic parts production OR on-demand part production OR Nickel-titanium alloy production OR special steel grades OR specialty metal fabrication OR high-performance alloys OR CAD design OR production of rapid prototypes
Digital Controlled Micro-Precision Manufacturing	Computer Numerical Control Machining OR Computer Numerical Control grinding OR Computer Numerical Control turning OR wire Electrical Discharge Machining OR sinker Electrical Discharge Machining OR laser cutting OR laser micromachining OR laser welding OR selective laser melting OR Micro-stereolithography OR Micro-stereolithography OR Ultrasonic Machining OR Ion Beam Machining OR Micro-Drilling OR Focused Ion Beam OR Photolithography OR CNC Machining

Source: compiled by the study team based on search in Chat GPT and desk research.

8. Annex 3: Company list (excel file)

Please find the excel list with analysed Slovak automotive companies as a separate attachment.

PPMI

Part of the
Verian Group

Funded by
the European Union

Visit our website:

Find out more
about the Technical
Support Instrument: