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INNOVATION HUBS AS CATALYSTS FOR INDUSTRY 4.0 ADOPTION TO ENHANCE BUSINESS GROWTH

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Abstract. The objective of this paper is to analyse the ways that innovation hubs support the implementation of Industry 4.0 in the textile industry of Latvia and establish a relationship between digitalisation, business model innovation and sustainability for the growth of the sector. Thus, it is possible to state that further research allows us to determine that industry capability in Latvia's textile sector and readiness for Industry 4.0 can be improved by the integrated approach based on technologies' integration and development and economic and sustainable strategies application. The authors used an online questionnaire survey to gather responses from different experts and analysed the data using Spearman correlation analysis. The findings thus re-emphasise the need for a range of support from hubs, bearing in mind that the support that is required ranges from physical structures, access to strategic information, advisory services, and other essential services for firms to be able to effectively transform digitally and adapt their business models. Recommendations, which are focused on the improvement of the Latvian innovation environment, are the increase of support for innovation hubs, the development of business model innovations, the better tackling of sustainability issues and the provision of further tailored high-quality innovation support services for the textile sector.

Keywords*: Business growth, digital technology integration, Industry 4.0 adoption, innovation hubs, textile industry.*

JEL Classification: O14, O33, O36

INTRODUCTION

The OECD (2023) recognizes Latvia's efforts in introducing Industry 4.0 through innovation hubs and anticipatory innovation ecosystems, facilitating SME integration into digital transformation. These hubs support digital technology management, enhancing knowledge exchange and access to innovation. Similarly, Sassanelli et al. (2021) highlight the critical role of Digital Innovation Hubs (DIHs) in Industry 4.0 adoption, emphasizing their significance in guiding firms through technological advancements.

Innovation hubs are key enablers of Industry 4.0, offering education, technological support, consulting, capacity building, and strategic planning for

SMEs (Cotrino et al., 2021). This research fills a critical gap in scholarly literature, as limited studies have explored Latvia's textile sector in the context of digital transformation. While Hmamed et al. (2024) and Sassanelli et al. (2021) have examined digital innovation broadly, no prior research has specifically analysed Latvian innovation hubs' role in Industry 4.0 adoption within the textile industry. Therefore, the research focuses on the research questions 'What are the different impacts of Innovation hubs in the adoption of Industry 4.0 technologies in the textile industry of Latvia?' and 'What can be done to enhance the industry 4.0 adoption in the Latvian textile industry?'. The research questions had been developed to address the research gap developed from the existing literatures.

Research by Hmamed et al. (2024) suggests that innovation hubs in the textile sector accelerate Industry 4.0 adoption, reduce inefficiencies, and promote business model transformation. Egessa et al. (2024) emphasize the need for innovation hubs to foster collaboration, drive new solutions, and support Industry 4.0 integration. Digital Innovation Hubs (DIHs) further enhance organizational initiatives and regional interactions (Egessa et al., 2024).

This study explores the role of innovation hubs in facilitating Industry 4.0 adoption in Latvia's textile industry to drive business growth. It posits that innovation hubs contribute to technological expansion, cost and time efficiency, productivity optimization, business model innovation, and increased competitiveness. The research highlights their crucial role in advancing digital transformation and industry competitiveness.

1. CONCEPTUAL FRAMEWORK AND DEVELOPMENT OF HYPOTHESES STATEMENTS

1.1. Overview of the Latvian Textile Industry

History and Market Growth

Latvia's textile and clothing sector has a long history rooted in natural materials, high quality, and a true-to-life ethos (Investment and Development Agency of Latvia, 2022). While the industry remains significant, it now focuses on specialized products such as linen ropes and technical textiles. The revenue trends from 2012 to 2022 highlight periods of decline, recovery, and resilience. Revenue fell from €235.9 million in 2012 to €189.1 million in 2016, followed by a recovery to €208.8 million in 2018. A slight drop in 2019 (€202.5 million) was followed by a sharp decline in 2020 (€177.3 million) due to the COVID-19 pandemic. However, the industry rebounded to €196.6 million in 2021 and €210.7 million in 2022, indicating resilience and growth potential. Cooperation within the industry provides competitive advantages in lead time, volume, price, and quality relations (Investment and Development Agency of Latvia, 2022). Additionally, Fig. 1 illustrates the export volume of Latvia's textile industry, reinforcing its role in the global market.

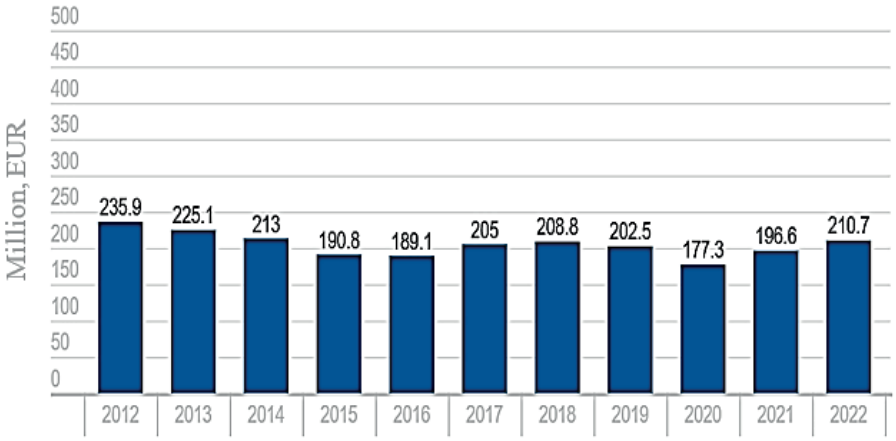

Fig. 1. Export volume of Latvian textile industry (Investment and Development Agency of Latvia, 2022).

Therefore, the Latvian textile industry has shown fluctuating growth over the past decade, with a notable decline from 2012 to 2016, recovery in the following years, and a significant dip in 2020 due to the pandemic. However, the industry has demonstrated resilience and post-pandemic recovery, indicating potential for further growth in the coming years. The following paragraphs describes the major textile companies in Latvia.

Major Textile Companies in Latvia

Latvia has a significant number of textile companies, including Lauma Fibers, Nexis Fibers, Malan Ltd, Gefa Latvija, Klippan-Saule, Marta-F ASRiga, Mertex Latvia, Ezroze, Foli Baltic, Froli Baltic, Magestt, Giwama, Mmatotex, MTele Textile Latvia, Martex Latvia RazotneSmiltenes, Mrukis, Mwooly World, eora Pluss, MVIP Factory, Lite, Audentia, Mwww.Zaluzi.Eu, Mreo Lat, MTativa Fibris, Masakura, Mppbb, Muze, and Thomson Solutions. These companies contribute significantly to the country's textile industry (Dun & Bradstreet, 2024).

Characteristics of Current Business Model

The business which is used in the Latvian textile industry is increasingly focused on the concept of a circular economy (Atstāja et al., 2021). This is a good reason why businesses are changing to circular business models in order to address social sustainability indicators in business. Enterprise modelling for the industry since cost production and ecological effects are some of the changes that need to be considered in relieving needs in a competitive market (Geipele et al., 2015).

Role of Industry 4.0 Adoption in the Textile Industry

The research by De Oliveira Neto et al. (2022) points to the view that Industry 4.0 fast technologies and Digital Innovation Hubs (DIHs) in the textile industry advance creativity and responsibility. The concept is that the integration of the Internet of Things (IoT), blockchain, and big data can contribute to the successful implementation of sustainable practices (De Oliveira Neto et al., 2022). The following are the different impacts of innovation hubs in the adoption of Industry 4.0 in the Latvian Textile Industry.

1.2. Digital Technology Integration

To address declining production, Latvian textile companies established innovation hubs like the Textile Prototyping Lab (TPL) to drive digitalization and open innovation (Šahta et al., 2012). Digital Innovation Hubs (DIHs) play a vital role in textile digitization, offering SMEs services to experiment with and implement digital innovations, fostering cooperation (Vijayakumar & Davidova, 2023). They contribute to regional innovation systems and align with smart specialization strategies, requiring stable financial support (Georgescu et al., 2023).

The application of digital technologies, facilitated by innovation hubs, has strengthened Latvia's textile sector globally through smart textiles and advanced manufacturing. These efforts have boosted productivity and innovation, but sustained financial investment is necessary for continued digital integration. The hypothesis statement of the research is as follows. H1: Higher levels of digital technology integration in the textile industry, facilitated by innovation hubs, positively contribute to the success of digital transformation efforts.

1.3. Business Model Innovation

Business model innovation serves as a key driver of digitalization and competitiveness in the textile industry, including Latvia. Digital Innovation Hubs (DIHs) play a crucial role in facilitating this transformation by enhancing cooperation, supporting SMEs, and providing modern digital solutions (Sotirofski & Kraja, 2024). Additionally, the integration of Industry 4.0 technologies fosters changes in operations, competition, and sustainability, enabling companies to adopt innovative business models such as subscription services, product-service systems, and mass customization (Ikeng & Wang, 2024). By leveraging these advancements, Latvian textile firms can enhance productivity, sustainability, and customer satisfaction, securing a stronger position in the global market. The hypothesis statement is as follows. H2: Business model innovation driven by Industry 4.0 technologies positively impacts the economic growth of Latvia's textile sector.

1.4. Reduction in Waste and Inefficiencies

Business model innovation serves as a key driver of digitalization and competitiveness in the textile industry, including Latvia. Digital Innovation Hubs (DIHs) play a crucial role in facilitating this transformation by enhancing cooperation, supporting SMEs, and providing modern digital solutions (Sotirofski & Kraja, 2024). Additionally, the integration of Industry 4.0 technologies fosters changes in operations, competition, and sustainability, enabling companies to adopt innovative business models such as subscription services, product-service systems, and mass customization (Ikeng & Wang, 2024). By leveraging these advancements, Latvian textile firms can enhance productivity, sustainability, and customer satisfaction, securing a stronger position in the global market. The hypothesis statement is as follows. H3: The integration of sustainable practices positively impacted by innovation hubs leads to a reduction in waste generation and inefficiencies in the textile industry.

1.5. Competitiveness Improvement

According to the research by Radko et al. (2022), innovation hubs are an essential factor toward improving competitiveness in the textile business. The specific concept of this nation's economic development is venturing capital or VC, human capital or HC, and clustering. The case is evident that the integration of technology and information transfer is a critical success factor for long-run development (Radko et al., 2022).

According to the research by Al Bunni and Saleh, they also insist on the necessity of studying anticipatory innovation governance as the primary factor that can act as a catalyst for change and development of anticipatory innovation ecosystems. They focus more on attaining the aim of innovation and collaboration strategies for enhancing the textile industry and benefiting from the technologies (Al Bunni et al., 2019).

Thus, it is notable that increasing competitiveness in the textile sector among the countries like Latvia is the result of the application of innovative technologies, launch of innovative clusters, expansion of markets, use of environmentally friendly technologies and conditioning of personnel. These strategies seek to improve the products' quality, increase product differentiation and adapt to new markets, and overall meet the buyer's green characteristics. Therefore, the hypothesis statement can be developed as follows. H4: The variety and effectiveness of support services provided by Digital Innovation Hubs positively enhance the competitiveness of textile companies. Figure 2 shows the conceptual framework of the research.

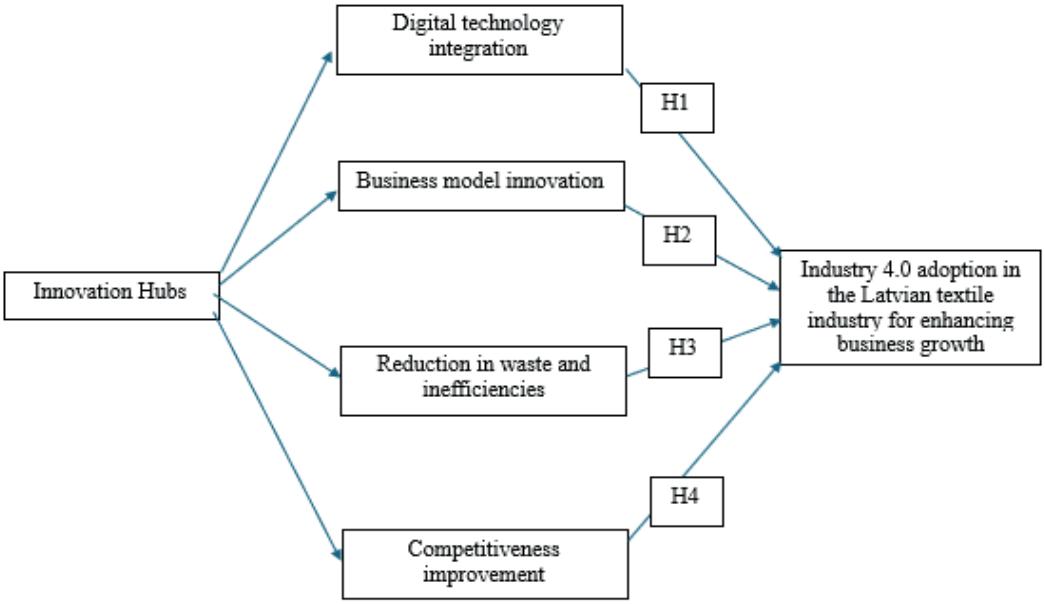

Fig. 2. Conceptual framework of the research (Created by authors).

The conceptual framework highlights the role of innovation hubs in driving Industry 4.0 adoption within Latvia's textile industry through four key mechanisms: digital technology integration, business model innovation, reduction in waste and inefficiencies, and competitiveness improvement. These factors collectively contribute to enhanced business performance, emphasizing the need for innovation-driven ecosystems. To validate this framework, the next section outlines the research methodology, detailing the data collection process, analytical techniques, and overall research design to ensure a comprehensive evaluation of these relationships.

2. METHODOLOGY

The study explores the impact of innovation hubs on Industry 4.0 technology adoption for enhancing the business growth of Latvia's textile industry. Data was collected through an online questionnaire survey and secondary sources. A representative sample of textile companies was selected based on their expertise in adoption of Industry 4.0 technology. The study used descriptive statistics and a Spearman correlation analysis. Ethical considerations were maintained, including informed consent, confidentiality, transparency, and limited access to proprietary data. The findings were specific to Latvia's textile industry, but the study provided a robust analysis of how innovation hubs could contribute to its digital transformation and competitiveness.

2.1. Research Design

This research examines the impact of innovation hubs on Industry 4.0 adoption in the Latvian textile industry using a web-based survey. Key factors analysed include innovation centres, adoption rates, interdisciplinary cooperation, sustainability, business model innovation, digital technology integration, support services, waste reduction, innovation outcomes, economic development, digital transformation success, and competitiveness. Quantitative methods such as descriptive analysis, chi-square tests, and Spearman correlation analysis were applied. Ethical considerations included informed consent, confidentiality, and transparency. While findings highlight how innovation hubs facilitate Industry 4.0 adoption and digital transformation, they may not be directly applicable to other regions or industries without further research.

2.2. Data Collection

Thus, the objective of the study was to seek to understand impacts of Innovation hubs on the industry 4.0 adoption in the Latvian textile industry. A cross-sectional online questionnaire survey was used to identify the extent of adopting technologies in Latvia's textile industry. Such information was obtained from organizations such as textile firms and innovation hub management executives such as:

1. Human resources managers.
2. General managers.
3. Human resource management employees.

4. Research and development department employees.
5. Industry experts.
6. Academic researchers.

The survey consisted of 10 questions, including demographics and Likert scale questions to assess perceptions of Industry 4.0 adoption and business competitiveness (Vijayakumar & Davidova, 2023). The dependent variable was the adoption of industry 4.0 in Latvia's textile industry for business performance, with Likert-scale responses used for measurement. Secondary data sources included government publications, business magazines, and research articles.

Conducted between January 10 and February 14, 2024, via Google Forms, the survey used exponential non-discriminative snowball sampling. Out of 200 invitations, 150 responses were received, but 30 lacked consent, leaving a final sample of 120 respondents. The participants, representing HR managers (16.67 %), general managers (16.67 %), HR employees (20.83 %), R&D employees (16.67 %), industry experts (12.5 %), and academic researchers (16.67 %), provided diverse insights.

The survey targeted Riga and Daugavpils for convenience. Data was analysed using SPSS 29, with Cronbach's alpha (0.853) confirming reliability. Descriptive and Spearman correlation analysis provided key insights into Industry 4.0 adoption, indicating broader applicability beyond Latvia.

2.3. Data Analysis

Spearman correlation analysis was used to assess the strength and direction of relationships between ranked variables in Latvia's textile industry, particularly in the context of Industry 4.0 adoption. The study utilized an online questionnaire via Google Forms, with data analysed using Microsoft Excel and SPSS 29. The analysis revealed significant correlations, providing valuable insights for stakeholders to enhance Industry 4.0 adoption, improve competitiveness, reduce waste, and adapt business models.

3. RESULTS

This study used descriptive and Spearman correlation analysis to analyse data on Industry 4.0 adoption, business model innovation, waste reduction, and competitiveness in Latvia's textile industry.

3.1. Results of Descriptive Analysis

The survey was performed with the help of Google Forms, and the data was analysed using SPSS 29 software. The survey data descriptive statistics are briefly detailed in Table 1.

Based on the item statistics, one can conclude that overall, Latvian textile industry's organisations have a fairly positive attitude towards Industry 4.0 technologies. These statistics are useful for other recommendations and investigations on the steps to increase the usage of Industry 4.0 technologies in the industry.

Table 1. Descriptive Analysis (Created by authors using SPSS 29)

Item statistics			
	Mean	**Std. deviation**	***N***
Industry 4.0 adoption in the Latvian textile industry	4.017	0.5343	120
Digital technology integration	3.283	0.8218	120
Business model innovation	3.842	0.6481	120
Reduction in waste and inefficiencies	3.992	0.6416	120
Competitiveness improvement	3.375	0.9707	120

3.2. Results of Spearman Correlation Analysis

The study uses the Spearman correlation coefficient test to evaluate the impact of innovation hubs on Industry 4.0 adoption in Latvia's textile industry. The analysis finds a strong association between Industry 4.0 adoption and digital technology integration, business model innovation, efficiency improvements, and competitiveness. A significant correlation ($p < 0.05$) with a coefficient of 0.587 confirms a positive relationship between Industry 4.0 and digital technology in the sector. Table 2 describes the results of the Spearman correlation analysis of the variable digital technology integration.

Table 2. Spearman Correlation Analysis of Digital Technology Integration (Created by authors using SPSS 29)

Correlations				
			Adoption of Industry 4.0 in the Textile industry of Latvia for enhancing business performance	**Digital technology integration**
Spearman's rho	Adoption of Industry 4.0 in the textile industry of Latvia for enhancing business performance	Correlation coefficient	1.000	0.587
		Sig. (2-tailed)	X	0.000
		N	120	120
	Digital technology integration	Correlation coefficient	0.587	1.000
		Sig. (2-tailed)	0.000	X

The findings suggest that higher digital technology integration leads to better business performance and success in digital transformation efforts. Table 3 describes the Spearman correlation analysis of the business model innovation variable.

Table 3. Spearman Correlation Analysis of Business Model Innovation
(Created by authors using SPSS 29)

Correlations				
			Adoption of Industry 4.0 in the textile industry of Latvia for enhancing business performance	**Business model innovation**
Spearman's rho	Adoption of Industry 4.0 in the textile industry of Latvia for enhancing business performance	Correlation coefficient	1.000	0.689
		Sig. (2-tailed)	X	0.000
		N	120	120
	Business model innovation	Correlation coefficient	0.689	1.000
		Sig. (2-tailed)	0.000	X
		N	120	120

The study identifies a strong positive correlation between business model innovation and Industry 4.0 adoption in Latvia's textile industry. Based on a 120-sample analysis, the findings highlight the importance of innovative business models in driving technology adoption and improving business performance. Continuous innovation and strategic business model development are essential for the industry's growth. Table 4 shows the Spearman correlation analysis of the reduction in waste and inefficiencies variable.

Table 4. Spearman Correlation Analysis of Reduction in Waste and Inefficiencies
(Created by authors using SPSS 29)

Correlations				
			Adoption of Industry 4.0 in the textile industry of Latvia for enhancing business performance	**Reduction in waste and inefficiencies**
Spearman's rho	Adoption of Industry 4.0 in the textile industry of Latvia for enhancing business performance	Correlation coefficient	1.000	0.730
		Sig. (2-tailed)	X	0.000
		N	120	120
	Reduction in waste and inefficiencies	Correlation coefficient	0.730	1.000
		Sig. (2-tailed)	0.000	X
		N	120	120

This study suggests that the implementation of Industry 4.0 will enhance efficiency and reduce unproductiveness in Latvia's textile industry. The summative studies based on the 120-sample provide evidence that it is possible to reduce waste through the adoption of sustainable practices containing innovation centres. Industry 4.0 technologies enhance business performance and sustainability in the textile industry. This supports the current research on how advanced technologies aid in enhancing process improvement.

The result of the analysis proves that there is a positive relationship between the extent of Industry 4.0 implementation and competitiveness enhancement in Latvia's textile industry. The correlation that we found is highly statistically significant, which means that the probability of observing such a correlation randomly is low. It would, therefore, be important to note that with a sample size of 120, the study has a reliable sample upon which the findings and analysis will be made. A summary of these findings is that overall, the support services offered by the Digital Innovation Hubs contribute to enhanced competitiveness of the textile firms. The use of Industry 4.0 technologies in the improvement of competitiveness has the potential of enhancing the performance of the business and thus advancing the economy within the textile industry.

Evaluation of the competitiveness improvement variable, as presented in Table 5, reveals that Industry 4.0 has a positive impact on the competitiveness improvement of Latvia's textile industry. This relationship is statistically significant, which means that the probability of obtaining such an association by random chance is very small. The number of participants is 120, that do make the sample size adequate for the analysis. The results of the research confirm the hypothesis that the services offered by Digital Innovation Hubs enhance the competitiveness of textile firms. Table 5 below shows the Spearman correlation analysis of the competitiveness improvement variable.

Table 5. Spearman Correlation Analysis of Reduction in Waste and Inefficiencies (Created by authors using SPSS 29)

Correlations				
			Adoption of Industry 4.0 in the textile industry of Latvia for enhancing business performance	**Competitiveness improvement**
Spearman's rho	Adoption of Industry 4.0 in the textile industry of Latvia for enhancing business performance	Correlation coefficient	1.000	0.629
		Sig. (2-tailed)	X	0.000
		N	120	120
	Competitiveness improvement	Correlation coefficient	0.629	1.000
		Sig. (2-tailed)	0.000	X
		N	120	120

The analysis shows a strong positive correlation between Industry 4.0 adoption and key factors in the Latvian textile industry. Waste reduction, closely linked to sustainability, has the highest correlation (0.730), followed by business model innovation (0.689) and digital technology integration (0.629). These findings highlight the significant impact of Industry 4.0 on improving efficiency, competitiveness, and sustainability in the sector.

4. DISCUSSIONS

The theoretical framework examines the Latvian textile industry's adoption of Industry 4.0. Mean scores indicate a favourable perception of key factors, with Spearman's rho analysis showing moderate to high positive correlations. This suggests that companies integrating these factors are more likely to adopt and implement Industry 4.0 technologies. The research hypotheses and their validation are presented in the following paragraphs.

H1: Higher levels of digital technology integration in the textile industry, facilitated by innovation hubs, positively contribute to the success of digital transformation efforts.

The correlation analysis revealed a moderate positive relationship (0.587) between digital technology integration and Industry 4.0 adoption in Latvia's textile industry. Innovation hubs play a key role in advancing digitalization by providing essential tools and expertise. Supporting literature, including Georgescu et al. (2023), highlights digital transformation as crucial for maintaining competitiveness. Additionally, IoT and smart manufacturing technologies are vital for achieving full-scale digitalization in the textile sector.

H2: Business model innovation driven by Industry 4.0 technologies positively impacts the economic growth of Latvia's textile sector.

The data analysis indicates a strong positive correlation (0.689) between business model innovation and Industry 4.0 adoption, demonstrating that increased digitization facilitates the development of new business models. Supporting research by Ikeng & Wang (2024) suggests that Industry 4.0-driven business models can enhance economic diversification in the textile industry. The level of adoption varies, but these technologies play a crucial role in reshaping value propositions, optimizing interactions, and streamlining operations. Ultimately, leveraging advanced digital tools fosters business model innovation, driving economic growth and improving the textile sector's overall performance.

H3: The integration of sustainable practices positively impacted by innovation hubs leads to a reduction in waste generation and inefficiencies in the textile industry.

The data analysis reveals a strong positive correlation (0.730) between Industry 4.0 adoption and waste minimization in the textile sector. This highlights the crucial role of innovation hubs and sustainable practices in enhancing efficiency and reducing resource wastage. The findings suggest a high probability that Industry 4.0 technologies contribute to waste reduction, aligning with research by Chaloupková et al. (2023), which emphasizes the impact of automation and advanced analytics in optimizing production processes.

H4: The variety and effectiveness of support services provided by Digital Innovation Hubs positively impact the competitiveness of textile companies.

The data analysis confirms a positive correlation between Industry 4.0 adoption and improved competitiveness, highlighting the need to support Digital Innovation Hubs in enhancing the competitiveness of textile companies. Research by Radko et al. (2022) emphasizes the role of innovation hubs in providing essential services, consultancy, and advanced tools. Overall, digital technologies, business model adaptation, sustainable initiatives, and support from Digital Innovation Hubs drive Industry 4.0 adoption in the Latvian textile industry. These factors contribute to digitalization, economic growth, and competitiveness. Figure 3 presents a recommendation plan for strengthening Industry 4.0 adoption through Innovation Hubs.

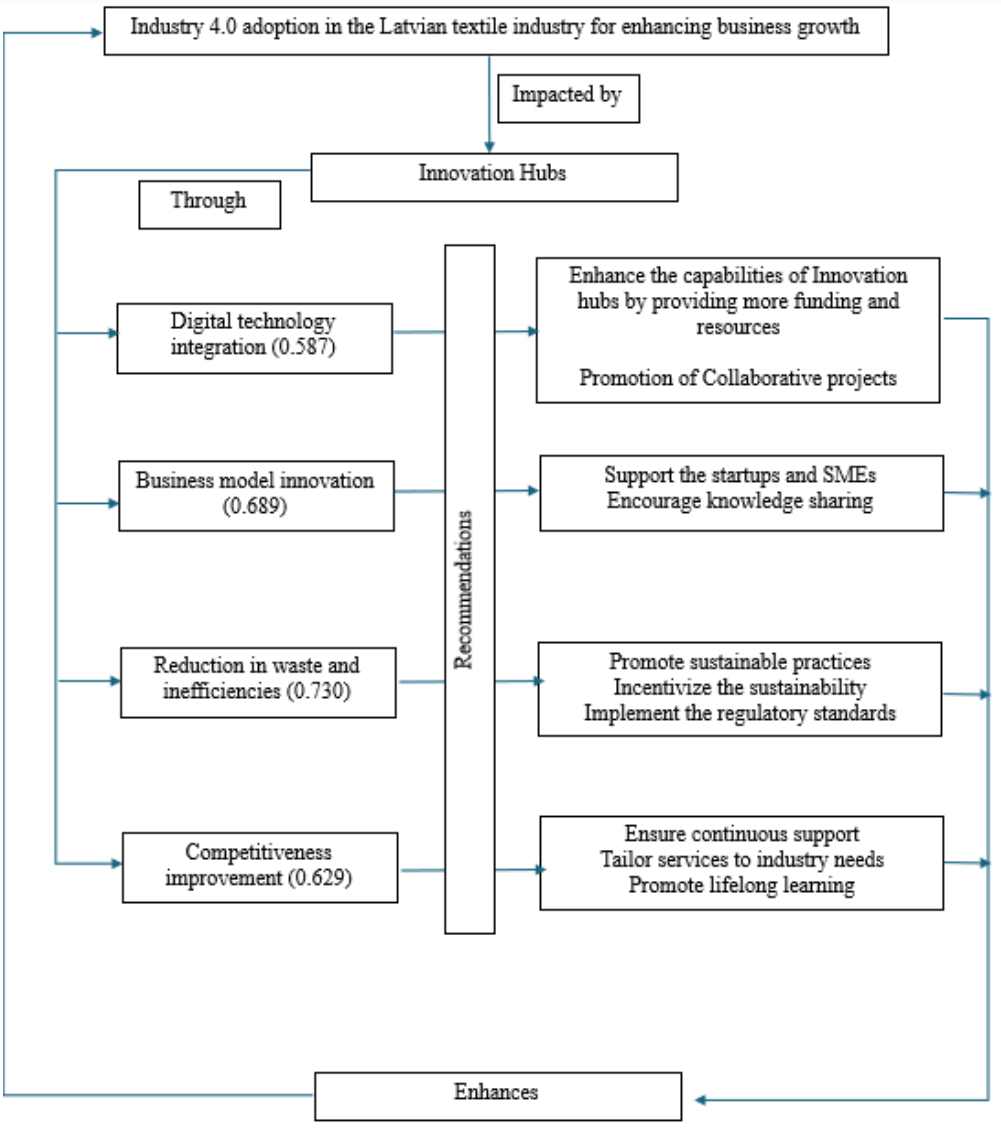

Fig. 3. Recommendation plan for the adoption of Industry 4.0 using innovation hubs (Created by authors).

Therefore, it is suggested that the Latvian textile industry should progressively adopt and expand the use of digital technologies, should persistently adapt business models, work on minimizing inefficiencies and waste reduction initiatives, and provide competitiveness improvement demonstrations on Industry 4.0. It is possible to conclude that addressing these areas will help the industry move forward faster on the way to Industry 4.0 and achieve sustainable development in the long term.

CONCLUSIONS

Digital technologies in the Latvian textile industry and Industry 4.0 concept are necessary for creating a digital environment and improving economic and sustainable performance. An innovation hub, therefore, supports this transition by offering technological enablers, business model innovation stimuli, sustainability enablement, and integrated service provision. All these elements contribute to digitalization, economic development, effectiveness and overall competitiveness.

It is also noted that increased use of digital technologies, as supported by innovation hubs, enhances the likelihood of success in digitalization initiatives in the textile sector. The technological upgrade through the application of Industry 4.0 technologies in business model innovation adds to the growth and improvement of this economic sector in the future. By applying these sustainable practices innovated through innovation hubs, the excess and unnecessary spending that is witnessed in the textile industry will be greatly eliminated.

Key challenges that must be addressed for successful adoption of Industry 4.0 technologies include managing of financials and budgets, improving the skills of human capital, and choosing a competent vendor.

In conclusion, it can be stated that in order to successfully implement Industry 4.0 technologies in Latvia's textile industry, it is necessary to contain four elements of Industry 4.0 strategy, including the innovation hubs, business model innovation, sustainable development and support services. The research can be generalized and can be applicable to other geographical areas since it has excellent reliability as per the Cronbach's alpha test. By implementing the recommended strategies, the industry can achieve a competitive edge, foster sustainable growth, and secure its position in the global market.

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