DOCTORAL THESIS

RESEARCH ON THE SUPPLY CHAIN OF MEDICAL EQUIPMENT FOR EDUCATIONAL INSTITUTIONS OF THE KYRGYZ REPUBLIC

AVAZ KAZAKOV

MINISTRY OF SCIENCE, HIGHER EDUCATION
AND INNOVATION OF THE KYRGYZ REPUBLIC
Kyrgyz State Technical University named after I.Razzakov

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DOCTORAL THESIS

for the degree of Doctor of Philosophy (PhD)

"RESEARCH ON THE SUPPLY CHAIN OF MEDICAL EQUIPMENT FOR EDUCATIONAL INSTITUTIONS OF THE KYRGYZ REPUBLIC"

PhD Doctoral Student: **Kazakov Avaz Asanovich**

Scientific Supervisor: **Orozonova Azyk Abdykasymovna,**
Candidate of Economic Sciences, Associate Professor
Foreign Scientific Supervisor: **Dr. Peter Veres,**
Associate Professor, University Miskolc

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INDEX OF ABBREVIATIONS

ADB – Asian Development Bank
AI – Artificial Intelligence
AHP – Analytical Hierarchy Process
B2C – Business-to-Consumer
BDA – Big Data Analytics
BWL – Betriebswirtschaftslehre (German Business Economics)
CIS – Commonwealth of Independent States
COVID-19 – Coronavirus Disease 2019
DL – Digital Logistics
ERP – Enterprise Resource Planning
ESG – Environmental, Social and Governance
EU – European Union
GDP – Gross Domestic Product
HSCM – Healthcare Supply Chain Management
ICT – Information and Communication Technologies
IoT – Internet of Things
ISM – Interpretive Structural Modelling
IT – Information Technology
JIT – Just-in-Time
KR - Kyrgyz Republic
LCC – Life Cycle Costing
MESC – Medical Equipment Supply Chain
MICMAC – Matrice d'Impacts Croisés Multiplication Appliquée à un Classement
OECD – Organisation for Economic Co-operation and Development
PPP – Public–Private Partnership
RBV – Resource-Based View
RFID – Radio Frequency Identification
RSC – Resilient Supply Chain
SCM – Supply Chain Management
SDG – Sustainable Development Goal
SSCI – Sustainable Supply Chain Innovation
TCE – Transaction Cost Economics
TOE – Technology–Organization–Environment Framework
UNDP – United Nations Development Programme
USA – United States of America
WOS – Web of Science

DEDICATION

I dedicate this dissertation to my beloved parents —
for their boundless love and unwavering faith in me every step of the way.

To my respected mentors, brothers Amangeldi and Esengeldi Zhumadilov —
for their support and inspiration.

To my sister Rimma —
for her constant support, warmth, and belief in me when it mattered most.

Thank you for always being there and helping me move toward my goals.

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I, **Avaz Kazakov**, would like to express my sincere gratitude to my scientific supervisor, **Azyk Abdykasymovna Orozonova**, Candidate of Economic Sciences and Associate Professor, for her invaluable guidance, constant support, and professional advice throughout all stages of this dissertation. Her high academic expertise, personal attention, and dedication have greatly contributed to the success of this research and to my professional growth.

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My deep gratitude also goes to my international supervisor, **Dr. Peter Veres** from the **University of Miskolc (Hungary)**, for his valuable recommendations, methodological guidance, and academic insights that have enhanced the quality and international relevance of my dissertation.

Finally, I would like to thank all professors, colleagues, and staff of the **International Higher School of Logistics**, whose support, professionalism, and goodwill made this academic journey productive, inspiring, and rewarding.

Best regards,
Avaz Kazakov

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ABSTRACT

This doctoral dissertation examines the structure, challenges, and optimisation of the medical equipment supply chain for educational institutions in Kyrgyzstan. The study examines one of the most critical issues facing national education and healthcare systems: the need to provide modern, high-quality equipment for training medical specialists in accordance with international standards. The study places this issue in the context of a broader global transformation of Supply Chain Management (SCM), where logistics, digitalization, and sustainability play a critical role in ensuring institutional effectiveness and competitiveness. The growing demand for medical education and the need to integrate Kyrgyz higher education into international educational and technological systems are also considered.

The main objective of the dissertation is to analyze and improve the existing system of medical equipment supply to universities and medical faculties in Kyrgyzstan to increase its accessibility, efficiency, and sustainability. To achieve this goal, the study formulates several key objectives: assessing the current state and regulatory environment for medical equipment procurement; identifying logistical and institutional bottlenecks; comparing domestic practices with international models; and develop recommendations for sustainable and digitally optimised supply chains in the education sector.

The study's methodological approach combines qualitative and quantitative approaches, including a literature review, comparative analysis, fieldwork, and interviews with suppliers, logistics companies, and representatives of educational institutions. The study utilizes systemic and structural analysis to identify interdependencies between stakeholders, as well as benchmarking and adaptation of best practices to evaluate international experience. The methodological framework integrates concepts from the resource-based approach (RBV), institutional theory, and sustainable SCM, enabling a comprehensive assessment of both the economic and organizational aspects of medical equipment procurement.

The results show that the current supply chain in Kyrgyzstan is characterized by a fragmented logistics infrastructure, overreliance on imported equipment, complex bureaucratic procurement procedures, and limited digital integration. Financial constraints and a lack of coordination between stakeholders further reduce efficiency and lead to delivery delays. Despite these challenges, the study identifies significant opportunities for improvement through the adoption of modern logistics technologies, developing partnerships with local manufacturers, and implementing e-procurement and real-time inventory systems. The analysis

also highlights the potential of public-private partnerships and donor-supported projects, such as those funded by the Islamic Development Bank, to enhance supply chain resilience.

A comparative analysis with leading international models reveals that the United States prioritizes digitalization, predictive analytics, and flexible outsourcing; Germany enhances supply chain resilience through strict regulatory compliance and public-private collaboration; China integrates logistics into industrial clusters and AI-based management systems; and India combines localization policies with digital tracking and decentralized logistics networks. These experiences provide a methodological basis for developing a Kyrgyz model that combines government coordination with market mechanisms and technological innovation.

The scientific novelty of this dissertation lies in its integrated approach to analyzing medical equipment supply chains, combining economic, institutional, and technological aspects. For the first time in Kyrgyzstan, the study proposes a comprehensive concept that combines traditional logistics principles with digital technologies, sustainable procurement, and risk management methods. The implementation of advanced tools, such as big data analytics, blockchain-based traceability, and intelligent inventory control, is justified as a strategic direction for increasing transparency, efficiency, and sustainability.

The practical significance of the study is confirmed by the implementation of its findings in scientific publications and institutional recommendations. The results can serve as a basis for policy reforms in public procurement, educational infrastructure planning, and logistics education. They provide practical guidance for universities, ministries, and private sector partners seeking to modernize procurement systems and ensure equal access to high-quality medical equipment.

In conclusion, the dissertation contributes to the theoretical and methodological development of SCM in the education and healthcare sectors of Kyrgyzstan. By proposing evidence-based strategies for digital transformation, sustainable development, and partnership development, it provides a roadmap for building a more efficient, transparent, and sustainable medical equipment supply system, facilitating long-term improvements in medical education and the formation of human capital in the national economy.

RESUME

Medicine is one of the most dynamically developing areas of human activity, which is due to the constant growth of the need for qualified specialists. These specialists must be able to perform a number of important functions, including diagnostic, therapeutic and preventive, which makes their training especially important in the modern world. Modern technologies and scientific discoveries require continuous professional development of medical workers, as well as high- quality education based on international standards and recommendations.

Training doctors in accordance with international recommendations creates demand for educational services offered by higher professional education systems in many countries. In the conditions of a market economy, which is the main form of economic life, this demand is becoming increasingly significant. As a result, higher education systems, especially in the field of medicine, are becoming an important component of the global educational industry. Countries that are able to provide high quality education attract students from other countries, which contributes to the development of educational services exports.

Educational services exports are a significant part of the economy in many countries around the world. In a number of countries, educational services occupy leading positions among other export services in terms of profitability. For example, countries where universities and institutes provide higher education programs in medical fields are able to attract significant financial resources by educating foreign students. This phenomenon has become an important element of economic strategy for many developed and developing countries.

Today, the undisputed leaders in the global educational services market are the countries of Western Europe and North America. These countries set world standards in the field of training specialists, including medical workers. Their educational programs are recognized as the highest quality, which makes them attractive to students from different countries of the world. Business competition between the main partners in the educational services market is subject to the laws of economic relations, which forces each country to improve the quality of its programs and create increasingly attractive conditions for students.

In response to growing competition in the global educational services market, Western European countries took the initiative to harmonize their educational systems. In 1999, the process of creating a unified system of higher education began, which was called the Bologna Process. The goal of the Bologna Process is to create a unified educational model that will allow European universities to integrate into the global educational system and compete on an equal footing with other regions. The European educational system, based on standardization and mutual recognition of diplomas and qualifications, allows students to move freely between educational institutions in different countries, which significantly expands the opportunities for obtaining a quality education. In the medical field, this is especially important, since the training of doctors requires uniform approaches and standards to ensure a high level of professionalism.

Thus, the export of educational services in the field of medicine is becoming an important element in the economy of many countries, and integration processes such as the Bologna Process allow Western European countries to occupy leading positions in the world market. These efforts are aimed at increasing the attractiveness of the higher education system, which contributes to the development of scientific research, the creation of new technologies and, ultimately, improving the quality of medical care at the global level.

The study of the medical equipment supply chain for educational institutions in the Kyrgyz Republic is a relevant topic, since high-quality medical education is impossible without modern equipment for practical classes and student training. Educational institutions specializing in medical sciences require constant supplies of both basic and specialized equipment to ensure a high-quality educational process.

The main problems in the medical equipment supply chain are insufficient infrastructure, logistical difficulties, high dependence on imported equipment, as well as bureaucratic procedures that can slow down procurement processes. In most cases, educational institutions in Kyrgyzstan depend on international suppliers, which makes the process expensive and subject to fluctuations in global markets.

In addition, support from the state and international organizations, such as the Islamic Development Bank, which is actively involved in financing such projects, plays an important role. To optimise the supply chain, it is necessary to introduce modern logistics methods, cooperate with local manufacturers, and develop a flexible procurement regulation system.

This study will help identify bottlenecks in the current supply chain and propose solutions that will help improve the efficiency and availability of medical equipment for educational institutions in Kyrgyzstan.

Research objectives. First, analysis of the current state of the medical equipment supply chain for educational institutions in the Kyrgyz Republic. This stage is aimed at identifying the main participants in the supply chain, such as suppliers, manufacturers, logistics companies and educational institutions. The stages of equipment procurement, storage and delivery are also analyzed. The goal is to identify key aspects of this chain and understand how effectively it functions.

Second, studying the problems and barriers that educational institutions face in the process of purchasing and supplying medical equipment. This includes an analysis of logistical difficulties, such as transportation of equipment to remote regions, financial constraints of educational institutions, bureaucratic barriers, and dependence on international suppliers. This stage of the study is important for identifying weaknesses in the supply chain.

Third, proposing solutions and recommendations for supply chain optimisation. Based on the identified problems, ways to improve logistics processes, opportunities for cooperation with local manufacturers, and ways to reduce administrative procedures will be proposed. This is aimed at increasing the efficiency and availability of medical equipment, which will ultimately improve the quality of training of medical specialists in educational institutions of the Kyrgyz Republic.

Research method

Literature Review Method: Involves conducting an extensive review of domestic and foreign literature to understand the current state and progress in the study of medical equipment supply chains. This method will identify existing approaches and practices in this area.

Comparative Analysis Method: Involves comparing various models of medical equipment supply chains, both at the level of the Kyrgyz Republic and international practices. This will help identify the strengths and weaknesses of existing approaches.

Fieldwork Method: Includes conducting in-depth interviews with key participants in the supply chain, surveys of educational institutions and suppliers, as well as field research to obtain data on the actual supply process.

Combination of Qualitative and Quantitative Methods: Using both qualitative (interviews, observations) and quantitative methods (data analysis, statistical research) to obtain a comprehensive picture of the supply chain and proposals for its optimisation.

Research purpose

The aim of this study is to analyze and optimise the supply chain of medical equipment for educational institutions in the Kyrgyz Republic in order to increase their availability, efficiency and sustainability. The study aims to identify current problems and limitations in the existing supply system, as well as to develop recommendations for improving logistics processes and procurement management, which will improve the quality of medical education and training of specialists in the country.

Research results and significance

The findings of this study provide a comprehensive understanding of the current structure of the medical equipment supply chain in educational institutions in the Kyrgyz Republic, identifying key bottlenecks, logistical challenges, and dependencies on foreign suppliers. By analyzing these issues, the study highlights specific areas where the supply chain can be optimised to improve efficiency, reduce costs, and ensure timely delivery of essential medical equipment to educational institutions.

The findings of the study highlight the important role of Public-Private Partnerships and international organizations in strengthening the supply chain infrastructure. Recommendations for sustainable improvements, including collaboration with local suppliers and streamlining bureaucratic procedures, are aimed at promoting a more resilient and self-sufficient supply chain.

Research Innovative

A comprehensive approach to analyzing the medical equipment supply chain: Unlike most studies that focus on individual aspects (such as logistics or procurement), this study examines the supply chain in its entirety — from purchasing equipment to delivering it to educational institutions. This allows us to identify interdependencies between different stages and determine key bottlenecks.

Comparative analysis with foreign practices: The study uses a comparative analysis with successful models of medical equipment supply chains in other countries. This allows us to adapt best practices and apply them to the conditions of the Kyrgyz Republic, taking into account regional characteristics and constraints.

Using technologies to optimise the supply chain: For the first time, digital solutions such as data-driven demand forecasting, real-time inventory management systems, and automation of procurement processes are offered to optimise the supply chain of medical equipment in educational institutions of the Kyrgyz Republic. These innovations will create a more efficient and adaptive supply chain.

Approach to sustainable supply chain development: The study examines the environmental and economic aspects of the supply chain, including reducing reliance on imported equipment and encouraging local production. Introducing sustainable practices such as optimising transport routes and reducing waste will help build a greener and more sustainable supply chain.

Approval of works and implementation of research results

The main scientific provisions, methodological recommendations and practical results of the dissertation were tested and implemented through publications in peer-reviewed scientific journals included in international databases.

In particular, the problems of quality control of logistics services in the B2C sector based on the economic approach were discussed in detail in the article by Orozonova, A., Akmatova, A., Kazakov, A. (2024) "B2C-oriented quality control of logistics services based on an economic perspective", published in the journal Advanced Logistic Systems – Theory and Practice (vol. 18, no. 2, pp. 42–50, DOI: 10.52566/msu-econ2.2024.42).

Of practical importance are the results presented in the collective work of Kazakov, A., Musaeva, N., Goncharova, I., Mambetkulova, A., Orozonova, A. et al. (2024) "Sustainable Logistics Management of Public Procurement of Medical Equipment", published in BIO Web of Conferences (vol. 120, article no. 01066), where ways of optimising procurement in the field of medical care are substantiated, taking into account the principles of sustainable development.

Additional application of methodological approaches in the field of logistics is presented in the article Mosiiuk, S., Voitovych, S., Sorokoumov, H., Saichuk, V., Kazakov, A. (2023) "Logistics Management of Health Resorts and Tourism Facilities", published in the Journal of Education and Learning (vol. 12, no. 4, pp. 609–615, DOI: 10.55365/1923.x2023.21.63). In addition, the provisions concerning the role of logistics in the regional economy are reflected in the work of Sun, X., Zhumadilov, A., Myrzalieva, M., Kazakov, A., Akmatova, A. (2024) "Current State of Logistics Development and Its Role in the China's Regional Economy", published in Qubahan Academic Journal (vol. 4, no. 4, pp. 361–373). Thus, the results of the dissertation research have undergone comprehensive testing in leading scientific publications, which confirms their scientific and practical significance.

CHAPTER I

CHAPTER 1.

1.1. Introduction

Over the past two decades, interest in SCM has grown significantly among researchers, practitioners, and policymakers. SCM has evolved from a traditional logistics function into a strategic area that determines the sustainability and competitiveness of national economies. Current trends in SCM reflect profound structural transformations in the global economy and are closely linked to digitalization, environmental responsibility, and institutional transformation (Ivanov & Dolgui, 2020; Christopher, 2016; Sarkis, 2021). One key area is the digitalization of logistics processes, including the application of artificial intelligence (AI), the Internet of Things (IoT), blockchain, and big data technologies to improve transparency, forecasting accuracy, and supply chain sustainability. According to research by Kamble, Gunasekaran, and Gawankar (2020) and Ghobakhloo and Iranmanesh (2022), digital transformation enables organizations to create smart and interconnected supply chains, increasing their agility and reducing transaction costs. Digitalization also facilitates the integration of sustainable business models and the implementation of platform solutions that facilitate data exchange between manufacturers, suppliers, and end users (Tiwari et al., 2023).

A second important trend is the adoption of ESG (Environmental, Social, and Governance) approaches, which involve a shift from a profit-driven approach to integrating principles of environmental responsibility, social sustainability, and corporate governance into supply chain strategy. Recent research (Carter et al., 2019; Rehman et al., 2022) shows that companies implementing ESG-focused practices demonstrate higher levels of innovation and resilience to external risks. The development of responsible and transparent supply chains is becoming an important element of international corporate governance standards and sustainable development strategies (UNDP, 2022). Furthermore, the concept of smart supply chains is rapidly developing, where logistics processes become self-learning through automated decision-making systems and the integration of cyber-physical technologies. Such systems enable real-time adaptation to changes in supply and demand, inventory management, and the prediction of disruptions (Tang & Veelenturf, 2019; Dubey et al., 2023).

Table 1.1. Global Trends in SCM and Their Relevance to Sustainability

№	Trend / Direction	Core Focus and Description	Key Technologies / Methods	Main References	Relevance to Education and Medical Equipment Supply
1	Digital Transformation and Smart Supply Chains	Integration of AI, IoT, blockchain, and Big Data for improved transparency, forecasting, and process automation. Enables real-time analytics and data-driven decisions.	AI, IoT, Blockchain, Big Data, Digital Twins	Kamble et al. (2020); Ghobakhloo & Iranmanesh (2022); Ivanov (2023)	Enhances accuracy and transparency in procurement of medical and educational equipment; reduces delays and transaction costs.
2	ESG and Sustainable Supply Chain Governance	Integration of environmental, social, and governance principles in supply chain strategy to ensure ethical and responsible operations.	ESG frameworks, SDG alignment, sustainability metrics	Carter et al. (2019); Rehman et al. (2022); UNDP (2022)	Promotes ethical sourcing, social accountability, and alignment with global sustainability standards (SDG 4, 9, 12).
3	Sustainable Procurement (Responsible Purchasing)	Transition from price-based to lifecycle-based procurement decisions; evaluation of suppliers by social, environmental, and ethical criteria.	Life Cycle Costing (LCC), supplier assessment, green criteria	Walker & Brammer (2019); Appolloni et al. (2022); Thai (2020)	Strengthens transparency, reduces corruption risks, and supports the modernization of public procurement in education and healthcare.
4	Green Logistics and Decarbonization	Implementation of eco-efficient logistics and carbon-neutral transport systems to minimize ecological footprint.	Renewable energy, carbon accounting, circular economy	Seuring & Müller (2008); Li & Sarkis (2022); OECD (2024)	Supports sustainable campus operations and eco-friendly delivery of medical and laboratory equipment.
5	Resilient and Adaptive Supply Chains (RSC)	Development of flexible, shock-resistant systems capable of withstanding pandemics, political instability, and climate events.	Scenario planning, redundancy, predictive analytics	Chowdhury et al. (2021); Queiroz et al. (2022); Ivanov & Dolgui (2020)	Ensures continuity of equipment supply during crises; critical for universities and medical institutions.
6	Regionalization and Localization (Nearshoring, Friendshoring)	Reorientation of production and supply networks toward regional clusters to enhance economic security and reduce dependency on global disruptions.	Regional hubs, local supplier development, cross-border logistics	Gereffi (2022); Wang et al. (2023)	Encourages regional cooperation in educational and medical infrastructure within Central Asia and EAEU.

Source: Compiled by the author based on contemporary SCM literature (2020–2024).

Decarbonization and green logistics (Green SCM), aimed at reducing carbon footprints and using renewable energy sources in transportation, storage, and production, are becoming increasingly important. Research by Seuring & Müller (2008) and Li & Sarkis (2022) confirm that green supply chains are becoming not only an ethical but also an economic priority, improving companies' energy efficiency and reputational sustainability. In Europe and OECD countries, carbon accounting standards and Net Zero Logistics initiatives are actively implementing, stimulating the transition to carbon-neutral transportation models (OECD, 2024).

A separate area of research is focused on the development of resilient and adaptive supply chains (RSCs) capable of withstanding external shocks such as pandemics, geopolitical crises, and climate risks. According to Chowdhury et al. (2021) and Queiroz et al. (2022), following COVID-19, particular attention is being paid to the development of hybrid supply chain models, backup routes, and digital risk forecasting platforms. Resilience is viewed as a strategic asset, ensuring the survival and long-term competitiveness of businesses (Ivanov & Dolgui, 2020).

In the context of global turbulence, SCM is also evolving toward regionalization and localization (nearshoring and friendshoring), which helps reduce logistics risks and dependence on remote suppliers. There is growing interest in local manufacturing clusters and regional value chains that ensure economic security and reduce the carbon footprint of supply chains (Gereffi, 2022). Real-time analytics and the development of digital twins are playing an increasingly significant role, enabling supply chain behavior modeling, risk prediction, and data-driven process optimisation (Ivanov, 2023; Wang et al., 2023).

In the education and healthcare sectors, including the supply of medical equipment, SCM is increasingly being viewed as a tool for achieving the Sustainable Development Goals (SDG 4, SDG 9, and SDG 12), ensuring improved education quality, innovative development, and the reduction of ineffective spending. Recent publications emphasize the need for systemic integration of sustainability and digitalization principles into the management of educational infrastructure, particularly in developing countries (Kumar & Goswami, 2021; Moktadir et al., 2021).

While global trends are shaping the future of SCM, their implementation varies significantly across countries. In Kyrgyzstan, supply chain systems, particularly in the public sector, remain at an early stage of institutional and technological maturity. The country's logistics infrastructure, procurement mechanisms, and information systems continue to face fragmentation, outdated standards, and limited digital capabilities (Asian Development Bank, 2023). As a result, most educational and healthcare institutions face chronic delays in equipment deliveries, inconsistent quality control, and ineffective procurement management.

In particular, the medical equipment supply chain for educational institutions plays a critical role in training qualified medical professionals capable of addressing modern healthcare challenges. Universities and colleges must ensure continuous access to simulation laboratories, diagnostic equipment, and educational technologies. However, the existing equipment procurement and distribution system remains dependent on imports and centralized tendering procedures, is often opaque, and lacks long-term sustainability (World Bank, 2023). The dominance of short-term cost criteria over life-cycle value further reduces efficiency and hinders the adoption of modern, energy-efficient, and environmentally friendly technologies.

In this context, sustainable procurement appears to be a promising mechanism for modernization. Its application in Kyrgyzstan could transform the approach of public institutions to planning, evaluating, and managing the procurement of medical and educational equipment. By shifting from cost minimization to life-cycle value assessment, educational institutions will be able to reduce waste, improve service quality, and ensure greater accountability. Moreover, the integration of digital tools such as e-procurement platforms, real-time inventory management systems, and supplier rating mechanisms will significantly enhance transparency and expand monitoring capabilities in the public procurement system (OECD, 2024).

Table 1.2. Key Challenges and Strategic Directions for Developing the Supply Chain of Medical Equipment in the Kyrgyz Republic

№	Problem Area / Challenge	Underlying Causes	Strategic Direction / Proposed Solution	Expected Outcome / Link to SDGs	Key References
1	Fragmented procurement system	Centralized tenders, lack of coordination between ministries and universities	Introduce integrated e-procurement platform and unified public database for equipment needs	Transparency, cost reduction, SDG 16 (Institutional efficiency)	ADB (2023); Government of the Kyrgyz Republic (2023)
2	Dependence on imported medical equipment	Limited local production, weak supplier	Support local manufacturing and public–private partnerships (PPP)	Import substitution, local innovation,	World Bank (2023); OECD (2024)

		network	in medical equipment production	SDG 9 (Industry, Innovation, Infrastructure)	
3	Outdated logistics infrastructure	Poor warehousing, lack of digital monitoring tools	Implement digital inventory systems and tracking using IoT and barcoding	Real-time visibility, reduced losses, SDG 12 (Responsible Consumption and Production)	Ivanov & Dolgui (2020); Ghobakhloo & Iranmanesh (2022)
4	Low level of sustainable procurement practices	Absence of green criteria in public tenders	Integrate environmental and social indicators into procurement evaluation (ESG-based scoring)	Sustainable purchasing, green modernization, SDG 13 (Climate Action)	Appolloni et al. (2022); Thai (2020)
5	Insufficient digital competencies	Lack of training among procurement and logistics staff	Introduce capacity-building programs and digital literacy courses for university managers	Improved management efficiency, SDG 4 (Quality Education)	UNDP (2022); Kumar & Goswami (2021)
6	Lack of resilience to external shocks	Absence of risk forecasting systems and contingency planning	Develop risk-management frameworks, create reserve funds, diversify suppliers	Resilient supply chains, crisis readiness, SDG 11 (Sustainable Communities)	Queiroz et al. (2022); Chowdhury et al. (2021)

Source: Compiled by the author based on national policy documents and SCM research (2020–2024).

From a policy perspective, the Government of Kyrgyzstan has declared the digital transformation of public administration and the alignment of national development strategies with the SDGs as key priorities (Government of Kyrgyzstan, 2023). However, the implementation of these principles in the education and healthcare sectors remains uneven. Limited interdepartmental coordination, insufficient staff training, and the absence of unified digital platforms hinder the practical implementation of these reforms. This creates a gap between the conceptual goals of sustainable development and their practical implementation in SCM.

Therefore, this study is timely and necessary. It helps bridge this gap by providing a comprehensive analysis of the medical equipment supply chain for educational institutions, identifying structural and institutional weaknesses, and proposing practical solutions based on the principles of sustainability and innovation. The study emphasizes that effective SCM in education is not simply a logistical issue, but a strategic prerequisite for national development, impacting human capital formation, the quality of medical care, and technological competitiveness.

1.2. The Research Gap

Over the past twenty years, SCM has emerged as a key academic and practical discipline, located at the intersection of logistics, information technology, operations management, and strategic management (Christopher, 2016; Mentzer et al., 2001).

Initial research in the late 20th and early 21st centuries focused on improving resource flow efficiency, reducing transaction costs, and optimising inventory. However, since the mid-2010s, emphasis has shifted toward the concepts of integration, sustainability, and digital transformation (Ivanov & Dolgui, 2020; Sarkis, 2021). As a result, SCM has come to be viewed not simply as a logistical control tool, but as a strategic system that ensures the creation of added value at all stages of the product and service lifecycle.

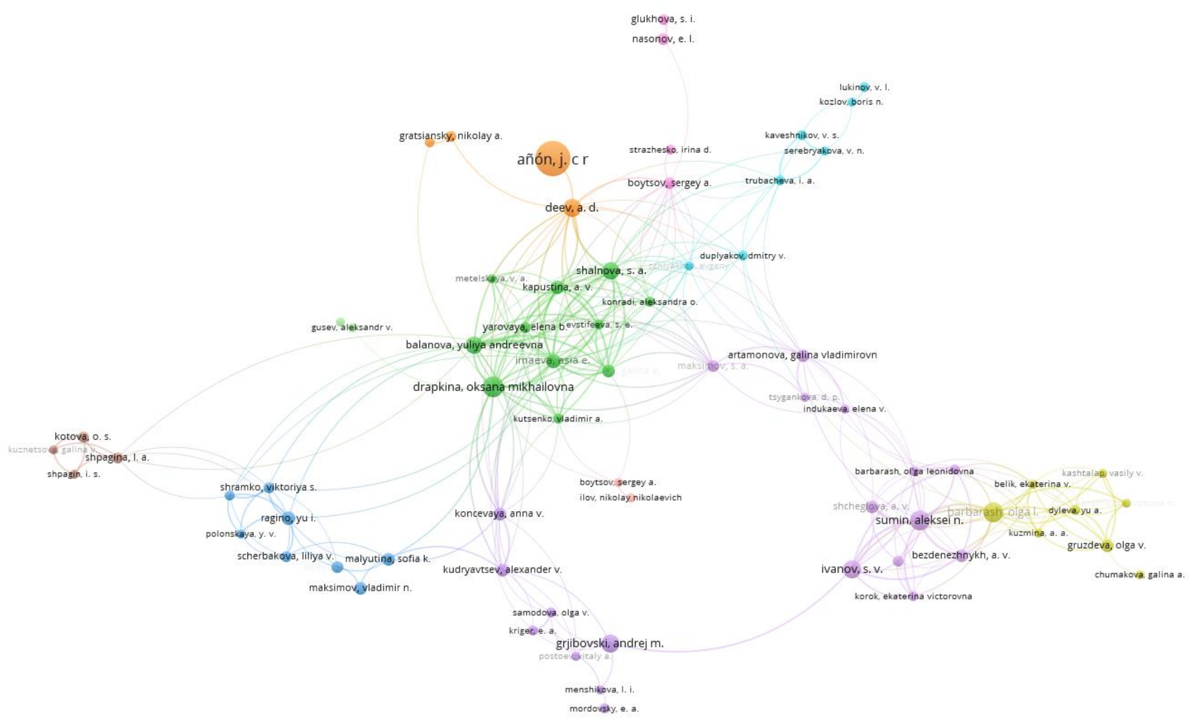

Figure 1.1. Bibliometric network of SCM research authors (2020–2025), generated using VOS viewer software.

Over the past two decades, SCM has evolved into one of the key interdisciplinary domains integrating logistics, information technologies, operational management, and strategic development.

According to the bibliometric analysis conducted using the VOS viewer software, there has been a notable diversification of research directions and collaboration networks among scholars exploring emerging SCM trends. The visualization map illustrates several clusters of researchers who actively contribute to the development of new paradigms such as digital transformation, sustainable procurement, and resilient supply networks. In particular, the leading research groups focus on integrating AI, IoT, and blockchain technologies into logistics processes; implementing ESG-based supply chain governance; and advancing models of circular and green logistics. The cluster density and interconnections indicate that, since 2020, the global research community has increasingly concentrated on data-driven, sustainable, and adaptive SCM systems, confirming a paradigm shift from cost efficiency toward resilience and sustainability. This trend is also evident in 2025 publications, where collaborative research among European, Russian, and Asian institutions demonstrates growing attention to sustainable procurement in healthcare and education supply chains, reflecting the internationalization and interdisciplinarity of SCM research.

These bibliometric data confirm that the scientific community's focus has shifted from purely operational optimisation to a systemic and interdisciplinary integration of sustainability, technology, and management within supply chains. Emerging literature emphasizes that not only technological innovation but also institutional adaptation and policy transformation are critical factors in sustainable SCM (Ivanov, 2023; Gereffi, 2022). This holistic approach aligns with the UN Sustainable Development Goals (SDGs), particularly SDG 9 (Industry, Innovation, and Infrastructure) and SDG 12 (Responsible Consumption and Production), underscoring the global recognition of SCM as a key driver of sustainable development.

However, despite the rapid development of the SCM field, the geographic distribution of research remains highly uneven. The most influential studies have been conducted in technologically advanced countries—Europe, North America, and East Asia—while developing and transition economies, such as those in Central Asia, Africa, and parts of Eastern Europe, are significantly underrepresented in global bibliometric networks (OECD, 2024; World Bank, 2023). Consequently, many theoretical frameworks and digital models of SCM are developed for contexts with established institutional infrastructure, developed logistics systems, and mature digital ecosystems, limiting their applicability in resource-constrained settings.

A critical analysis of recent publications (2020–2025) reveals that while sustainability and digitalization issues are widely studied in the manufacturing and trade sectors, public supply chains, particularly those related to healthcare, education, and social infrastructure, remain understudied in the literature. Research on sustainable procurement in these areas is fragmented, and empirical evidence on how digital tools and ESG principles can be effectively implemented in the public sector is limited. This imbalance highlights a growing need for research aimed at bridging the gap between private sector innovation and public sector adaptation, particularly in countries undergoing digital transformation.

In this context, the case of Kyrgyzstan is particularly relevant. As a developing economy in the Central Asian region, Kyrgyzstan faces unique institutional, technological, and infrastructural challenges that limit the effectiveness of its supply chains. Public procurement processes, particularly in education and healthcare, remain largely centralized, paper-based, and cost-driven, with limited integration of sustainability criteria or digital monitoring mechanisms (ADB, 2023; Government of Kyrgyzstan, 2023). This leads to inefficiencies, delays, and transparency issues that hinder the long-term development of sustainable and resilient supply systems.

Thus, bibliometric and contextual data reveal a significant research gap regarding how sustainability-focused innovations such as green procurement, digital supply platforms, and collaborative governance can be adapted and institutionalized in emerging economies. To address this gap, an interdisciplinary framework is needed that integrates institutional theory, the Technology–Organization–Environment (TOE) model, and the dynamic capabilities perspective to capture both the structural and behavioral dimensions of SCM transformation in resource-constrained settings.

This doctoral thesis substantially contributes to theoretical and empirical advancements in the field of sustainable SCM by developing an integrated conceptual and analytical framework that links sustainability, digital transformation, and institutional efficiency. It extends existing theories — including the Resource-Based View (RBV), the Dynamic Capabilities Theory, and the TOE framework — to the context of public supply chains in developing economies. Through a combination of bibliometric analysis, structural modeling, and empirical validation, the study not only identifies critical drivers and barriers of sustainable supply chain innovation but also formulates policy and managerial recommendations aimed at improving procurement practices in education and healthcare sectors.

Ultimately, this research bridges the gap between global SCM theories and the realities of emerging economies, offering a practical roadmap for achieving transparency, efficiency, and resilience in the supply chain of medical equipment in the Kyrgyz Republic.

1.3. Research Objectives

This doctoral thesis aims to achieve the following research objectives, which are designed to address the identified theoretical, methodological, and institutional gaps in the field of sustainable SCM, particularly within the context of the Kyrgyz Republic's education and healthcare sectors:

Objective 1. To analyze the global evolution and current trends of SCM, with an emphasis on sustainability, digital transformation, and institutional innovation. This objective involves reviewing theoretical foundations such as the Resource-Based View (RBV), Dynamic Capabilities Theory, and the Technology–Organization–Environment (TOE) framework, as well as examining empirical evidence from international SCM practices relevant to public procurement systems.

Objective 2. To assess the existing state of the medical equipment, supply chain for educational institutions in the Kyrgyz Republic, identifying key institutional, technological, and operational challenges. This includes an evaluation of procurement policies, infrastructure readiness, and the degree of digitalization within public sector logistics systems, highlighting inefficiencies and systemic barriers to sustainable performance.

Objective 3. To identify and **model** the critical drivers, barriers, and interrelationships influencing sustainable supply chain innovation (SSCI) in the public sector. For this purpose, the study employs interpretive structural modeling (ISM) and analytical hierarchy process (AHP) techniques to establish a hierarchy of factors and determine their relative importance in shaping supply chain outcomes.

Objective 4. To develop a comprehensive framework and practical recommendations for improving transparency, efficiency, and sustainability in the procurement and distribution of medical equipment for educational institutions in Kyrgyzstan.

This framework aims to align national SCM practices with global standards and the United Nations Sustainable Development Goals (SDG 4 — Quality Education, SDG 9 — Industry, Innovation, and Infrastructure, and SDG 12 — Responsible Consumption and Production).

1.4. Thesis Structure

The doctoral thesis titled *"Research on the Supply Chain of Medical Equipment for Educational Institutions of the Kyrgyz Republic"* is structured into five interconnected chapters, each serving a distinct academic and analytical purpose. The structure ensures a logical progression from the theoretical foundations to empirical validation and practical recommendations.

CHAPTER I. Introduction

This chapter establishes the conceptual foundations and significance of the dissertation. It presents the global and national context of SCM, emphasizing digital transformation, sustainable procurement, ESG governance, and resilience as key vectors shaping public-sector logistics. Special attention is given to their relevance for the education and healthcare sectors.

The chapter formulates the research problem and identifies the research gap associated with a lack of integrated, sustainability-oriented supply chain models for medical equipment in developing countries such as Kyrgyzstan. It defines the research objectives, outlines the methodological approach, and presents the theoretical background (RBV, Dynamic Capabilities, Institutional Theory, TOE Framework) used throughout the study. The chapter concludes with a detailed overview of the thesis structure and its alignment with SDGs 4, 9, and 12.

CHAPTER II. Theoretical Basis and Literature Review

This chapter provides a comprehensive theoretical and literature foundation for the study. It examines:

The evolution of logistics and major scientific schools (American, European, Japanese, Chinese), highlighting their contributions to modern SCM.

Theoretical frameworks underpinning the dissertation, including Systems Theory, RBV, TCE, Institutional Theory, Network Theory, and Dynamic Capabilities.

Global dynamics of logistics research (2000–2024), supported by bibliometric analysis from Scopus, Web of Science, and Google Scholar.

Current trends in SCM, such as digital logistics, green supply chains, resilience, risk management, and regionalization.

Literature on Healthcare Supply Chains and Medical Equipment Supply, including specialized contributions from Chinese research (RFID, IoT, intelligent logistics, government-supported procurement).

The chapter synthesizes findings related to digitalization, sustainable procurement, risk factors, and optimisation models, identifying a clear gap: the limited study of medical equipment supply chains specifically for educational institutions in developing economies.

CHAPTER III. Analysis Of the Current State of Medical Equipment Supply for Educational Institutions of The Kyrgyz Republic

This chapter presents an in-depth empirical and analytical assessment of the existing medical equipment supply chain in the Kyrgyz Republic. It includes:

Evolution of the regulatory and institutional framework, including public procurement laws, sectoral regulations, and institutional mandates that shape supply processes.

Analysis of forms and methods of medical simulation training, identifying the equipment needs of universities and the role of modern training technologies.

Macroeconomic and budgetary analysis, including state budget expenditure on education and medical training, trends in GDP, public investment, CPI, salaries, and foreign investments.

The role of educational services export, demonstrating how international student inflows and service exports strengthen financial capacity and influence equipment needs of higher education institutions.

This chapter identifies fragmentation, bureaucratic procurement procedures, dependence on imports, outdated logistics infrastructure, and insufficient digitalization as key bottlenecks in Kyrgyzstan's system. It provides the empirical foundation for subsequent modeling.

CHAPTER IV. Structural Framework Development for The Medical Equipment Supply System of The Kyrgyz Republic

This chapter applies Interpretive Structural Modelling (ISM) to identify, classify, and hierarchically structure the critical factors influencing the effectiveness of medical equipment supply chains in the Kyrgyz Republic. It includes:

ISM Modeling of key supply chain drivers and constraints, grounded in expert surveys and field data. Partitioning and analysis of the Reachability Matrix, identifying the hierarchy of drivers and their interrelationships. Theoretical implications, connecting the ISM results with RBV, Institutional Theory, and Dynamic Capabilities. Managerial implications, presenting strategic recommendations for policymakers, universities, logistics companies, and procurement authorities. This chapter produces a structural conceptual framework tailored to the national context and serves as the basis for evidence-based reforms.

CHAPTER V. Ways to Optimise the Supply Chain.

This chapter presents system dynamics models that reveal how financial, logistical, and regulatory factors influence the availability of medical equipment in Kyrgyz educational institutions. Based on simulation results, it proposes key optimisation measures — digitalization, customs incentives, improved logistics, and development of local production. A phased roadmap aligned with national strategies outlines short-, medium-, and long-term steps to modernize the supply chain and strengthen the quality of medical education.

CONCLUSION. The dissertation concludes by integrating theoretical insights, empirical findings, structural modelling outcomes, and simulation-based optimisation strategies. It proposes a comprehensive modernization strategy for Kyrgyzstan's medical equipment supply system founded on sustainability, digital transformation, and institutional capacity-building. The modelling results demonstrate how targeted policy interventions — including digitalization, customs incentives, improved logistics, and the development of local production — can significantly enhance equipment availability and strengthen supply chain resilience. The proposed roadmap offers phased, actionable measures aligned with national development priorities and provides a practical foundation for advancing the quality of medical education in the Kyrgyz Republic.

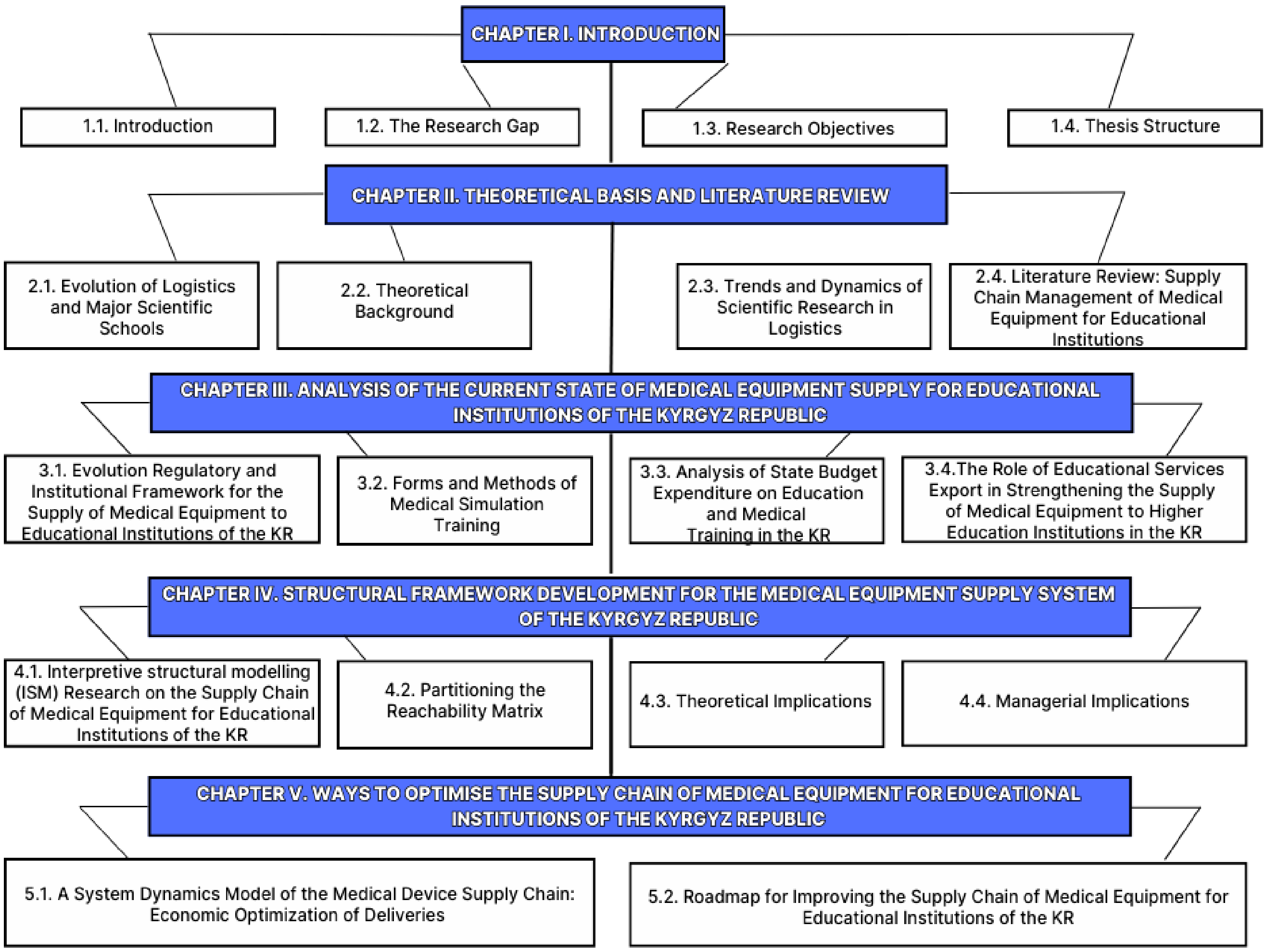

Figure 1.2. Structure of the Doctoral Thesis

Source: Own elaboration

CHAPTER II

CHAPTER II. THEORETICAL BASIS AND LITERATURE REVIEW

2.1. Evolution of Logistics and Major Scientific Schools

The formation of logistics as a scientific discipline occurred gradually, under the influence of various factors: military needs, economic reforms, technological progress and globalization. In different historical periods, the concept of logistics was transformed from the military art of supply to a systems approach to managing material, information and financial flows.

One of the turning points in the institutionalization of logistics was the First European Logistics Conference, held in Berlin from March 20 to 22, 1974, where the first official definition of logistics was proposed as a science of planning, management and control of the movement of resources in various systems. From that moment on, logistics began to be perceived not only as an applied function, but also as an interdisciplinary direction, actively studied in the scientific community.

Development of logistics in the USA. The most significant contribution to the formation of logistics as a separate scientific field was made by American researchers. Among them, Donald J. Bowersox and David J. Closs stand out, whose works laid the foundation for a systems approach to logistics and SCM. Bowersox was one of the first to consider logistics in a strategic context, including interaction with marketing, finance and information technology. His joint work with Closs and Cooper - Logistical Management: The Integrated Supply Chain Process - became a fundamental work for many scientific schools.

A significant contribution was also made by Douglas M. Lambert, who developed a model for managing relationships in supply chains, and James R. Stock, one of the first to formulate scientific approaches to reverse logistics (RL). The development of this sub-industry was also supported by Paul R. Murphy and Richard F. Poist, who identified the importance of reverse flows in logistics systems. German School of Logistics.

In Germany, logistics developed in close connection with engineering, production management and business economics (Betriebswirtschaftslehre).

The contribution of Herbert Kotzab and Stefan Seuring to the formation of sustainable logistics systems and logistics networks was widely recognized in Europe. They raised questions of environmental friendliness, social responsibility and economic efficiency in logistics. At the same time, Wolfgang Kersten actively researched the digitalization of logistics processes and the integration of IT into logistics infrastructure.

Table 2.1. Evolution of Logistics as a Scientific Discipline

Country / School	Key Scholars	Main Contributions	Distinctive Features / Focus Areas
USA	Donald J. Bowersox, David J. Closs, Douglas M. Lambert, James R. Stock, Paul R. Murphy, Richard F. Poist	Formation of system-based logistics and SCM concepts; integration with marketing, finance, and IT; relationship management; reverse logistics	Strategic logistics management, supply chain integration, development of reverse logistics models
Germany (European School)	Herbert Kotzab, Stefan Seuring, Wolfgang Kersten	Institutionalization of logistics as part of business economics (BWL); sustainability and digitalization of logistics systems	Engineering-oriented logistics, sustainable and digital supply networks, emphasis on social responsibility
United Kingdom	Martin Christopher	Development of concepts of flexibility, sustainability, and competitiveness through logistics	Logistics as a source of competitive advantage in uncertain environments
Netherlands	Rommert Dekker	Mathematical modelling of logistics and reverse logistics systems	Quantitative methods, optimisation, and analytical approaches to logistics networks
Japan	Taiichi Ohno	Development of lean production and Just-in-Time logistics	Elimination of waste, synchronization of flows, adaptability, Toyota Production System
China	Wang Zhenyu, Chen Xiangming, Liu Jianyong	Integration of logistics into national economic strategy and spatial development	Logistics as a factor of national competitiveness, emphasis on infrastructure, digitalization, and government policy
CIS / Post-Soviet Space	Emerging researchers in Russia, Kazakhstan, Kyrgyzstan, etc.	Adaptation of Western logistics models to transition economies; focus on cross-border cooperation	Institutionalization of logistics education, integration with customs, and regional economic development

Chinese Contribution to the Development of Logistics. In China, the scientific understanding of logistics began to take shape in the 1990s against the backdrop of the country's reforms and opening up. Among the Chinese scholars who have studied the essence of logistics, Wang Zhenyu, who studied logistics as part of the state economic strategy, Chen Xiangming, who focused on the role of logistics in the urbanization process, and Liu Jianyong, who analyzed the development of logistics parks and infrastructure, stand out.

Logistics in China is viewed not only as an economic tool, but also as a factor in spatial development, national competitiveness and supply sustainability. At the same time, Chinese studies emphasize the importance of government regulation, transport policy and information technology.

Japanese approach: lean logistics. The Japanese school of logistics was based on the principles of lean manufacturing and Just-in-Time (JIT). The key representative of this school was Taiichi Ohno, who developed the Toyota Production System. His approach radically changed the understanding of production logistics, focusing on minimizing losses, synchronizing supplies and adaptability of supply chains.

European and international logistics. In the UK, the development of logistics is associated with the name of Martin Christopher, who promoted the concepts of logistics flexibility, sustainability and supply chain integration. His research became the basis for understanding logistics as a competitive advantage in conditions of high uncertainty and global risks.

In the Netherlands, Rommert Dekker made a special contribution by focusing on the mathematical modelling of logistics processes, including the design of reverse logistics systems. His work at Erasmus University became the basis for the development of analytical approaches to logistics networks.

In recent decades, logistics has undergone a significant transformation, becoming one of the key disciplines actively studied in the scientific community. The number of publications on logistics is steadily growing, which indicates a growing interest in this area from both academia and business practitioners.

2.2. Theoretical Background

Several theoretical frameworks enrich the conceptual understanding of logistics and SCM. The evolution of logistics from a functional activity to a strategic discipline has been supported by a diverse set of theories that explain coordination, integration, and performance within supply networks. The main theoretical foundations include systems theory, resource-based view (RBV), transaction cost economics (TCE), institutional theory, and network theory.

Table 2.2. Theoretical Foundations of Logistics and SCM

Theory / Framework	Key Scholars	Core Idea	Application in Logistics and SCM	Relevance / Contribution
Systems Theory	Ludwig von Bertalanffy (1968)	Organization as an integrated system of interrelated parts	Coordination of material, information, and financial flows across subsystems	Provides a holistic view of logistics and integration with production, marketing, and finance
Resource-	Wernerfelt	Competitive	Logistics capabilities	Explains how

Based View (RBV)	(1984); Barney (1991)	advantage is built through unique internal resources and capabilities	(infrastructure, IT, expertise) as strategic assets	logistics capabilities enhance firm competitiveness and efficiency
Transaction Cost Economics (TCE)	Coase (1937); Williamson (1985)	Firms minimize transaction costs through optimal governance structures	Make-or-buy decisions, outsourcing, and 3PL management	Justifies outsourcing and strategic alliances in logistics systems
Institutional Theory	DiMaggio & Powell (1983); Scott (1995)	Organizations adapt to institutional pressures (regulations, norms, culture)	Compliance with sustainability standards, government policies, and industry norms	Explains regional variations and policy-driven transformation of logistics
Network Theory	Hakansson & Snehota (1995)	Economic behavior shaped by inter-organizational relationships	Collaboration, trust, and information sharing in supply networks	Supports understanding of supply chains as interactive, relationship-based systems
Dynamic Capabilities Theory	Teece, Pisano & Shuen (1997)	Firms' ability to integrate, build, and reconfigure resources in changing environments	Adaptation to market volatility, digitalization, and disruptions	Explains agility and resilience in global logistics systems
Contingency Theory	Lawrence & Lorsch (1967)	No universal structure—effectiveness depends on contextual fit	Design of logistics systems based on uncertainty, product type, and environment	Guides flexible logistics design and decision-making under uncertainty

Systems Theory. The systems approach, developed in the mid-20th century, views logistics as an interconnected network of material, information, and financial flows (Bertalanffy, 1968). According to this view, logistics efficiency arises from optimising the relationships among subsystems rather than isolated operations. This theoretical foundation underpins the integration of logistics with production, marketing, and finance, forming the basis for holistic SCM.

Resource-Based View (RBV). The RBV, popularized by Barney (1991), considers logistics capabilities—such as distribution networks, information technologies, and human expertise—as strategic resources that create competitive advantage. Firms that effectively develop and leverage their logistics competencies achieve superior service quality and cost efficiency. This approach is widely applied in contemporary studies of digital and green logistics.

Transaction Cost Economics. Introduced by Coase (1937) and expanded by Williamson (1985), TCE explains coordination mechanisms in logistics partnerships. It suggests that firms balance between internalizing logistics functions and outsourcing them to reduce transaction costs. The theory is instrumental in analyzing make-or-buy decisions, third-party logistics (3PL), and contract management in global supply chains. 4. Institutional Theory. Institutional theory emphasizes the influence of regulatory, normative, and cultural frameworks on logistics practices (DiMaggio & Powell, 1983). It explains how logistics systems adapt to environmental pressures such as government regulations, sustainability standards, or technological modernization. In emerging economies, institutional theory provides insight into how logistics evolves under state policy and international integration.

Network Theory. Network theory (Hakansson & Snehota, 1995) conceptualizes logistics as a system of relationships among firms, emphasizing collaboration, trust, and inter-organizational learning. It supports the understanding of supply chains as dynamic networks that co-create value through interaction, rather than linear chains of transactions. Collectively, these theories highlight that logistics is not merely an operational activity but a strategic, systemic, and relational process embedded within complex institutional and technological environments. Each framework contributes to a deeper understanding of how logistics systems evolve, interact, and adapt to changes in the global economy.

2.3. Trends and Dynamics of Scientific Research in Logistics (2000–2024)

Analysis of international scientific databases such as Scopus, Web of Science and Google Scholar shows that since the early 2000s, there has been an exponential increase in the number of studies devoted to logistics. Works are published especially intensively in the following areas: SCM; Digital logistics and process automation; Green (ecological) logistics and sustainable development; Information technology in logistics (IoT, Big Data, AI); E-commerce logistics and reverse logistics; Global logistics networks and risks in unstable conditions.

In addition, topics related to the optimisation of transport routes, inventory management, integration of logistics with production processes, as well as logistics in emergency situations (for example, during the COVID-19 pandemic) remain relevant. The countries with the greatest scientific activity in the field of logistics are the USA, Germany, China, Great Britain and the Netherlands. In recent years, the contribution of the CIS countries has also increased, especially in terms of adapting logistics models to the post-Soviet space and cross-border cooperation.

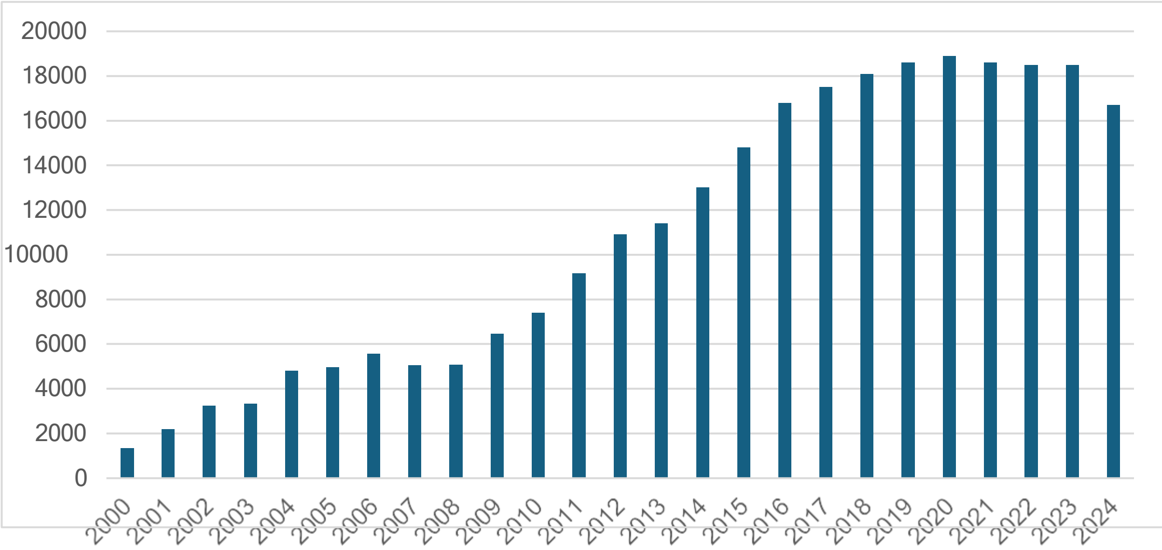

Figure 2.1. Annual publication of articles on the topic in the period 2000- 2024 in the CIS countries. (Google Scholar)

An analysis of quantitative data on annual publications in the field of logistics in the CIS countries for the period 2000–2024 allows us to identify several characteristic stages in the development of scientific activity in this area.

In the initial period (2000–2005), there is a moderate increase in the number of publications: from 1,340 to 4,960 articles. This is explained by the gradual recognition of logistics as a separate discipline important for economics and management. During this period, basic scientific schools are formed and a theoretical base is accumulated.

From 2006 to 2011, the pace of publication activity noticeably accelerates — the number of articles more than doubles: from 5,560 to 9,150. This reflects the growing interest in logistics in the context of the integration of the CIS into the global economy and the need to optimise internal and external trade flows.

The period 2012–2020. is characterized by the most active growth: the number of publications increases from 10,900 to 18,900. During this period, logistics is actively developing under the influence of digital technologies, e-commerce and sustainable development concepts. In addition, the challenges associated with global crises (for example, COVID-19) stimulated research in the field of sustainability and adaptability of logistics systems. Since 2021, there has been stabilization and a slight decline in publication activity (to 16,700 in 2024), which is due to partial saturation of the topic, changes in research priorities or foreign economic factors.

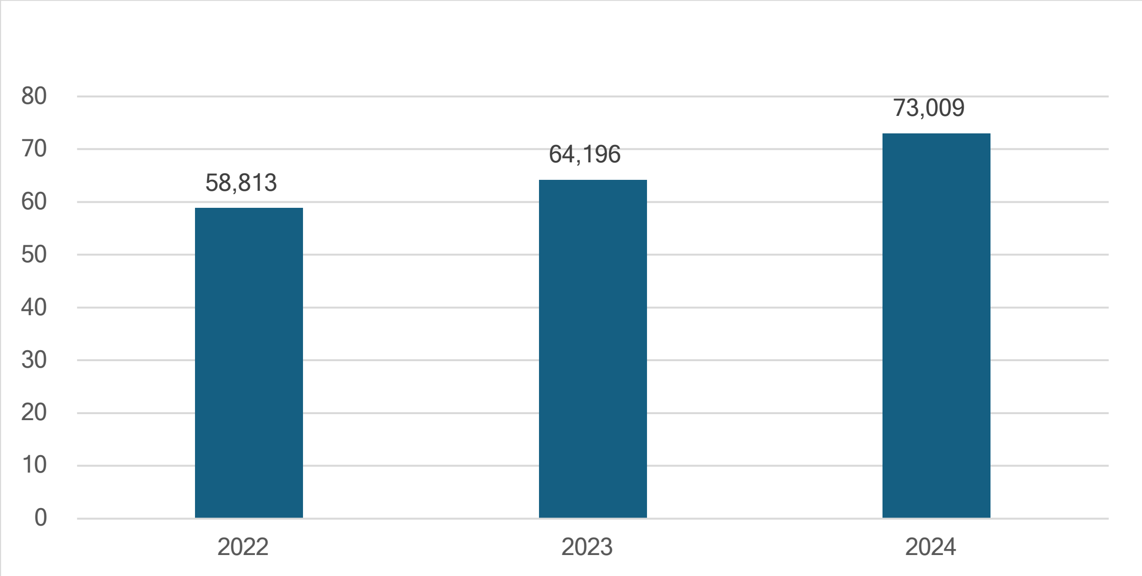

Figure 2.2. Analysis of publication activity on the topic «logistics» in the Scopus database (2022-2024)

Thus, logistics in the CIS countries remains a significant area of scientific research, demonstrating sustainable dynamics and strategic importance for the development of the region.

According to the international database of scientific publications Scopus, over the past three years there has been a steady positive trend in the number of scientific articles devoted to logistics issues. In 2022, 58,813 publications were registered for the query «logistics». Already in 2023, this figure increased to 64,196, and in 2024 it reached 73,009 scientific papers.

Such growth (approximately 24% over two years) indicates a high and growing interest of the global scientific community in logistics issues. This is due to several global trends: active development of e-commerce and digital supply platforms; implementation of innovative technologies (Big Data, IoT, AI) in logistics chains; growing importance of sustainable and green logistics solutions; the need to adapt logistics systems to crises (COVID-19, geopolitical instability, resource shortages).

The increase in the number of publications also indicates the expansion of interdisciplinary research: logistics is increasingly considered in the context of management, information technology, ecology, economics and social sciences.

Thus, Scopus data confirms that logistics remains one of the most dynamically developing and researched areas in the modern scientific environment.

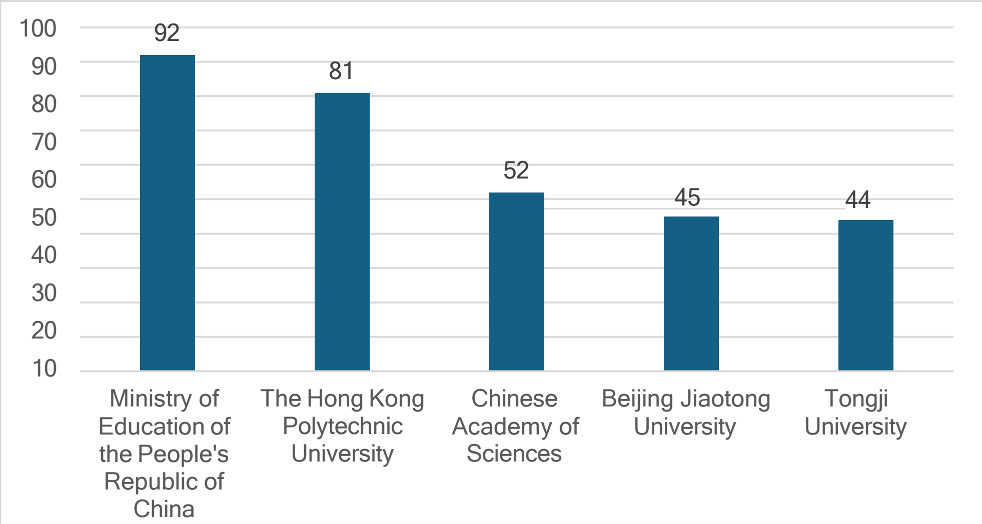

Figure 2.3. Top 5 organizations by number of publications in the field of logistics (Scopus, 2024).

In 2024, the field of logistics saw high research activity from Chinese research institutions. The Ministry of Education of the People's Republic of China led the way in terms of the number of publications with 92 papers. This reflects the strategic support for scientific research in China at the national level. The Hong Kong Polytechnic University (81 publications) came in second, traditionally holding a strong position in the applied aspects of logistics, especially supply chains and sustainable solutions.

The Chinese Academy of Sciences, with 52 publications, demonstrates contributions to fundamental and interdisciplinary research, including logistics digitalization, AI, and supply chain optimisation. Beijing Jiaotong University (45 publications) and Tongji University (44 publications) are actively developing topics in transportation logistics, intelligent transportation systems, and urban logistics solutions.

The overall analysis shows that China has significantly strengthened its position in the global logistics research agenda. The dominance of Chinese organizations in publication activity indicates large-scale investments in scientific research, technological development and international cooperation. Trends point to an interest in sustainable logistics, digital platforms and the integration of logistics with innovative technologies, which will determine the development vector of the industry in the coming years.

In 2024, authors from various countries stood out in the scientific publications on logistics, especially from Asia, the Middle East and Latin America. The most active researchers were from China, which demonstrated leadership in both the number of publications and the coverage of topics in the field of logistics. Among them, Li Wei (China), representing Tsinghua University, actively publishes on digital supply chains. Zhang Yong (China, Shanghai Jiaotong University) and Chen Ming (China, Beijing Jiaotong University) study transport logistics and freight optimisation.

Wang Xia and Liu Jie publish on sustainable and urban logistics, applying modern digital tools such as AI and blockchain. Among the international researchers, Mohamed Al-Farsi from Saudi Arabia, who works on logistics efficiency in the Middle East, and Rahul Kumar from India, who analyzes logistics in the context of emerging markets and digital platforms, stand out.

Fatemeh Ahmadi from Iran studies the adaptation of logistics strategies in an unstable economic environment, and John Mokoena from South Africa contributes to the development of regional logistics and infrastructure on the African continent. Luis García from Mexico studies cross-border logistics and sustainable supply in Latin America.

Thus, 2024 has shown an increase in international interest in logistics and the active participation of researchers from different regions of the world.

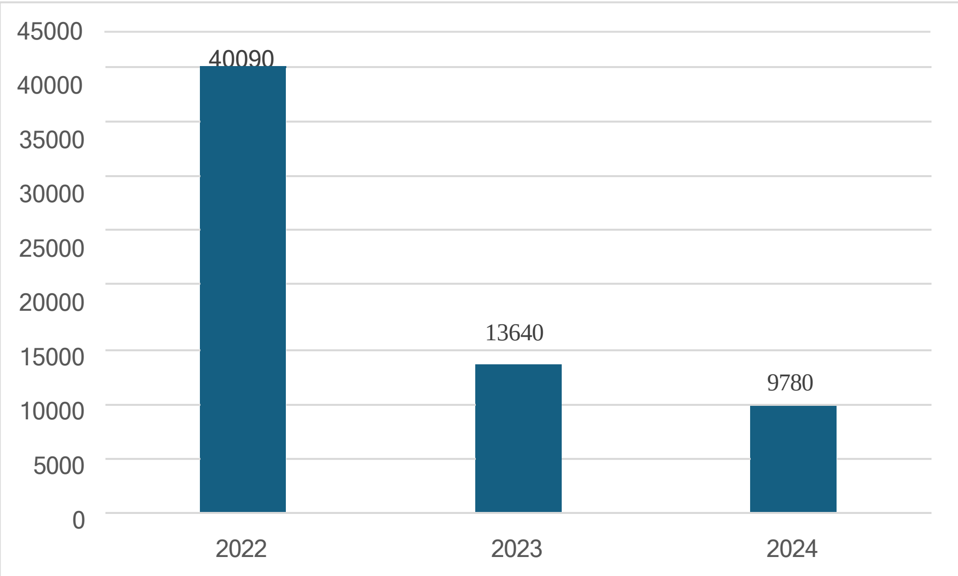

Figure 2.4. Publication activity on the topic «Healthcare SCM» (2022–2024)

Scientometric analysis of publications by the keywords "Healthcare SCM" for the period from 2022 to 2024 shows a clear decline in scientific activity. In 2022, a record number of publications was recorded - 40,090, which may be due to the consequences of the COVID-19 pandemic, when logistics issues in healthcare became especially relevant. Scientists around the world were actively studying weaknesses in the supply chains of medical equipment, drugs, vaccines, as well as logistics in emergency situations.

In 2023, the number of publications decreased by more than half - to

13,640, which indicates a shift in scientific focus towards other pressing problems, as well as the saturation of the academic field with basic research.

By 2024, the number of publications continues to decline - to 9,780, but this can be explained by both a temporary shift in the indexing of articles and stabilization of interest in the topic. Despite the decline, healthcare logistics remains an important interdisciplinary field that combines elements of economics, management, information technology and medicine.

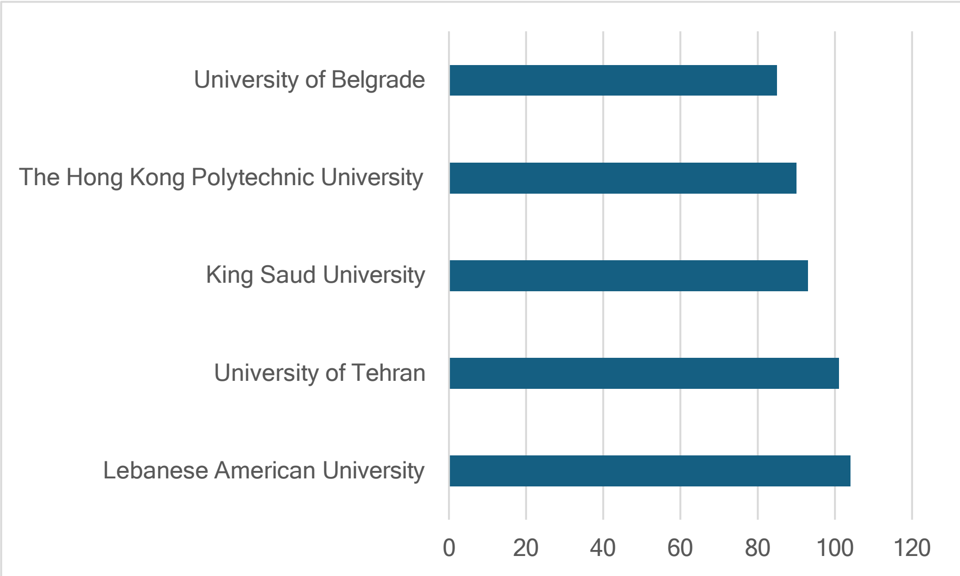

Figure 2.5. Top 5 universities by number of publications in "Healthcare SCM" (2022–2024)

In the period from 2022 to 2024, universities from the Middle East, Asia and Europe showed the greatest activity in scientific publications on the topic of Healthcare SCM. The leader was the Lebanese American University with 104 publications, which indicates a high level of interest among researchers in the issues of healthcare logistics in the context of developing countries and regional healthcare systems.

In second place is the University of Tehran (Iran) with 101 publications. This reflects active scientific work in the field of medical supply logistics in the context of economic and infrastructural constraints. King Saud University (Saudi Arabia) also showed high results (93 publications), focusing on the efficiency of supply chains, especially in public hospitals and institutions.

Among Asian universities, The Hong Kong Polytechnic University (90 publications) stands out, actively researching digital solutions, logistics automation and supply chain sustainability. The University of Belgrade (Serbia) rounds out the top 5 with 85 publications, indicating growing interest in the topic in the South- Eastern Europe region.

Overall, the data demonstrates the broad geography and relevance of the HSCM topic, especially in the post-pandemic period, when the efficiency of medical resource supplies has become critical.

SCM is a critical area in both business practice and academic research because it focuses on coordinating and optimising all processes involved in the production, shipping, and delivery of goods from suppliers to end customers. SCM encompasses several interrelated activities, including purchasing, manufacturing, transportation, and logistics, all of which are aimed at maximizing efficiency, reducing costs, and increasing customer satisfaction. This literature review provides an overview of key concepts, theoretical frameworks, and recent advances in the field of SCM.

The concept of SCM emerged in the 1980s as companies began to recognize the importance of coordinating activities across departments and with external partners to improve competitiveness. Early research on SCM focused on logistics and the efficient movement of goods within individual organizations. Pioneering work by researchers such as Bowersox (1989) and Mentzer (1987) emphasized the role of logistics in minimizing costs and improving service quality within organizations. This early focus on logistics laid the foundation for SCM as a field that prioritizes aligning supply chain activities with organizational strategy.

By the 1990s, globalization and advances in information technology had expanded SCM into a multifaceted discipline encompassing both local and international supply chain networks. Key developments during this period included the introduction of just-in-time and lean manufacturing techniques, which were aimed at reducing waste and streamlining inventory management. These practices were particularly influenced by the Japanese manufacturing model, and authors such as Ohno (1988) and Womack & Jones (1990) contributed to the development of Lean principles. In addition, advances in information technology allowed companies to integrate systems for real-time data exchange and inventory tracking, allowing for more effective coordination of supply chain partners (Christopher, 1992).

Overall, the evolution of SCM during this period reflected a shift from isolated logistics functions to a holistic view of the supply chain, emphasizing efficiency, flexibility, and collaboration across global networks.

Following the seminal developments of the 1980s and 1990s, research in SCM has continued to evolve, placing increasing emphasis on creating integrated, adaptive, and resilient supply chains. Below are some of the key research areas and advances that have shaped SCM since the 2000s: Supply Chain Integration and Collaboration. Researchers such as Lambert, Cooper, and Pugh (1998) emphasized the need for collaboration among supply chain partners, introducing the supply chain integration and partnership management models [6]. This approach emphasized that close relationships with suppliers and customers can improve the flow of information, reduce inefficiencies, and create value throughout the supply chain. Simchi-Levi et al. (2003) expanded on this by examining the role of integrated supply chains in responding to demand variability and improving operational flexibility. Their work provided a framework for achieving integration through joint planning and information sharing.

Supply Chain Risk and Resilience Management. As global supply chains have become more complex and vulnerable to disruption, risk management has gained importance. Christopher and Peck (2004) were among the pioneers who emphasized the importance of building resilience in supply chains, advocating for risk mitigation strategies such as diversified sourcing and inventory buffers. -Following the 2008 financial crisis and subsequent disruptions such as natural disasters, scholars such as Wagner and Bode and Tan focused on developing risk assessment frameworks and strategies to enhance supply chain resilience, ensuring business continuity during crises.

Sustainable and Green SCM. Environmental sustainability has become a central focus of SCM research, driven by growing awareness of climate change and corporate social responsibility. Srivastava provided a comprehensive review of green SCM, outlining practices such as waste reduction, green sourcing, and energy-efficient logistics]. Carter and Rogers introduced the concept of sustainable SCM by incorporating environmental, social, and economic aspects and examining how companies can integrate sustainability into their supply chain practices without sacrificing profitability. Digitalization and the Impact of New Technologies.

With the rise of the digital economy, SCM research has begun to focus on the transformative impact of new technologies, including the IoT, AI, blockchain, and big data analytics. Ivanov and Dolguy discussed the role of digital supply chains and digital twins, emphasizing how these technologies improve visibility, real-time monitoring, and decision making. Wang, Gunasekaran, and Ngai examined the impact of big data on supply chain performance, showing how data-driven insights can lead to improved forecasting, risk management, and customer satisfaction. Smart and Agile Supply Chain. Agility and responsiveness have become essential attributes of modern supply chains, especially in fast-moving industries such as technology and fashion. Li discussed the “Triple-A” supply chain concept of agility, adaptability, and consistency as the key to managing demand uncertainty and improving responsiveness to market changes. Yusuf, Gunasekaran, and Adeleye also contributed to the study of agile supply chains by examining how lean and agile processes can improve the performance and sustainability of supply chains.

Thus, logistics as a scientific field has come a long way - from the ancient system of military supply to a modern interdisciplinary science. Initially performing the functions of providing the army in Ancient Greece and Rome, logistics gradually became institutionalized and acquired a theoretical and methodological basis, which was reflected in the works of such thinkers as A. Jomini and G. Leibniz. An important stage in the formation of the conceptual apparatus was the adoption of the official definition of logistics at the First European Congress in Berlin in 1974, where logistics was defined as the science of planning, management and control of resource flows.

The contribution of foreign schools to the development of logistics is extremely significant. American scientists (Bowersox, Kloss, Lambert, Stock) focused on strategic SCM. European researchers (Kotzab, Soering, Christopher) developed the areas of sustainable and digital logistics. The Japanese school (Ohno) has implemented the principles of lean manufacturing and JIT. Chinese scientists have been actively developing issues of public logistics and digital logistics platforms since the 1990s.

Analysis of publication activity (Scopus, Web of Science, Google Scholar) shows a significant increase in interest in logistics from both the scientific community and practitioners. Areas related to digitalization, sustainable development, reverse logistics and healthcare logistics are developing especially actively. The leading countries in terms of the number of publications are China, the USA and Germany.

2.4. Literature Review: SCM of Medical Equipment for Educational Institutions

The study of medical equipment supply chains has gained increasing attention within logistics and SCM research due to their direct impact on the effectiveness and quality of healthcare education. Educational institutions, especially medical universities and colleges, rely on a steady flow of specialized equipment—such as simulators, diagnostic tools, laboratory instruments, and digital platforms—to ensure the competence of future healthcare professionals. However, the management of these supply chains presents a unique combination of challenges that differ significantly from those in traditional healthcare or manufacturing sectors. This review synthesizes existing academic research on medical equipment supply chains (MESCs) in educational institutions, identifies dominant themes, and highlights key research gaps.

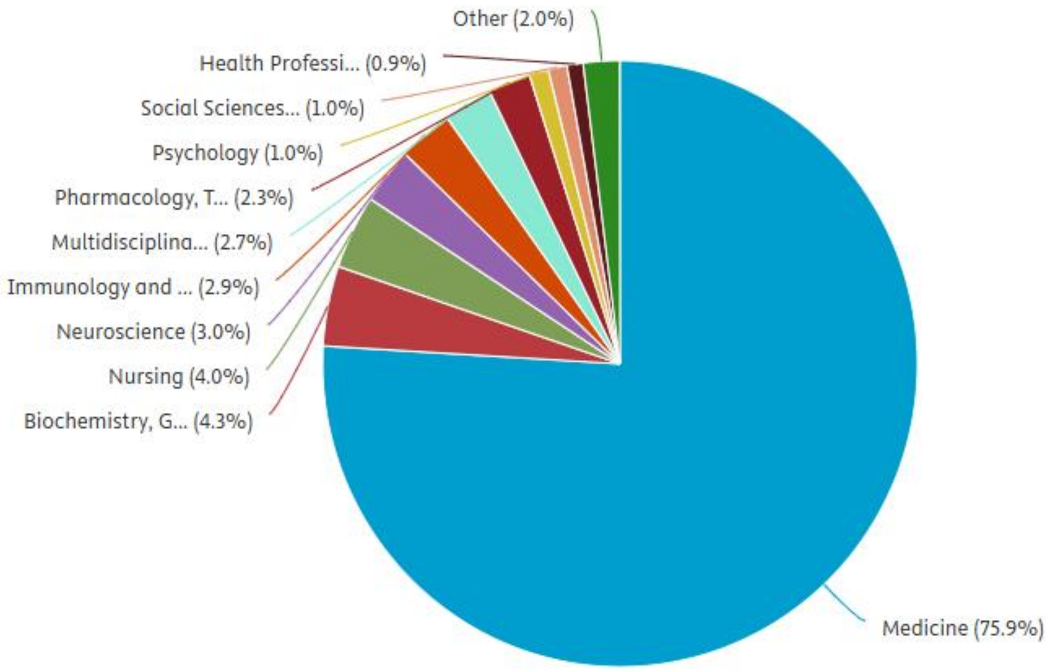

Figure 2.6. Analysis of Publication Activity on Healthcare Logistics in Scopus Database (2025)

Source: Scopus data processed using VOSviewer, 2025.

Conceptual Foundations of Medical Equipment Supply Chains. Medical equipment supply chains represent complex, multi-stakeholder systems that connect manufacturers, distributors, regulatory bodies, educational institutions, and end users.

The supply chain's objective is not merely to deliver physical products but to ensure compliance with technical, educational, and ethical standards. As emphasized by Mentzer et al. (2001) and Christopher (2016), SCM must integrate logistics, operations management, and strategic planning to align supply activities with institutional goals. Early literature primarily treated medical equipment supply as an extension of healthcare logistics, focusing on hospitals, clinics, and public health organizations (Govindan et al., 2018). However, since the 2010s, researchers have begun to recognize educational supply chains as a distinct field requiring tailored models of planning, procurement, and risk management.

The educational environment imposes specific constraints—budget limitations, procurement cycles tied to academic years, and the need for durable, reusable, and safe equipment suitable for training rather than direct patient care.

In parallel, a number of Chinese scholars have made significant contributions to this emerging area. Wang Zhenyu (2016) and Chen Xiangming (2018) emphasized the importance of digital transformation and intelligent logistics systems in supporting medical education infrastructure in China. Liu

Jianyong (2019) and Zhang Hua (2020) explored government-coordinated procurement models and the integration of smart logistics technologies such as RFID, IoT, and Big Data analytics into university supply systems. Furthermore, studies by Shen Houcai (2021) and Ma Shihua (2022) analyzed the strategic alignment between educational institutions and industrial clusters within the framework of the "Healthy China 2030" initiative, demonstrating how state-driven logistics innovation improves access to medical equipment and enhances training quality. Collectively, Chinese research has expanded the theoretical and practical understanding of educational logistics, positioning it as a vital component of national human capital development.

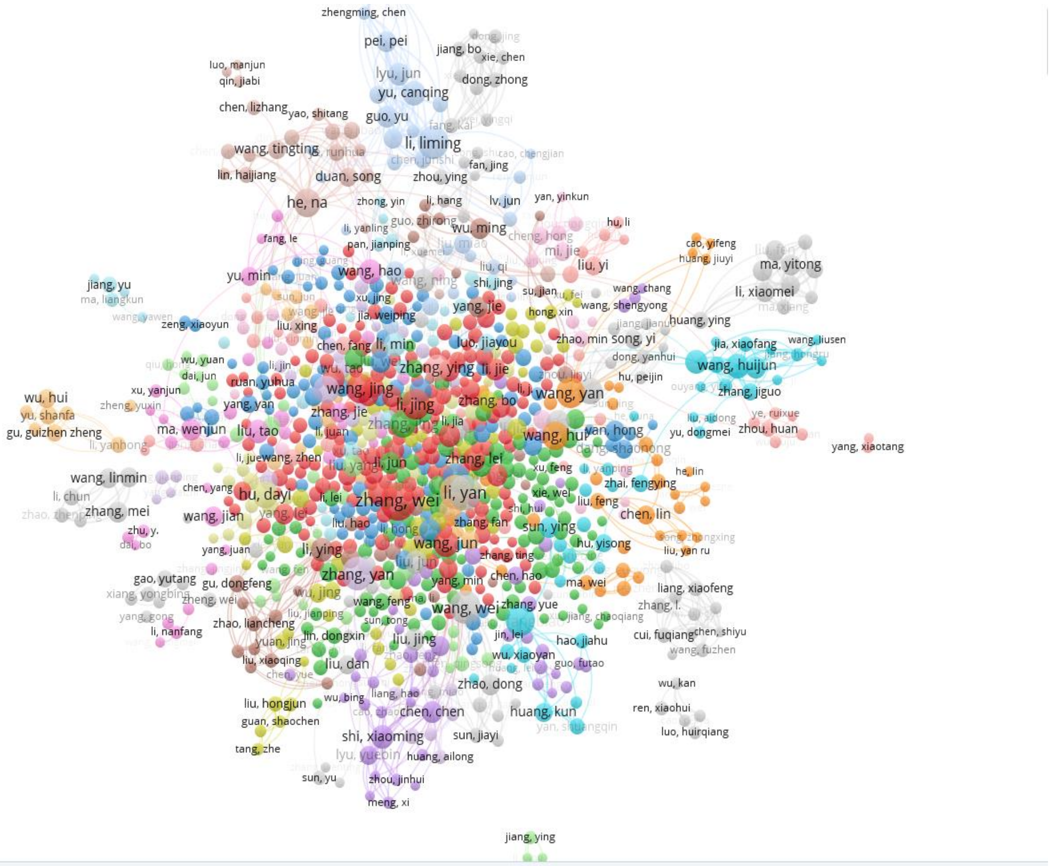

Figure 2.7. Co-authorship Network of Researchers in Healthcare Logistics (2025)
Source: Scopus data processed using VOSviewer, 2025.

Colors indicate clusters of collaboration, often corresponding to institutional or regional research communities. The visualization shows that Chinese scholars form the most extensive and interconnected cluster, reflecting the country's strong publication activity and leadership in this domain.

Optimisation of Logistic and Procurement Processes

Optimisation of logistics and procurement processes is one of the central research directions in SCM, particularly relevant for sectors where precision, timing, and quality assurance are critical — such as healthcare and medical education. The efficiency of supply chains in educational institutions not only determines the timely availability of medical equipment but also directly influences the quality of training of future healthcare professionals. Consequently, the study of procurement mechanisms, logistics coordination, and digitalization of supply flows has attracted increasing attention from scholars worldwide.

According to Porter (1985), logistics and procurement optimisation form a key element of the value chain that defines a company's competitive advantage. The integration of logistics processes with strategic management allows organizations to minimize operational costs, ensure reliability, and maintain adaptability in dynamic market environments. Tang & Lee (2007) extend this concept by emphasizing the importance of adaptive supply chains, which can flexibly respond to fluctuations in demand, disruptions, and institutional constraints. For educational institutions, this adaptability translates into the ability to synchronize procurement cycles with academic calendars, anticipate needs for specific types of training equipment, and coordinate supply schedules to avoid interruptions in the learning process.

In the context of medical education, optimisation is achieved through strategic procurement planning, digital inventory monitoring, and partnership-based supplier relationships. Procurement cycles often require balancing between cost efficiency and high standards of product reliability, safety, and maintenance. The studies of Handfield and Nichols (1999) and Monczka et al. (2015) indicate that procurement effectiveness depends on a systematic evaluation of suppliers using both quantitative and qualitative indicators — price, quality certification, delivery punctuality, and after-sales service. This is particularly relevant for educational institutions that must maintain laboratories, simulation centers, and training hospitals equipped with certified, high-precision devices.

Ma Shihua, one of the leading Chinese researchers in logistics and SCM, views the supply chain not merely as a logistical or financial process but as a **value-added chain** in which each stage — from production and assembly to calibration, packaging, and transportation — contributes to the increase in value of the end product. His interpretation expands the traditional understanding of logistics by including the innovation and quality dimensions of the process. This perspective aligns with the principles of **Lean Production** (Ohno, 1988; Womack & Jones, 1996), emphasizing waste minimization, continuous improvement, and efficient resource allocation. In educational logistics, lean approaches ensure that procurement and distribution systems deliver equipment exactly when needed, avoiding excess inventory and storage costs.

Optimisation also involves implementing digital technologies that transform supply chain visibility and decision-making processes. Wang, Gunasekaran, and Ngai (2016) emphasize that data-driven logistics enable real-time monitoring of supply flows, predictive analytics for demand forecasting, and early detection of potential delays or shortages. Chinese researchers such as Chen Yimin and Zhang Ying (2023) have demonstrated how the integration of IoT, Big Data, and AI into educational logistics systems improves the precision of procurement planning and enables dynamic adjustment of orders according to actual usage rates. This approach has been successfully implemented in Chinese medical universities, where smart inventory systems track the usage of simulators and diagnostic devices and automatically generate procurement requests.

Furthermore, optimisation of logistics processes in the medical education sector requires cross-functional integration between academic, administrative, and financial departments. Studies by Lambert, Cooper, and Pagh (1998) highlight the role of internal coordination between different organizational units in achieving supply chain efficiency. In universities, logistics departments must interact with deans' offices, finance divisions, and technical services to ensure that procurement plans align with budget cycles, accreditation requirements, and curricula updates.

Table 2.3. Key Theoretical Approaches to Optimisation of Logistic and Procurement Processes

Author(s) / Year	**Main Focus / Concept**	**Contribution to Logistics and Procurement Optimisation**	**Application to Educational Institutions (Medical Equipment)**	**Limitations / Research Gaps**
Porter (1985)	Value Chain Concept	Identified logistics and procurement as key components of competitive advantage; emphasized integration between internal activities.	Strategic procurement planning and coordination with academic and administrative departments to align educational goals with resource efficiency.	Limited focus on the public and educational sectors.
Tang & Lee (2007)	Adaptive Supply Chain	Proposed models for flexible and responsive supply chains under uncertainty and crises.	Useful for adapting procurement cycles to academic calendars and dynamic equipment demand in medical universities.	Requires advanced data systems; limited in resource-constrained contexts.
Ma Shihua (China, 2015–2023)	Supply Chain as Value-Added Process	Defined supply chains as sequences of value creation — from assembly to delivery; emphasized lean production and digital tools.	Promotes integration of value-based logistics for educational labs and simulation centers; enhances quality and transparency.	Empirical studies in education are still scarce.
Ohno (1988); Womack	Lean Productio n / Just-	Reduced waste and non-value activities in logistics; improved flow	Supports on-demand procurement of teaching simulators and	JIT may be risky under long lead times or unstable

& Jones (1996)	in-Time	synchronization.	consumables; prevents overstocking.	imports.
Handfield & Nichols (1999); Monczka et al. (2015)	Strategic Supplier Management	Developed frameworks for supplier evaluation and partnership building.	Selection of certified and reliable equipment providers for universities and hospitals.	Requires institutional data and supplier transparency.
Wang, Gunasekaran & Ngai (2016)	Big Data and Smart Logistics	Demonstrated the role of data analytics in forecasting and optimising logistics.	Enables predictive procurement for educational institutions through ERP and IoT systems.	Implementation costs are high; digital maturity varies.
Ivanov & Dolgui (2020)	Digital Supply Chains and Resilience	Analyzed integration of digital twins, AI, and ERP systems in logistics.	Facilitates resilience planning, predictive maintenance, and emergency procurement in education.	Needs stable infrastructure and skilled personnel.
Srivastava (2007); Carter & Rogers (2008)	Green SCM	Combined economic efficiency with environmental sustainability.	Encourages procurement of eco-friendly educational equipment and recycling programs.	Green logistics underrepresented in education sector.
Umetaliev (Kyrgyzstan, 2019)	Educational Logistics Development	Formed the basis of national logistics education and management in Kyrgyzstan; focused on integration with public procurement.	Provides a localized framework for optimising procurement of medical devices for universities.	Needs further quantitative and comparative studies.

Source: Compiled by the Author based on Porter, Tang & Lee, Ma Shihua, Womack & Jones, Ivanov & Dolgui, Srivastava, and others (1985–2023).

As noted by Ivanov and Dolgui (2020), the integration of ERP with logistics management systems allows for centralized control over procurement processes, from order approval to delivery confirmation.

In developing countries, including the Kyrgyz Republic, optimisation faces additional barriers — limited infrastructure, bureaucratic delays, and fragmented supplier markets. Studies by Shcherbekova and Ysyrailova (2024) and Bekboev et al. (2017) reveal that inefficient coordination between suppliers and educational institutions often leads to overstocking or shortages of critical medical devices. Therefore, optimisation strategies should prioritize risk reduction through diversification of suppliers, digital tracking of shipments, and clear contractual terms. The introduction of public-private partnerships (PPP) in logistics, as practiced in Germany and China, may enhance procurement efficiency and sustainability

The Kraljic Matrix (1983) remains a valuable analytical tool for procurement optimisation, classifying suppliers based on supply risk and strategic importance. In the context of educational logistics, essential equipment such as diagnostic simulators, surgical models, and laboratory analyzers fall under the “strategic” or “bottleneck” categories, requiring careful supplier selection and long-term partnerships. On the other hand, routine supplies (e.g., consumables) can be managed through competitive tendering to ensure cost control.

From an operational standpoint, optimisation also entails improving transport logistics and warehouse management. Studies by Chopra and Meindl (2019) highlight the role of transport coordination in maintaining the integrity and safety of medical devices, particularly those sensitive to temperature and vibration. In the case of medical education institutions, specialized logistics operators are often contracted to ensure compliance with safety standards during the transportation of delicate devices. In China, for instance, companies such as JD Logistics Healthcare and Cainiao Health have implemented customized logistics chains for universities and teaching hospitals, which include temperature monitoring and digital proof of delivery.

Another key aspect of optimisation is risk management in logistics operations. Simchi-Levi (2010) and Christopher & Peck (2004) argue that resilient supply chains should be able to anticipate, absorb, and recover from disruptions caused by economic crises, pandemics, or geopolitical instability. The COVID-19 pandemic provided a practical test for these theories, revealing the importance of redundancy, safety stock, and alternative sourcing. Chinese and Indian universities responded to disruptions by creating regional distribution hubs and introducing emergency procurement protocols for educational medical equipment. These practices highlight the necessity of building resilience alongside efficiency in the optimisation process.

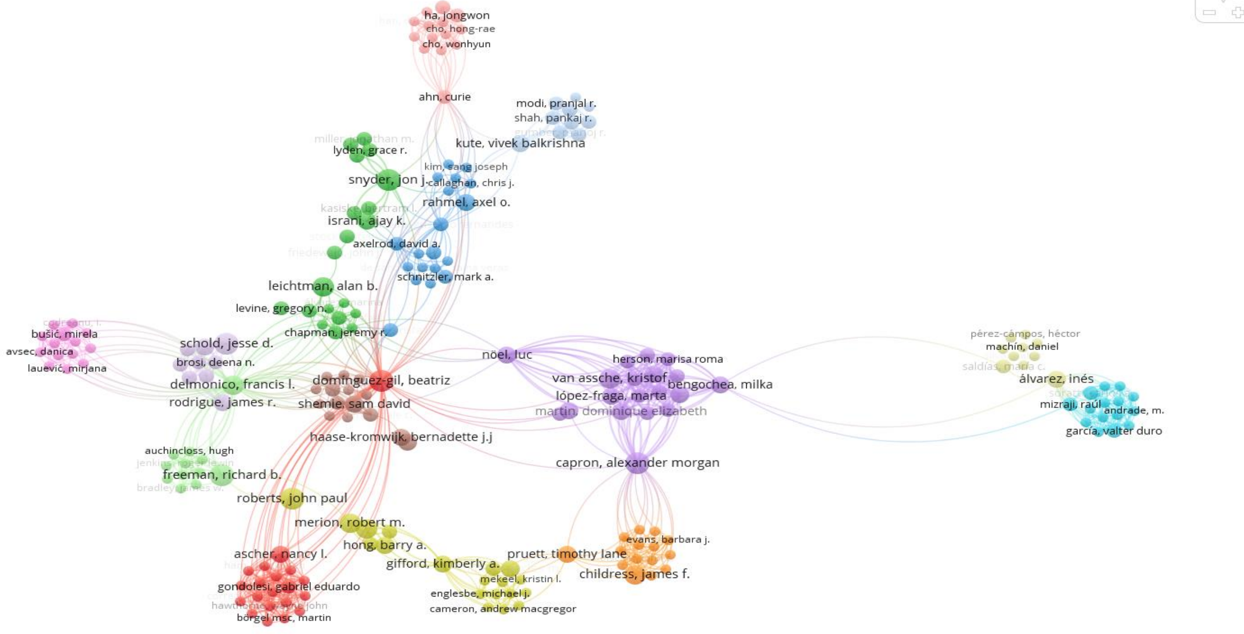

Figure 2.8. Researcher Co-authorship Network in Procurement Logistics (2025)

Source: Scopus data processed using VOSviewer, 2025

Economic and environmental sustainability have also become integral components of logistics optimisation. Srivastava (2007) and Carter & Rogers (2008) introduced the concept of Green SCM, which combines economic efficiency with environmental responsibility. In the educational sector, this involves the procurement of energy-efficient devices, eco-friendly packaging, and the recycling or refurbishment of outdated equipment. According to Wu Hui (2022), Chinese universities are leading in this domain, implementing digital platforms to monitor carbon emissions and energy usage in logistics operations. The integration of green logistics principles into educational SCM supports global Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 12 (Responsible Consumption and Production).

Finally, the optimisation of procurement and logistics processes cannot be separated from human capital development. As noted by Umetaliev (2019), the efficiency of logistics in education depends on the professional competence of staff responsible for procurement planning, supplier communication, and equipment maintenance. Training programs in logistics and SCM, especially those focusing on digital skills, are essential for ensuring sustainable improvement in this area. The International Higher School of Logistics in Kyrgyzstan and the Hong Kong Polytechnic University provide examples of integrating logistics education with practical industry applications, fostering innovation and analytical capabilities among students and practitioners.

In summary, the optimisation of logistics and procurement processes in the supply chain of medical equipment for educational institutions is a multidimensional task encompassing strategic management, digitalization, sustainability, and human resource development. The combination of traditional models (Porter, Kraljic) with modern digital and sustainable frameworks (IoT, AI, GSCM) provides a comprehensive foundation for further research and practice. Future studies should focus on adapting these models to the specific conditions of developing economies, enhancing transparency in procurement, and integrating predictive analytics for proactive decision-making. In this context, optimisation is not merely a matter of cost reduction but a strategic tool for ensuring educational quality, institutional resilience, and alignment with global sustainability standards.

CHAPTER III

CHAPTER III. ANALYSIS OF THE CURRENT STATE OF MEDICAL EQUIPMENT SUPPLY FOR EDUCATIONAL INSTITUTIONS OF THE KYRGYZ REPUBLIC

3.1. Evolution Regulatory and Institutional Framework for the Supply of Medical Equipment to Educational Institutions of the Kyrgyz Republic

Educational institutions, particularly those that train specialists in medicine and healthcare, require high-quality medical equipment to ensure an effective learning process. Modern trends in medical education demand the use of advanced technological devices, simulators, diagnostic tools, and laboratory equipment. However, the supply of medical equipment to educational institutions in the Kyrgyz Republic faces several challenges related to SCM, regulatory frameworks, financing, and logistics.

Improving the system of medical equipment supply to educational institutions requires a thorough analysis of the current situation, the identification of key problems, and the development of effective solutions. To achieve this, it is necessary to examine the regulatory framework, determine the main market participants, study the existing procurement mechanisms, and analyze the needs of educational institutions for medical equipment.

The supply of medical equipment is a complex process that involves several stages, including planning, procurement, logistics, installation, and technical maintenance. It is also crucial to consider funding sources, as a significant portion of the equipment is purchased using government funds, grants from international organizations, and private investments. Therefore, particular attention should be paid to the efficiency of public procurement procedures and the transparency of tendering processes.

The current challenges in the supply chain of medical equipment for educational institutions include: Financial constraints – a lack of budgetary funds for purchasing modern equipment, the high cost of medical devices, and the need for long-term financing. Logistical barriers – difficulties in transportation and storage, as well as a shortage of qualified personnel for installation and maintenance. Bureaucratic obstacles – lengthy tendering processes, inefficiencies in the regulatory framework, and challenges in coordinating various government and private sector entities. Lack of standardized regulations – the absence of unified standards for medical equipment in educational institutions, leading to inconsistencies in the procurement of necessary devices.

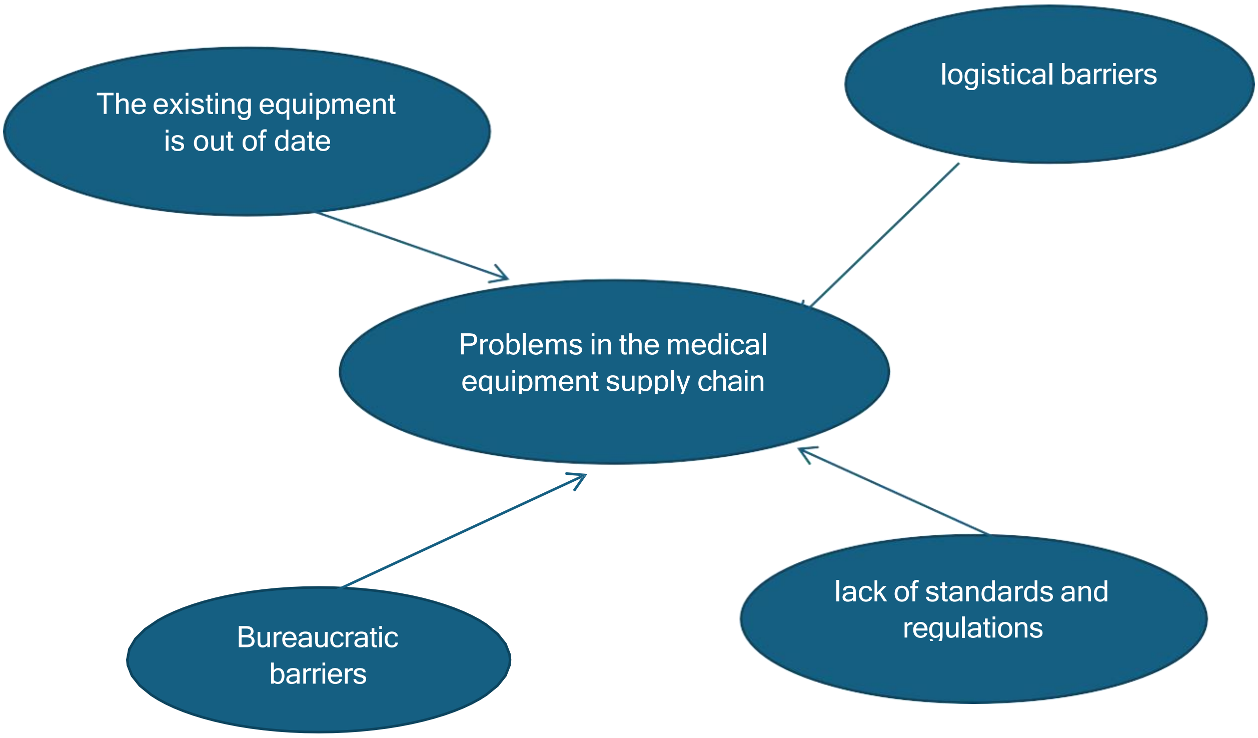

Figure 3.1. Challenges in the Medical Equipment Supply Chain

Outdated equipment – many educational institutions use obsolete technology, which reduces the effectiveness of medical training. This chapter aims to analyze all aspects of the medical equipment supply system for educational institutions in the Kyrgyz Republic. It examines the regulatory framework, key market participants, procurement mechanisms, and the main problems and limitations. Special attention is given to assessing the current level of equipment in educational institutions, their specific needs, and potential development prospects.

The results of this analysis will help identify key areas for improving the supply system and propose measures to optimise logistical, financial, and administrative processes. Ultimately, this will contribute to enhancing the quality of medical education in the country and preparing well-qualified professionals for the healthcare system.

Overview of the Regulatory Framework. Government Regulation of Medical Equipment Supply. In the Kyrgyz Republic, the supply of medical equipment is governed by national legislation that oversees procurement, certification, and utilization of medical devices. The primary regulatory bodies in this domain include the Ministry of Health, the Ministry of Education and Science, and the State Antimonopoly Service.

Procurement of medical equipment for educational institutions, especially medical universities, colleges, and schools with a medical focus, is conducted through a state tender system. The procurement procedures are defined by the Law of the Kyrgyz Republic «On Public Procurement» (No. 27, April 14, 2022), which establishes principles of transparency, equal participation, and efficient use of budgetary funds.

Beyond procurement, government regulation encompasses certification and licensing of medical devices. Medical equipment intended for educational purposes must comply with technical requirements set by the State Agency for Technical Regulation and Metrology**.** Imported equipment is subject to mandatory certification to ensure that only high-quality and safe devices are utilized in educational settings. Additionally, the state regulates the disposal of obsolete medical equipment.

According to legislative norms, medical devices that have exceeded their service life must be disposed of in accordance with environmental standards. This prevents the use of defective equipment and reduces health risks for students.

Laws and Regulations Governing Procurement and Supply in Education and Healthcare

The legal framework of the Kyrgyz Republic concerning the procurement and supply of medical equipment includes several key documents:

The Law of the Kyrgyz Republic «On Public Procurement»(No. 27, April 14, 2022) – regulates the process of acquiring goods, works, and services using public funds. It defines procedures for conducting tenders, criteria for selecting suppliers, and conditions for contract conclusion.

The Law «On Education» (No. 179, August 11, 2023) – establishes the fundamental principles of state policy in the field of education, as well as the legal, socio-economic, and organizational foundations of educational activities in the Kyrgyz Republic.

The Law «On the Fundamentals of Health Protection of Citizens» – regulates the use of medical equipment in educational institutions, university- affiliated medical centers, and practical training facilities for students.

Government Decree on Medical Equipment Certification – establishes the procedure for certifying medical devices, including those imported from abroad. Sanitary and Epidemiological Regulations (SanPiN) for Educational Institutions – contain requirements for medical equipment used in the educational process, as well as conditions for its operation.

These legal acts provide a regulatory basis for transparency and efficiency in procurement, ensuring that medical equipment meets educational and healthcare standards. However, in practice, challenges exist related to lengthy tender procedures, bureaucratic barriers, and limited financial resources.

International Standards and Their Impact on the Supply Chain

International standards play a crucial role in ensuring the quality and safety of medical equipment used in educational institutions. Among the key standards applied in the Kyrgyz Republic are:

- *ISO 13485* – an international standard regulating the quality management system for medical devices. Equipment that complies with this standard guarantees safety and effectiveness in the educational process.

- *IEC 60601* – an international standard defining safety and electromagnetic compatibility requirements for medical equipment. The use of equipment meeting this standard minimizes risks for students and instructors.

- *World Health Organization* Recommendations on Medical Equipment – WHO regularly develops guidelines on classification, usage, and procurement of medical equipment, assisting countries in aligning their supply systems with international requirements.

- *Harmonization with the Eurasian Economic Union* – The Kyrgyz Republic is a member of the EAEU, which necessitates aligning national standards with Union requirements, particularly in the certification and circulation of medical products.

The influence of international standards on the supply chain lies in their role in determining the requirements for medical equipment that can be procured and used in educational institutions. While this enhances equipment quality, it also increases costs associated with certification and importation.

In summary, the regulatory framework governing the supply of medical equipment to educational institutions in the Kyrgyz Republic comprises national laws, government decrees, and international standards. Despite the existence of well- defined rules, challenges persist, including lengthy procurement procedures, high compliance costs with international standards, and insufficient funding. The following sections of this chapter will examine key supply chain participants, procurement mechanisms, and major challenges hindering the efficient provision of medical equipment to educational institutions.

3.2. Forms and methods of medical simulation training

The history of medical simulation in the training of doctors goes back many millennia and is inextricably linked with the development of medical knowledge and scientific and technological progress. The development of the chemical industry led to the emergence of plastic mannequins, and progress in computer technology became the basis for the creation of virtual simulators and patient simulators.

A wide range of simulation technologies is used in the modern healthcare system: phantoms, models, dummies, simulators, virtual simulators and other training tools that allow simulating clinical processes and various aspects of the professional activities of medical workers. Simple phantoms, which are used to practice basic practical skills, have been used in some educational institutions for a long time. However, only in recent years have complex virtual simulators and systems for managing their use in the educational process become widespread. By now, considerable experience has been accumulated in the application of simulation methods in medical training, as described in the work of Naigovzin N.B., Filatov V.B., Gorshkov M.D., Gushchina E.Yu., and Kolysh A. For novice doctors, mastering the practical skills of performing medical interventions requires a long time. For example, doctors pecializing in endovideosurgery need to perform from 10 to 200 laparoscopic cholecystectomies, as well as 20-60 fundoplications, to master the techniques, as mentioned in the work of Petrov S.V., Strizheletsky V.V., Gorshkov M.D., Guslev A.B., and Schmidt E.V. Virtual simulators allow physicians not only to master basic skills, but also to practice complex interventions without risk to patients, as shown in studies by Dongen K.W., Zee D.C., and Broeders I.A.M.J. These technologies are becoming an important element of the medical education system and allow simulating situations that may not always be available in real practice, which helps physicians of different experience levels perform surgeries more efficiently and confidently. According to the authors Carter F.J., Farrell S.J., Francis N.K., Adamson G.D., Davie W.C., Martindale J.P. and Cuschieri A., virtual technologies are the only effective and safe way to practice practical skills in modern medicine.

Table 3.1. Levels of Simulation Training in Medical Education

№	Level of Simulation	Description / Training Characteristics	Pedagogical Purpose / Learning Outcome	Sources
1.	Visual Level	Use of traditional educational tools – diagrams, posters, anatomical models, e-books, and computer programs.	Provides basic visual understanding of medical procedures without hands-on practice.	Bradley (2006)
2.	Tactile Level	Practice of manual skills using phantoms imitating passive reactions.	Develops coordination and basic technical motor skills.	Naigovzin et al. (2013)
3.	Reactive Level	Phantoms respond to actions with simple active reactions; basic electronic simulators.	Allows evaluation of movement accuracy and sequence of manipulations.	Petrov et al. (2009)
4.	Automated Level	Mannequin responds to external stimuli using programmed computer algorithms.	Enhances sensory-motor coordination and cognitive skills.	Dongen et al. (2005)
5.	Hardware Level	Simulation of a medical office or operating theatre environment.	Builds confidence and readiness for real clinical practice.	Carter et al. (2005)

6.	Interactive Level	Interaction between simulator, student, and medical equipment. Physiological responses are simulated.	Enables assessment of clinical decision-making and procedural competence.	Rosen (2008)
7.	Integrated Level	Combination of simulators and medical devices, such as virtual trainers displaying patient data.	Develops psychomotor and sensorimotor skills; enhances realism.	Osanova et al. (2011)
8.	Virtual Level	Use of virtual reality for complete immersion into simulated scenarios.	Promotes active problem-solving and teamwork in critical care contexts.	Bradley (2006); Dongen et al. (2005)
9.	Hybrid Level	Integration of mannequins, VR, and interactive software modules.	Combines manual and cognitive training for multitasking readiness.	Osanova et al. (2011)
10.	Multimodal Level	Comprehensive clinical environment with mannequins, virtual models, medical devices, and software.	Provides holistic preparation for real clinical practice; full immersive learning.	Rosen (2008); WHO (2024)

Source: Compiled by the author based on works by Naigovzin et al. (2013), Petrov et al. (2009), Dongen et al. (2005), Rosen (2008), Bradley (2006), Osanova et al. (2011), and WHO guidelines (2024).

Computer modeling allows students to practice actions in situations that actively respond to their manipulations, completely simulating the patient's physiological responses or tissue reactions to the surgeon's actions. Doctors who have gained practical experience with virtual simulators demonstrate more confident and professional results in real interventions. In addition, the use of objective patient data, such as MRI, CT or ultrasound, allows you to model and practice upcoming

studies and operations in advance, which reduces potential risks and improves the quality of medical care.

According to Rosen, the origins of simulation in medicine can be defined as “the imitation of a real object, state, or process” for skill practice, problem solving, and decision-making. From the earliest simulators such as the “blue box” for pilot training, and the significant role of the military in transferring modeling and simulation technology to medicine, the global acceptance of simulation education continues to grow. Large, collaborative simulation centers are expected to enhance opportunities for interdisciplinary, interprofessional, and multimodal learning. Both immersive and web-based virtual worlds are at the forefront of innovation in medical education.

The article by Bradley, P. discusses the significant impact of clinical simulation on medical education at the undergraduate and postgraduate levels. The author notes the diversity of simulation technologies, but emphasizes the need for further research to substantiate their effectiveness.

Levels of Simulation Training in Medicine

Visual level – use of traditional educational technologies: diagrams, posters, anatomy models. This also includes simple e-books and computer programs. The basis of visual training is familiarization with the correct sequence of actions when performing medical manipulations, but it does not provide an opportunity for practical training.

Tactile level – practicing manual skills using phantoms that imitate a passive reaction. Students can improve coordinated movements and automate individual manipulations, which helps to acquire technical skills.

Reactive level – phantoms respond to the student's actions with simple active reactions. This allows you to evaluate the accuracy of actions at a basic level, simulators are usually made of plastic and equipped with electronic controllers to control reactions.

Automated level – the mannequin responds to external influences using computer technology. Scripts program reactions to certain actions, which contributes to the development of cognitive skills and sensory motor skills.

Hardware level – reproduction of the environment of a medical office or operating room. Training systems at this level help develop confidence and readiness to act in conditions similar to real clinical practice.

Interactive level – complex interaction of the simulator with medical equipment and the student. The manikin imitates physiological changes in response to the administration of drugs or errors, which allows assessing professional qualifications.

Integrated level – a combination of simulators and medical devices, such as virtual trainers displaying patient indicators. At this level, psychomotor and sensorimotor skills are practiced. The transition to the next level of realism requires significantly greater financial costs (the “triple” rule).

Virtual level – the use of virtual reality for full immersion in the educational process. Students practice complex clinical scenarios in an interactive environment that models critical situations, which allows them to develop skills in conditions that imitate reality.

Hybrid level – a combination of various simulation technologies, such as mannequins, virtual reality and interactive programs. This approach allows students to develop both manual skills and cognitive abilities, preparing them for multi-tasking scenarios.

Multimodal level – creating a full-fledged clinical environment, including mannequins, virtual models, medical equipment and software modules. This most advanced level of simulation training provides comprehensive training, allowing students to practice all aspects of professional activity in realistic conditions. These levels of simulation training provide educational institutions with the opportunity to gradually improve the quality of training specialists, ensuring the transition from basic forms to full immersive models. According to Osanova M.V., Timerbaev V.Kh., Valetova V.V. and Zvereva N.Yu. modern simulation educational technologies can be divided into two concepts. The first is training in practical skills and algorithms using specialized simulators and mannequins. The second is clinical modeling of critical situations using a training system in which the main component is a multifunctional computerized mannequin simulating a real patient. The first approach to training using simulation is aimed at developing specific practical skills or a set of them, methods and algorithms using simulators or mannequins of varying levels of complexity. Its main goal is to teach a specialist to perform specific manipulations, such as intubation, providing vascular access, defibrillation and other actions that require practicing their hands. Within the framework of this approach, specialists practice individual methods and algorithms, allowing them to study in detail and remember the sequence of actions in critical situations. Training is carried out individually, without the need to simulate teamwork or fully recreate the patient's appearance and emergency care conditions. The second approach - simulation in emergency medicine - covers a broader context. It aims to prepare a specialist to interact with a patient in a critical situation, bringing the training conditions as close as possible to real ones. This training simulates the patient's appearance, his vital functions (conversation, breathing, pulsation in peripheral vessels, sounds of the heart, lungs and gastrointestinal tract, as well as parameters on medical equipment monitors). The computer program allows changing the patient parameters and creating scenarios of various critical conditions so that students can apply their knowledge, analytical and practical skills, use medical equipment and develop clinical experience. Simulation training is based on creating conditions that imitate as much as possible all aspects of a real critical situation, including reproduction of the scene (operating room, intensive care unit, ambulance). If appropriate, the simulation can include psychological elements, using "actors" to create them – students, medical personnel or volunteers.

A survey of 200 students at a medical university in Kyrgyzstan revealed the following results and opinions about the educational process and the use of simulation technologies in training.

Section 1: Overall satisfaction with the educational process

- Most students (about 70%) expressed satisfaction with the quality of education at the university. They noted the availability of educational materials and resources, but 40% would like to see improvements in this aspect.

- About 60% of students feel partially prepared for practical work, but noted a lack of practical classes with real patients.

Section 2: Evaluation of simulation training

- 85% of respondents confirmed participation in simulation classes, with about 65% noting the high level of realism of the simulators used.
- More than half of the students consider the frequency of simulation classes insufficient, and 75% of respondents indicated that simulation training significantly helps in developing practical skills.
- Students most often work with mannequins and computer simulators, while 45% would like more virtual reality training.

Section 3: Practical training

About 55% of students believe that practical training at their university is insufficient for their specialization.

- The question about time allocation showed that many students would like to have more time to practice practical skills.
- 60% of respondents expressed confidence in performing manipulations after simulation training, but many noted a desire to practice complex procedures such as intubation and vascular access more often.

Section 4: Interaction with teachers and mentors

- Most students (70%) reported regular feedback from teachers, although 30% believe that teachers could explain errors more.
- Students generally rate the competence of teachers in using simulation equipment as high, but 20% noted that teachers could improve their skills in working with simulators.

Section 5: Assessing the Conditions and Resources

- 65% of students are satisfied with the state of the simulation labs, but 35% believe that the equipment needs to be updated.
- More than 50% of students noted a lack of simulators, especially when the student flow is high.
- Among the suggestions for improvement, students highlighted the need for additional simulators and more classes.

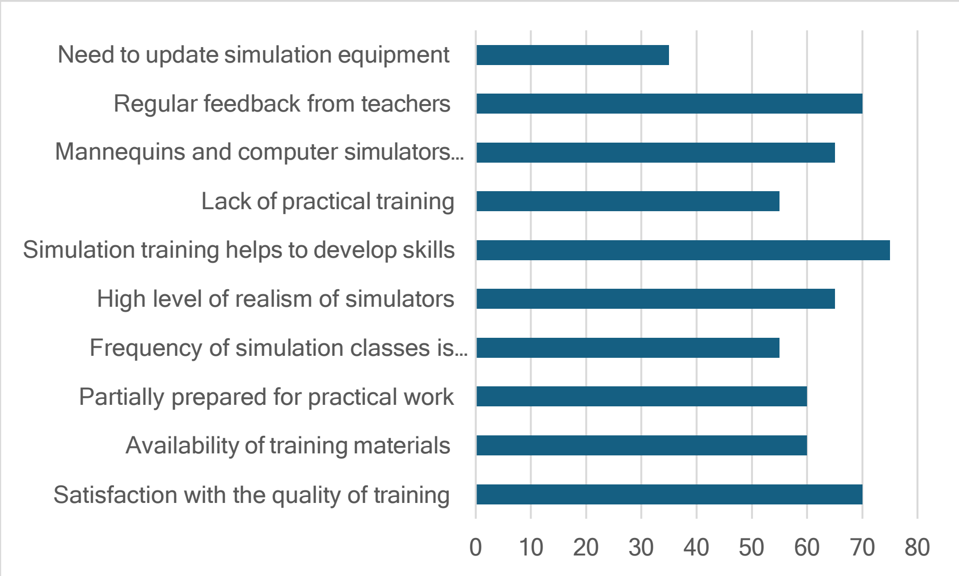

Figure 3.2. Survey Results on Students' Satisfaction with Medical Education and Simulation Training in KR

Most students believe that simulation training significantly improves their practical training, but they note the need for updated equipment, increased frequency of classes, and greater access to virtual reality.

The results of a survey of students at the Medical University of Kyrgyzstan indicate that the state of simulation equipment is one of the important issues affecting the quality of training of future medical specialists. According to the survey, about 65% of students were satisfied with the current state of simulation laboratories; however, 35% of respondents believe that equipment needs to be updated. The lack of modern equipment limits the opportunities for practical training of students' skills in conditions close to real clinical practice.

Most students also note the lack of simulators, which leads to queues for access to available equipment, especially with a large number of students in the course. This situation not only slows down the conduct of classes, but also reduces the effectiveness of the educational process due to the need to divide time between using simulators and limiting the opportunity for in-depth mastery of educational skills.

Students emphasized the importance of using modern technologies in education, such as virtual reality, which significantly improves the realism of the educational process. However, significant funding is required to integrate such technologies and update training simulators - this is becoming a problem for most universities in the country.

To solve this problem, it is necessary to attract funding from the state and private companies, as well as use international grants. Updating and expanding equipment for simulation training will not only improve the quality of practical training of students of medical universities in Kyrgyzstan, but will also help them meet international standards in the field of medical education.

3.3. Analysis of State Budget Expenditure on Education and Medical Training in the Kyrgyz Republic

State Expenditures and the Development of Higher Education and Medicine in Kyrgyzstan: A Macroeconomic Perspective.

To better understand Kyrgyzstan's fiscal capacity to support education and medical training, it is essential to examine the broader macroeconomic context. One of the key indicators in this regard is the **GDP**, which reflects the overall economic performance of the country and serves as the foundation for determining the proportionality of public spending.

The following figure illustrates the **dynamics of GDP (in current US dollars)** over recent years, providing a framework for evaluating the adequacy, stability, and sustainability of state budget allocations to the education and healthcare sectors.

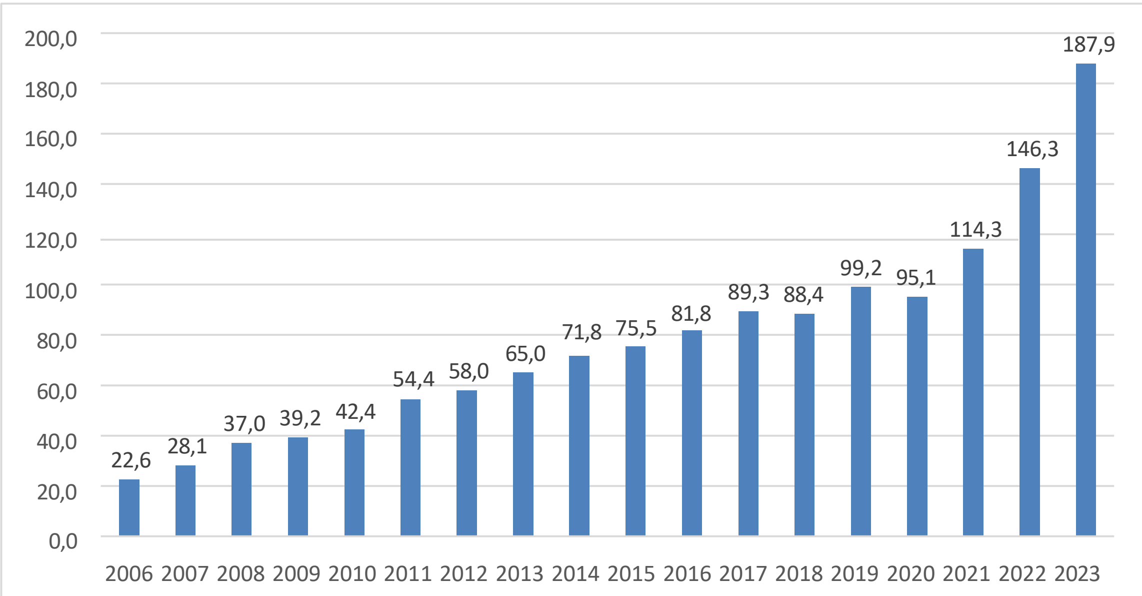

Figure 3.3. GDP of the Kyrgyz Republic (US$ million)

The dynamics of the GDP of Kyrgyzstan for 2006– 2024 shows a general growth trend with periodic declines. In 2007–2008, GDP increased significantly (by more than 34%), which could be due to active investment and economic growth. However, in 2009, a decline of 9.3% was observed, which is probably due to the consequences of the global financial crisis. Despite the overall growth of the GDP, a more accurate picture of economic development is given by an analysis of GDP per capita. This indicator allows us to take into account demographic changes and assess how economic resources are distributed among the population.

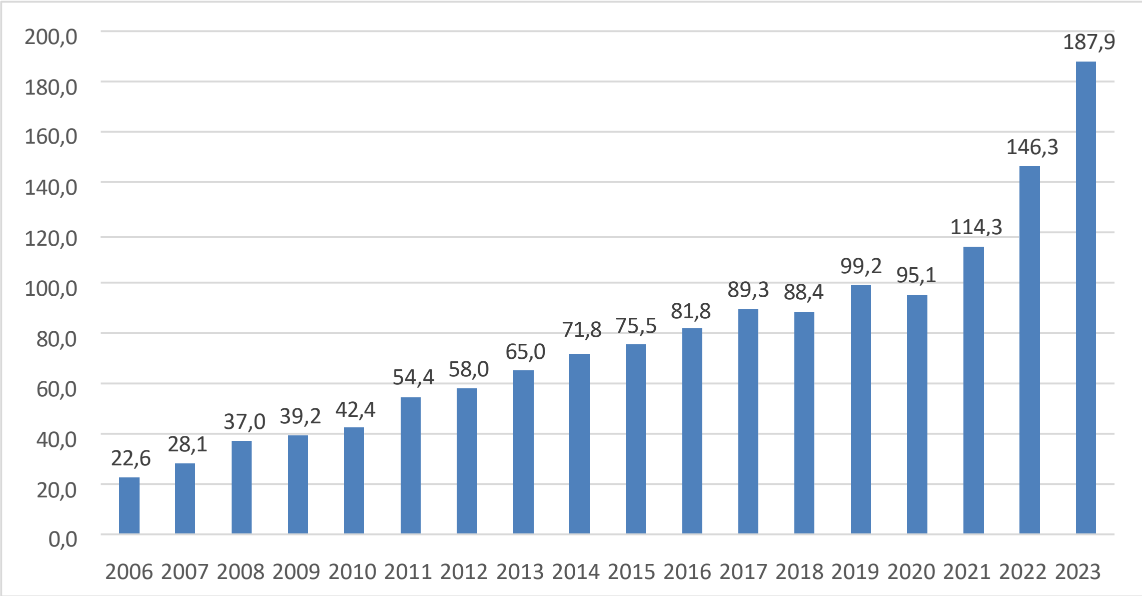

Figure 3.4. Figure Analysis of the dynamics of GDP per capita in Kyrgyzstan (2006–2023) (thousand soms).

Source: compiled based on data from the National Statistics Committee of the Kyrgyz Republic.

GDP per capita is an important indicator of the level of economic development and well-being of citizens. In the period from 2006 to 2023, Kyrgyzstan saw a steady growth in this indicator, but the dynamics were uneven.

In 2007–2008, significant growth in GDP per capita was recorded - by 24.3% and 31.7%, respectively, and in 2009, the growth rate slowed to 5.9% due to the effects of the global financial crisis.

In the period 2010–2019, GDP per capita increased, although there was a slight decrease in 2018. In 2020, the indicator decreased to 95.1 thousand soms, which is explained by the economic consequences of the COVID-19 pandemic.

Active growth begins in 2021: GDP per capita increased from 114.3 thousand soms in 2021 to 187.9 thousand soms in 2023. This increase may be due to economic recovery, increased investment, including Chinese investment, as well as inflationary processes.

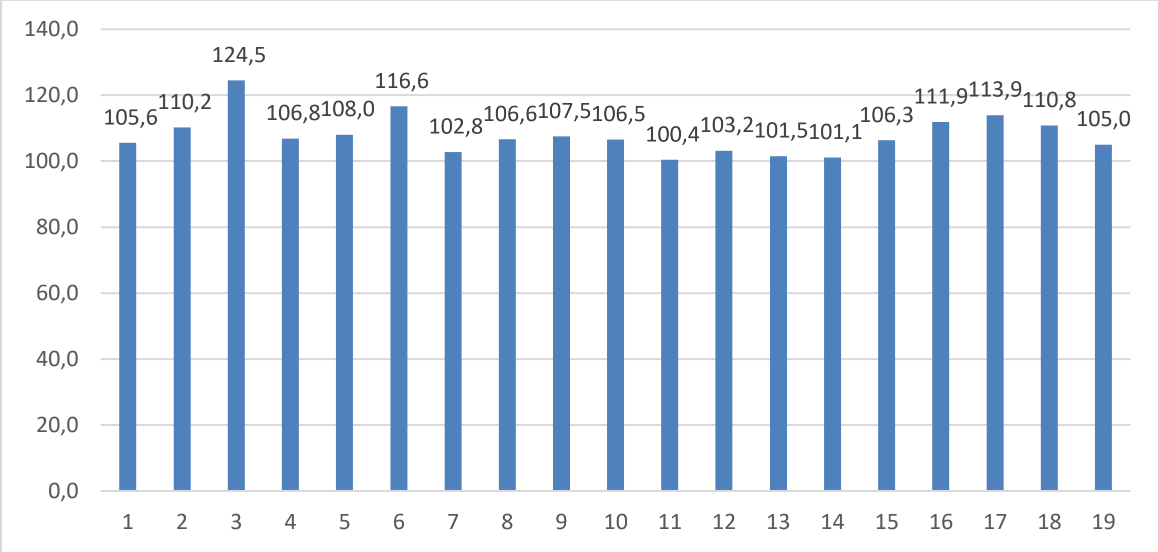

Figure 3.5. Consumer Price Index (as a percentage of the previous year)

Source: compiled based on data from the National Statistics Committee of the Kyrgyz Republic.

CPI is a key indicator of inflation, reflecting the level of change in prices for goods and services. In the period 2006–2023, Kyrgyzstan experienced significant fluctuations in inflation processes, which affected the standard of living of the population and purchasing power. In 2008, the highest inflation rate (124.5%) was recorded for the period under review, which could have been caused by the global financial crisis, rising food and energy prices. Stabilization was observed in subsequent years: from 2009 to 2016, inflation fluctuated in the range of 100.4–116.6%, indicating a moderate increase in prices. The minimum inflation rate was recorded in 2016 (100.4%), which may indicate a decrease in consumer demand. Since 2020, a new inflation cycle has begun, associated with the COVID-19 pandemic, disruption of global supply chains and rising energy prices. In 2021, the index was 111.9%, in 2022 - 113.9%, which led to a decrease in the real purchasing power of the population, despite the growth of GDP. In 2023, there is a slight decrease in inflation (110.8%), which may indicate stabilization of the economic situation.

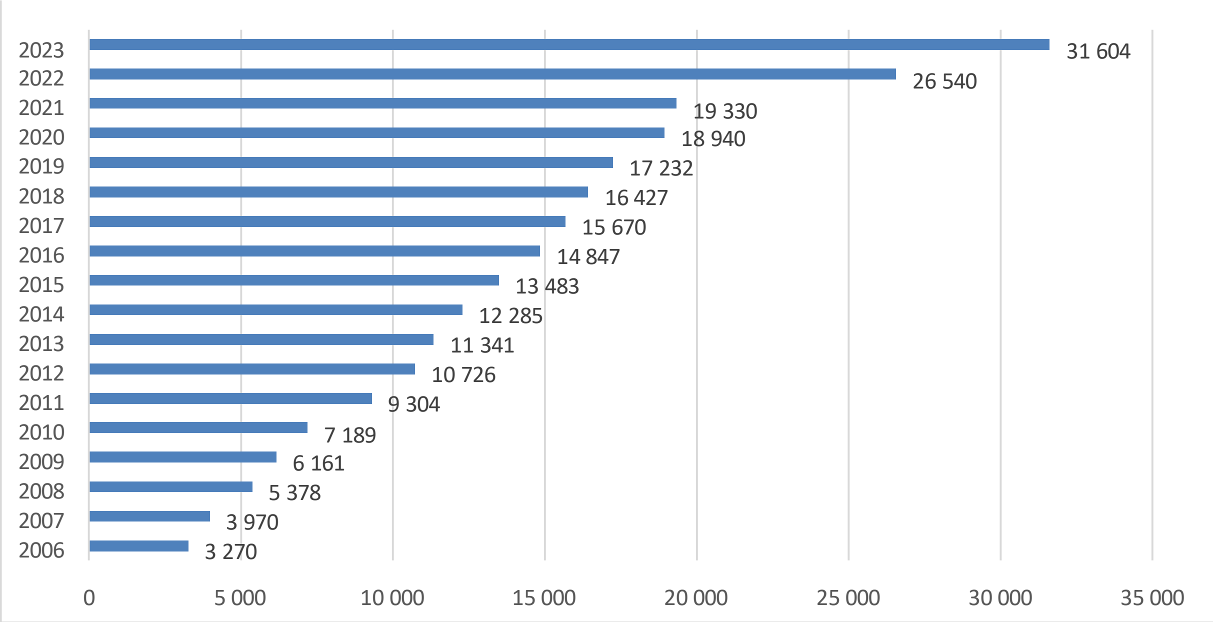

Figure 3.6. Analysis of the dynamics of the average salary in Kyrgyzstan (2006–2023) Source: compiled based on data from the National Statistics Committee of the Kyrgyz Republic.

The average salary is an important indicator of economic development and the level of well-being of the population. In the period 2006–2023, Kyrgyzstan saw a steady increase in salaries, but the growth rate was uneven.

From 2006 to 2008, the average salary increased from 3,270 to 5,378 soms, an increase of 35.5% in 2008, which is due to an increase in income in various sectors of the economy.

However, in 2009, against the backdrop of the global financial crisis, the growth rate slowed to 14.6%, but since 2010 it has begun to increase again.

In 2011–2020, wages grew at a stable pace, reaching 18,940 soms in 2020. However, real incomes could decline due to inflation. For example, in 2015–2016, wage growth was less significant amid economic difficulties in the region.

Since 2021, there has been a sharp increase in the average salary. In 2022, it reached 26,540 soms, and in 2023 – 31,604 soms. This increase is due to the revision of salaries in the public sector, an increase in the minimum wage.

The growth of wages has a direct impact on the formation of the tax base and, accordingly, on revenues to the state budget.

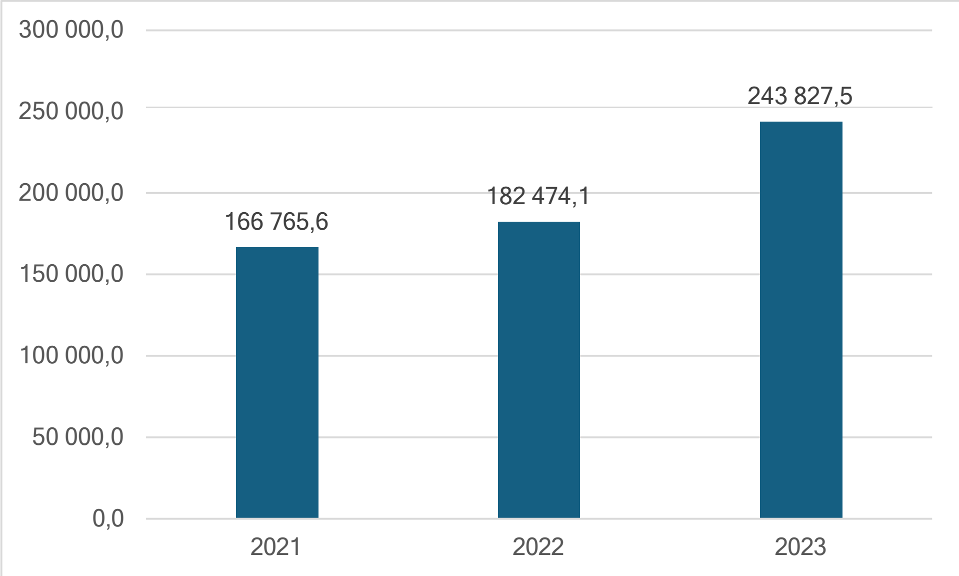

Figure 3.7. Dynamics of investments in non-financial assets, 2021–2023 (million soms)

The inflow of foreign investments in US dollars peaked in 2021 ($9,025.6 million), but fell to $7,110.6 million by 2023. The main share is made up of "other investments" (83.5–91.8%), while foreign direct investments are unstable, their share fluctuating from 7.8% to 15.9%. Portfolio investments are virtually absent.

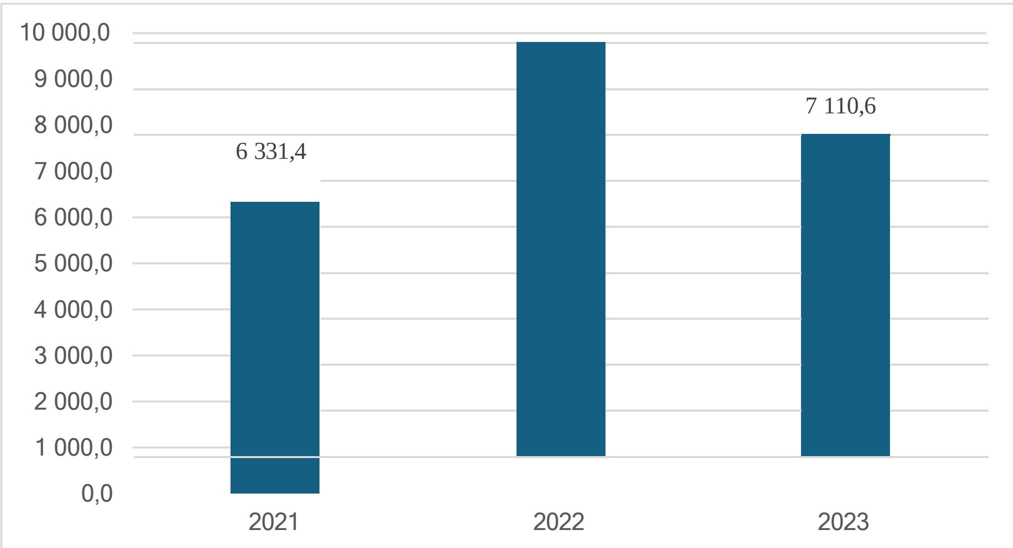

Figure 3.8. Change in the volume of foreign investment in the Kyrgyz Republic (2021–2023) (million soms)

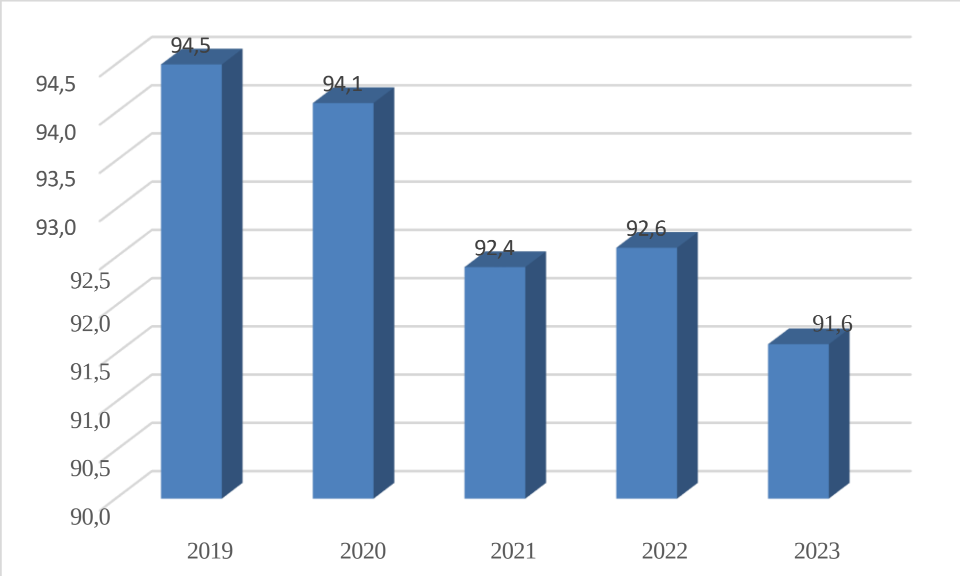

Figure 3.9. Investments in fixed assets (As a percentage of total)

Investments in fixed assets remain dominant within the overall investment structure of the Kyrgyz Republic, though they demonstrate a gradual decline — from 94.5% in 2019 to 91.6% in 2023. This slight decrease suggests an emerging diversification of capital flows into other economic areas, including innovation, digital infrastructure, and the social sectors such as education and healthcare.

This trend underscores the government's growing awareness of the importance of human capital investment as a long-term driver of sustainable development. Against this background, it becomes particularly relevant to analyze how financial and institutional resources are distributed across educational and medical training systems — sectors directly linked to workforce quality and national competitiveness.

The following analysis of the 2009 and 2022 population censuses provides insight into the educational level of youth aged 15–24 years, serving as an indicator of the future labor force's qualification structure. Despite positive trends in higher education access, the data reveal demographic contraction and imbalances in educational attainment, particularly between urban and rural areas.

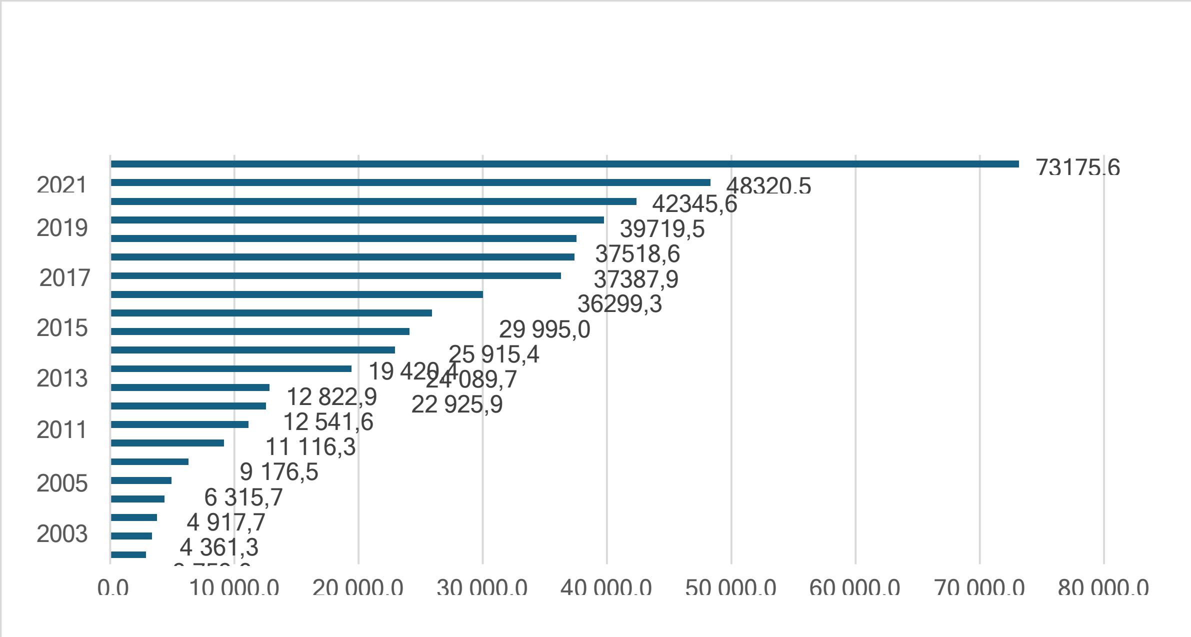

Figure 3.10. Structure of state budget expenditures on education in the Kyrgyz Republic (million soms)

The analysis of the figure shows an increase in state budget expenditure on education from 2001 to 2022, including spending on higher education. The total budget for education has been steadily increasing, especially since 2010, reaching 73,175.6 million soms in 2022, reflecting the state's priority in this area.

Expenditures on higher education have also grown, from 490.3 million soms in 2001 to 9,635.3 million in 2022. The share of funds for higher education has gradually increased, emphasizing the importance of training qualified personnel and increasing the availability of higher education in the country.

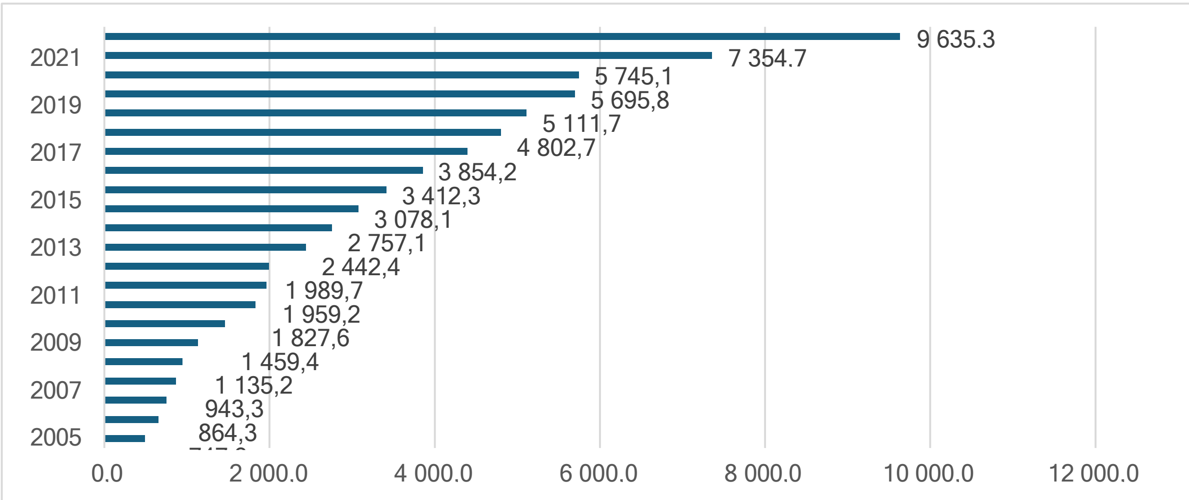

Figure 3.11. Structure of state budget expenditures on higher professional education (million soms)

The figure shows the number of non-CIS students enrolled in educational institutions at the beginning of the academic year from 2010 to 2023. The total number of non-CIS students increased from 3,366 in 2010 to 25,774 in 2023. The largest increase was observed after 2017.

Table 3.2. The number of students from countries outside the CIS
(at the beginning of the school year, persons)

Name of Indicators	Afghanistan	China	India	Iran	Mongolia	Nepal	Syria	Pakistan	Turkey	Georgia	Other countries
2010	73	539	581	17	13	82	27	955	793	5	281
2011	74	433	788	21	7	50	24	928	727	4	43
2012	54	385	1 137	25	2	21	43	778	772	3	66
2013	66	255	1 709	2	1	45	7	628	679	1	74
2014	107	267	2 377	7	8	23	15	559	696	2	196
2015	123	187	3 917	7	8	17	16	413	695	1	243
2016	148	269	4 745	2	6	15	14	390	655	-	276
2017	169	273	6 828	1	9	24	16	579	624	-	358
2018	161	220	8 662	3	13	11	20	830	510	1	431
2019	141	204	10 749	9	19	7	24	3 533	532	2	327
2020	49	99	12 272	7	26	3	21	6 003	509	1	539
2021	274	216	14 377	3	26	1	10	7 498	499	1	693
2022	347	399	15 306	10	20	4	23	8 407	467	-	338
2023	358	494	14 424	2	14	9	16	9 589	425	-	443

India and Pakistan stand out for their significant increase in student numbers, especially since 2015. By 2023, students from India made up the largest group at 14,424, while those from Pakistan accounted for 9,589. The number of students from China decreased significantly from 539 in 2010 to 494 in 2023.

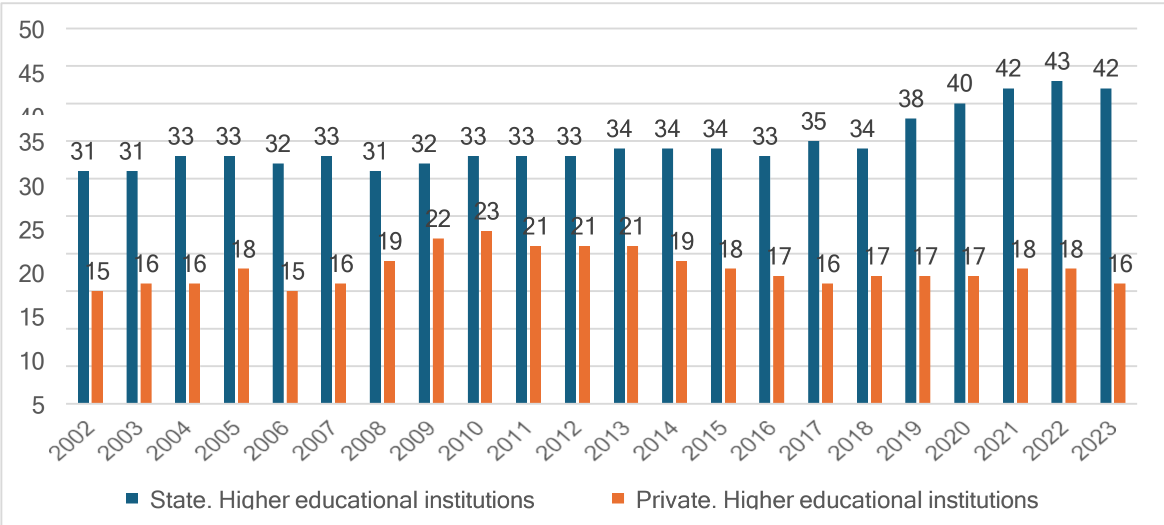

Figure 3.12. Number of educational institutions (units)

The data in the figure shows the changes in the number of public and private higher education institutions from 2002 to 2023. The analysis shows that the number of public universities fluctuated, starting from 31 in 2002, and gradually increased
to 42 in 2021, with a slight decrease to 42 in 2023. The largest increase was recorded between 2018 and 2020. Thus, the number of private universities increased from 15 in 2002 to a peak of 23 in 2010, after which it began to decrease, reaching 16 in 2023.

Table 3.3. Number of students in higher professional education institutions by educational profile

(at the beginning of the school year, people)

	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023
Number of students	164 585	183 778	214 157	230 206	227 582
including by educational profile:					
humanities	76 365	82 322	93 428	95 394	94 748
of which:					
management	6 290	6 303	7 656	5 151	4 847
health care	23 673	30 694	34 674	38 725	34 793
technical sciences	26 385	30 403	30 464	38 235	38 865
service	1 922	2 277	2 187	2 153	2 146

An analysis of the number of students in Kyrgyz universities in various fields from the 2018-2019 to 2022-2023 academic years shows a steady increase in the total number of students, although a slight decrease has been observed over the past year. From 2018-2019 to 2021-2022, the number of students increased from 164,585 to 230,206, but by 2022-2023 it had decreased to 227,582.

This growth indicates continued interest in higher education, with the exception of a slight decline last year. Humanities continue to be one of the most popular fields of study, attracting more and more students: from 76,365 students in 2018/2019 to 94,748 in 2022/2023, despite a slight decrease over the past two years. Within this management field, there is a decrease in the number of students from 7,656 in 2020/21 to 4,847 in 2022/23, which may indicate changes in labor market demands and a decline in interest in management specialties.

Healthcare shows a steady increase: from 23,673 students in the 2018/19 academic year, the number increased to a peak of 38,725 in 2021/22. In the next academic year 2022/23, there was a slight decrease to 34,793, but interest in health specialties remains high due to the increasing demand for professional health workers. The field of engineering also sees a steady increase in the number of students from 26,385 to 38,865, indicating an increasing interest in technical specialties and a high demand for such data scientists. The catchment area remains small, with a stable student population of around 2,000.

Overall, the data point to increasing interest in technical and medical fields and stable but slightly declining interest in the humanities. This reflects trends in the labor market and educational priorities in Kyrgyzstan.

3.4. The Role of Educational Services Export in Strengthening the Supply of Medical Equipment to Higher Education Institutions in the Kyrgyz Republic

In recent years, the export of educational services has become an increasingly important component of Kyrgyzstan's economy. The influx of international students, particularly in the field of medicine, has contributed to the development of higher education and the financial stability of universities. The presence of students from countries outside the CIS, such as India, Pakistan, and Nepal, highlights the growing demand for medical education in Kyrgyzstan. The tuition fees paid by these students serve as a significant source of revenue for universities and contribute to the national budget.

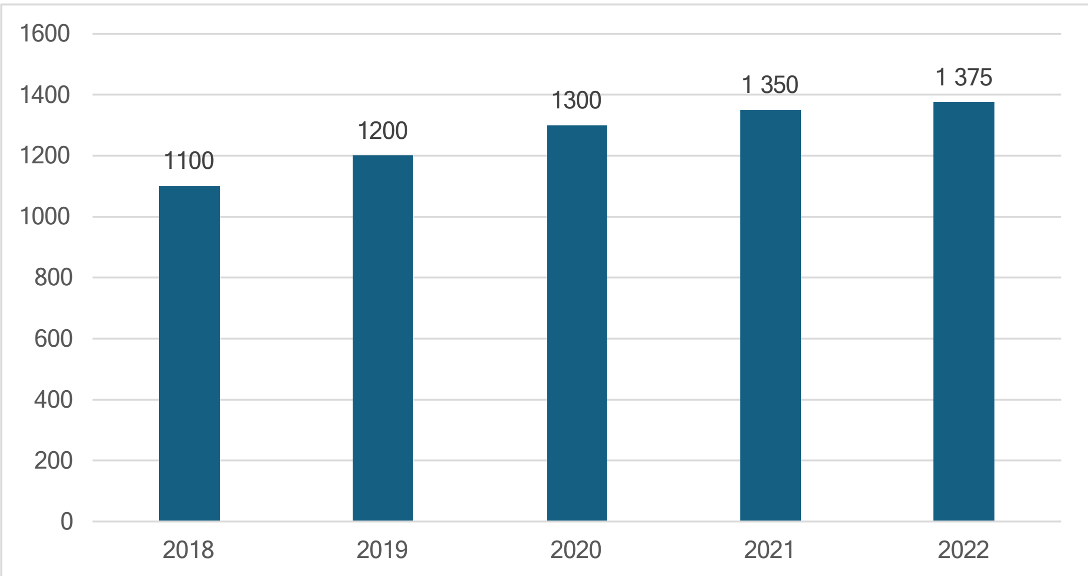

Figure 3.13. Dynamics of the volume of services exports in the Kyrgyz Republic (2018-2022) million US dollars

According to statistical data, the number of international students in Kyrgyzstan has increased significantly, from 3,366 in 2010 to 25,774 in 2023, with a particularly sharp rise after 2017. The largest groups of students come from India and Pakistan, accounting for over 50% of all foreign students in recent years. This growth has positioned Kyrgyzstan as an attractive destination for medical education due to affordable tuition fees, relatively low living costs, and the global recognition of its medical degrees.

The export of educational services in Kyrgyzstan not only generates tangible economic benefits but also strengthens the country's standing within the international academic community. The sector has become a strategic driver of both economic diversification and soft-power diplomacy, contributing to regional integration within Central Asia.

Over the past decade, Kyrgyzstan has emerged as one of the leading educational hubs in the region, particularly in medical and technical education. This growth is largely attributed to the competitive tuition fees, flexible admission policies, and the reputation of Kyrgyz medical universities recognized by institutions such as the World Health Organization (WHO) and the Medical Council of India (MCI). The enrollment of international students—mainly from India, Pakistan, Nepal, and Middle Eastern countries—has grown steadily, turning higher education into a visible source of foreign exchange revenue.

To further develop this promising sector, it is crucial to increase investment in educational infrastructure, including the modernization of university campuses, laboratories, and medical simulation centers. The introduction of advanced simulation technologies in medical education will allow universities to provide training that meets international standards for clinical practice. Parallel to infrastructure development, faculty training and academic mobility programs should be prioritized to align teaching methodologies with contemporary global standards.

Improving the quality of education and aligning medical programs with international accreditation frameworks (WFME, ENQA, UNESCO-CEPES) will ensure continued growth and enhance competitiveness in the global higher education market. Kyrgyz universities are already taking steps toward dual-degree programs, joint curricula, and digital academic exchanges, which foster both academic recognition and employability of graduates.

Moreover, the government's commitment to expanding the education sector is reflected in a series of policy initiatives aimed at increasing accessibility for international students. These include simplifying visa and residence procedures, developing bilingual (English/Russian) academic programs, and creating "one-stop service" centers for foreign students. Such measures have substantially improved Kyrgyzstan's reputation as a reliable and hospitable study destination.

The inflow of foreign students generates significant multiplier effects in the local economy. It stimulates demand for housing, transportation, telecommunications, food services, and cultural entertainment, thereby benefiting various sectors beyond education. According to preliminary estimates, each international student contributes to the creation of three to four local service-sector jobs, making educational export a driver of urban development in Bishkek, Osh, and other university cities.

In the longer term, Kyrgyzstan's higher education export potential will depend on its ability to ensure sustainability, digitalization, and quality assurance. Strengthening cooperation with global accreditation and quality assurance agencies, such as the World Federation for Medical Education and the European Association for Quality Assurance in Higher Education, is essential. Furthermore, the integration of digital learning platforms—including hybrid and distance learning formats—will expand access and increase resilience to external disruptions such as pandemics or geopolitical constraints.

Another strategic priority involves branding Kyrgyzstan as a regional educational center under the "Study in Kyrgyzstan" initiative, similar to "Study in India" or "Study in Turkey." Promoting national universities in international rankings, expanding participation in academic fairs, and establishing overseas education offices could substantially increase visibility. Developing English-taught programs in medicine, pharmacy, IT, and logistics would further diversify the student body and attract learners from new markets, including Africa and Southeast Asia.

In conclusion, the export of educational services represents a dynamic growth area with long-term benefits for the national economy, human capital, and international reputation of Kyrgyzstan. Sustained investments in infrastructure, faculty capacity, digital technologies, and global partnerships will allow the country to consolidate its position as a competitive regional hub for medical and higher education in Eurasia.

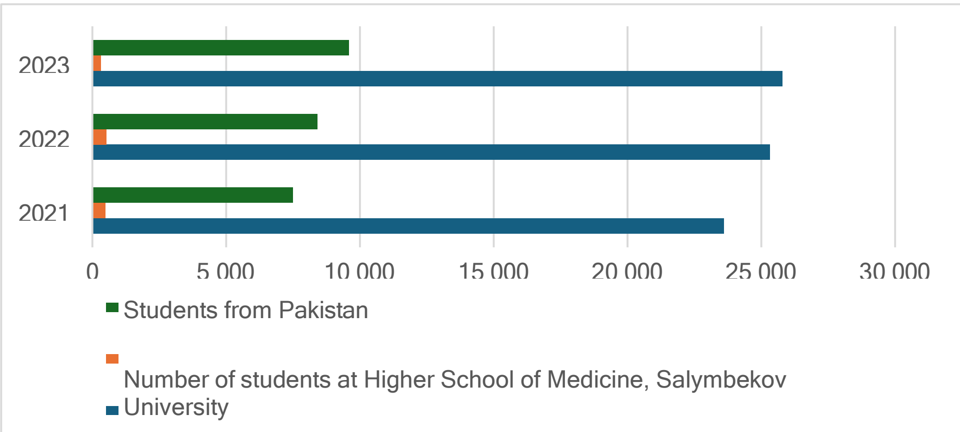

Figure 3.14. Graph of dynamics of the number of students at Salymbekov University, Higher School of Medicine (People).

Student Population Analysis (2021-2023) In 2021, students from Pakistan accounted for 31.77% of all students from non-CIS countries. In 2022, their share increased to 33.20%, and in 2023, it reached 37.20%. This indicates a steady increase in the number of students from Pakistan, which is due to the attractiveness of the university, accessibility of education, or interstate agreements. Proportion of students of the Higher School of Medicine of Salymbekov University. The percentage of students in relation to students from non-CIS countries remains similar: 31.77% in 2021, 33.20% in 2022, and 37.20% in 2023.

The number of students from non-CIS countries is growing, which indicates the popularity of the university among international applicants. The proportion of students from Pakistan is increasing, confirming the trend of growing demand for education at this university. Dynamics of gender distribution of students of the Higher School of Medicine of Salymbekov University (2021-2025).

Analysis of the change in the proportion of men and women. Data analysis shows a gradual change in the gender composition of students. In the 2021-2022 academic year, men accounted for 77.4%, and women 22.6%.

In 2022-2023, the proportion of men decreased to 73.8%, and women increased to 26.2%. In 2024- 2025, the trend became more pronounced: 61.3% men and 38.7% women.

The increase in the number of female students indicates improved access for women to medical education, increased interest in medical specialties, as well as state support for women's education.

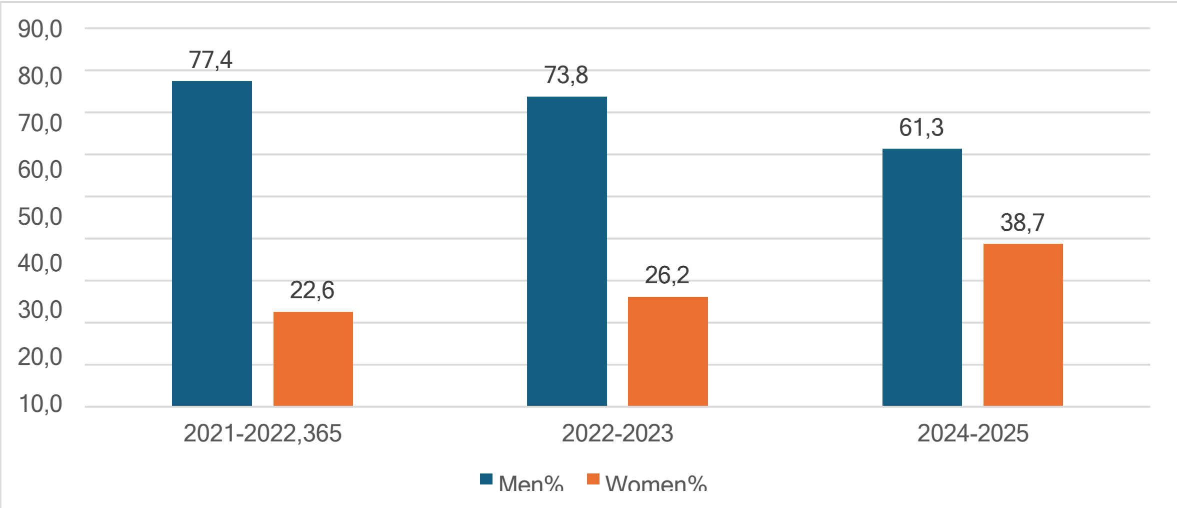

Figure 3.15. Analysis of the dynamics of the number of international students in PhD programs in the Kyrgyz Republic (2020-2022)

The data show a steady increase in the number of international students studying for a doctorate in the Kyrgyz Republic. In 2020, their number was 12,000, in 2021 it increased to 15,000 (an increase of 25%), and in 2022 it reached 18,000 (an increase of 20%). In general, the number of international students has increased by 50% over three years.

The main factors for this growth are strengthening international cooperation in the field of education, improving the quality of PhD programs, simplifying admission procedures and improving the academic infrastructure. In addition,

Kyrgyzstan can become an attractive educational platform due to the availability of education and its geographical location.

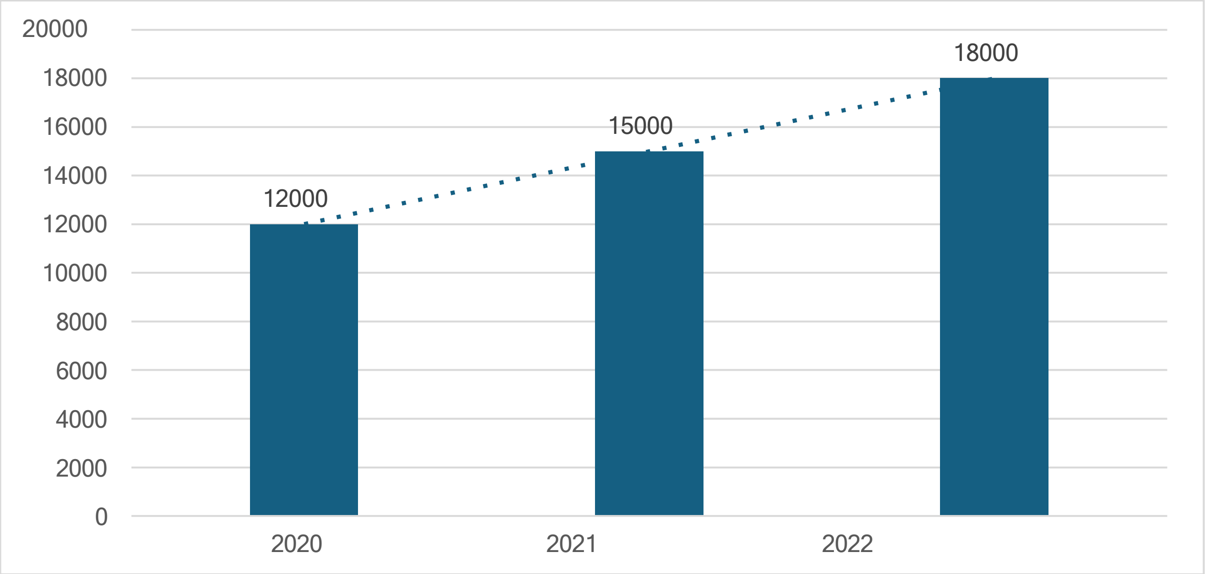

Figure 3.16. Number of international students in PhD programs in the Kyrgyz Republic (2020-2022)

However, there is a slight slowdown in the growth rate: if in 2021 the increase was 25%, then in 2022 it was 20%. This may indicate that a natural saturation point is approaching or that the attractiveness of educational programs needs to be further enhanced.

In the long term, the number of international students can be expected to continue to increase, but the growth rate may slow down. To maintain the positive dynamics, attention should be paid to the development of academic programs, improvement of student living conditions and expansion of international partnerships.

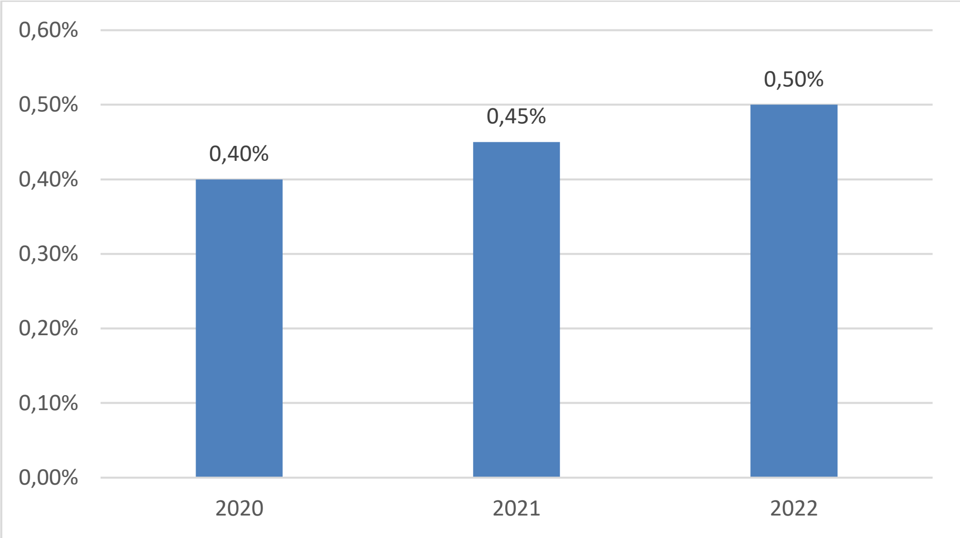

Figure 3.17. The economic impact of educational services exports on the economy of Kyrgyzstan

The data show a gradual increase in the contribution of educational services exports to the Kyrgyz Republic's GDP. In 2020, this figure was 0.4% of GDP, in 2021 - 0.45%, and in 2022 - 0.5%. This indicates a positive trend, the growth of which was 25% over three years.

The increase in the share of educational exports in GDP is associated with an increase in the number of foreign students, which leads to additional foreign exchange earnings. Visiting students contribute to the development of the economy through tuition fees, housing rental, consumption of goods and services, as well as through the creation of new jobs in the educational and service sectors.

Although the growth rate is positive, the overall contribution of the sector remains relatively low. To increase the economic effect, it is necessary to expand the export of educational services by attracting more foreign students, developing English-language programs and strengthening international academic ties.

If the current trend continues, further growth in the contribution of educational exports to GDP can be expected. However, to achieve a significant economic effect, more active government support and investment in higher education will be required.

Analysis of the supply chain of medical equipment for educational institutions of the Kyrgyz Republic

General characteristics of medical equipment

Data analysis shows that educational institutions of Kyrgyzstan have a wide range of medical equipment, including diagnostic, surgical, laboratory and resuscitation equipment.

Salymbekov University has:

- Ultrasound machines (Voluson E-8, PHILIPS iU22, new ultrasound),
- Operating tables, lamps, stands (DELMONT, Storz, BOWA),

- Ventilators (Mindray SV300, WATO EX-35),
- X-ray equipment (Jumong General, X-ray printer, digital detector),
- Electrocardiograph (ECG1200G Contec),
- Laboratory equipment (centrifuge, drying cabinet, analyzer, monitoring):
- Additional dental equipment (MEGAGEN IMPLANT NEXT chair, Vatech portable X-ray),
- Ultrasound and X-ray (Voluson E8, mobile ultrasound, DELL surgical X-ray),
- Laboratory and surgical equipment (SNIPE analyzer, urine analyzer, Lumenis Pulse 100H laser).

Supply chain structure

- Equipment is supplied in two directions
- The main suppliers are international brands (Mindray, PHILIPS, Contec, Olympus, Armed).
- Local distributors – ensure adaptation to the needs of universities.

Impact on the educational process

Modern equipment improves the quality of training specialists, providing access to real clinical scenarios.

Barriers in the supply chain of medical equipment for educational institutions of the Kyrgyz Republic.

The supply of medical equipment for educational purposes faces a number of barriers, which can be divided into economic, logistical, administrative and technological.

Economic barriers.

High cost of equipment – most modern medical devices (ultrasound, X-ray, artificial lung ventilation) are expensive, which requires significant budget expenditures.

Limited government investment – funding for educational institutions in Kyrgyzstan is limited, which limits the possibilities for purchasing modern equipment.

Currency fluctuations – most equipment is imported, and currency fluctuations make purchases unpredictable.

Logistic barriers

Transportation difficulties – medical equipment requires special transportation conditions (temperature conditions, insurance, certification). Delays in deliveries – customs procedures and instability of international logistics chains can lead to delays.

Lack of local manufacturers – dependence on imports increases supply risks.

Administrative and regulatory barriers

Bureaucracy – certification, licensing and permits can slow down the procurement process. Corruption risks – inefficient allocation of budget funds can hinder a transparent procurement process. Complexities in contract procedures – lengthy tender processes increase the time it takes to receive equipment.

Technological barriers

Lack of maintenance specialists – complex equipment requires qualified personnel for operation and repair. Lack of infrastructure for installation – some devices require special conditions (shielded rooms, uninterruptible power supplies).

Outdated technical standards – incompatibility of new equipment with old technologies in medical institutions and educational laboratories. Conclusions and recommendations To reduce barriers, it is necessary to: Develop public-private partnership programs for equipment financing. Optimise customs and certification procedures. Encourage local production and assembly of equipment. Implement training programs on operation and maintenance. Removing barriers will help improve educational institutions' access to modern medical equipment and improve the quality of specialist training. Barriers in the supply chain of medical equipment for educational institutions of the Kyrgyz Republic, taking into account the EAEU and sanctions restrictions. The supply of medical equipment to Kyrgyzstan, especially for educational institutions, faces a number of barriers. In addition to economic, logistical, administrative and technological factors, membership in the Eurasian Economic Union (EAEU) and sanctions restrictions have a significant impact.

The impact of membership in the EAEU

Kyrgyzstan is a member of the EAEU (Eurasian Economic Union), which affects the supply chain of medical equipment: Simplification of customs procedures - deliveries between the EAEU countries (Russia, Belarus, Kazakhstan, Armenia) are made without customs duties, which reduces the cost of purchases. Common certification market - equipment certified in one EAEU country is recognized in all the others. Dependence on dominant suppliers - imports mainly come from Russia and Kazakhstan, which reduces competitiveness and makes the market less diversified. Limited supplies from countries outside the EAEU – complex bureaucratic processes make imports from Europe and the US more difficult.

Impact of sanctions on medical equipment supplies

International sanctions imposed on Russia indirectly affect Kyrgyzstan and create new barriers to the import of medical equipment: Difficulties with payment and financing – banking restrictions complicate payments for equipment supplies, especially from countries that support sanctions. Logistics disruptions – sanctions have changed transport routes, extended delivery times and increased transportation costs. Limited access to Western technologies – it is becoming more difficult for Kyrgyzstan to purchase equipment from the EU and the US, as some manufacturers are ceasing cooperation with partners from the EAEU countries. Reorientation to alternative markets – increasing imports from China, Turkey and India as an alternative to Western technologies.

Key barriers to medical equipment supplies Economic barriers:

- High cost of equipment and limited budgets of universities.
- Exchange rate fluctuations complicating procurement planning.
- Logistics barriers:
- Delays in deliveries due to sanctions and disruptions in transport routes.
- Limited access to modern medical equipment from Europe and the USA. Administrative and regulatory barriers:
- Complex certification and licensing procedures for imports due to EAEU regulations.
- Long tender processes and the risk of corruption in public procurement.

Technological barriers:

Lack of specialists to service modern equipment.

Incompatibility of new equipment with old medical laboratories and educational buildings.

Recommendations for improving the supply of medical equipment

Developing cooperation with China, Turkey, India – expanding supplier markets to reduce dependence on Western technologies.

Accelerating digitalization and certification procedures within the EAEU – automating customs processes and improving the medical equipment registration system. State support for local production – stimulation of medical equipment assembly in Kyrgyzstan or EAEU countries. Creation of repair and maintenance service centers – reducing dependence on foreign specialists. Attracting foreign investment – searching for new partners not subject to sanctions. Thus, sanctions and restrictions within the EAEU complicate equipment supplies, but with the right approach, Kyrgyzstan can diversify import sources and create a more sustainable supply chain.

Multiple Regression Model for Public Expenditure on Education

The model indicates that the number of international students significantly influences government spending on education, with a coefficient of 2.34 million soms per student. However, GDP does not have a statistically significant impact on education expenditure, suggesting that government spending decisions on education are influenced by other factors. The model explains 45.9% of the variation in public expenditure on education, meaning other variables (e.g., policy changes, economic priorities) may play a crucial role. Further research is needed to include additional explanatory variables, such as government priorities, inflation, or foreign aid.

Growth in the Number of International Students in Kyrgyzstan

The steady increase in non-CIS international students (from 12,000 in 2020 to 18,000 in 2022) highlights the attractiveness of Kyrgyz education. A significant increase in students from Pakistan (31.77% in 2021 to 37.2% in 2023) suggests growing demand from specific regions. Gender diversity is improving, with female student enrollment rising from 22.6% (2021) to 38.7% (2025). Universities should

strengthen partnerships with international institutions and offer more programs in English to attract a wider range of students.

Economic Impact of Educational Services Exports

The contribution of educational exports to GDP increased from 0.4% (2020) to 0.5% (2022), showing a 25% growth in three years. Foreign students contribute not only through tuition fees but also through housing, consumption, and job creation.

However, the overall impact remains relatively low.

Recommendation: To enhance economic benefits, the government should support scholarship programs, marketing initiatives, and international accreditation of universities.

Supply Chain Challenges for Medical Equipment

Key barriers include high costs, complex import regulations, reliance on imported equipment, and lack of skilled technicians. Impact of EAEU membership: While customs procedures are simplified, dependency on Russia and Kazakhstan limits competition and increases risks. Impact of sanctions: Indirect restrictions complicate financial transactions and limit access to high-tech medical equipment from the US and Europe. Diversify imports by increasing cooperation with China, Turkey, and India.

Develop local manufacturing and assembly of medical devices

Accelerate digital certification and customs processing to reduce bureaucratic delays. The education sector in Kyrgyzstan is experiencing significant growth, particularly in attracting international students. Economic benefits from education exports are increasing but remain modest. Medical equipment procurement faces logistical and financial challenges, exacerbated by EAEU regulations and global sanctions. Future strategies should focus on diversifying partnerships, digitalizing bureaucratic procedures, and improving infrastructure for sustainable development in both education and healthcare sectors.

CHAPTER IV

CHAPTER IV. STRUCTURAL FRAMEWORK DEVELOPMENT FOR THE MEDICAL EQUIPMENT SUPPLY SYSTEM OF THE KYRGYZ REPUBLIC

4.1. Interpretive structural modelling (ISM) Research on the Supply Chain of Medical Equipment for Educational Institutions of the Kyrgyz Republic

In order to analyze the complexity of the medical equipment supply chain within educational institutions of the Kyrgyz Republic, the **Interpretive Structural Modelling (ISM)** approach has been employed. ISM is a well-established methodology developed by Warfield (1973) for identifying interrelationships among variables and constructing a hierarchical structure representing the order of influence and dependency. This method is particularly suitable for addressing complex socio-technical systems—such as educational logistics—where multiple factors interact dynamically and influence each other across different levels of policy, infrastructure, and management.

In the context of the Kyrgyz education sector, the supply chain of medical equipment represents a multilayered system encompassing economic, administrative, technological, and institutional dimensions. Limited financial resources, dependence on imported technologies, weak coordination between universities and government agencies, and insufficient infrastructure require a systemic analysis that can reveal causal linkages among these challenges. The ISM approach provides a structured way to visualize these interdependencies and to identify leverage points for policy intervention.

Research Objectives and Methodology

The purpose of this research is to identify and structure the key factors influencing the efficiency and resilience of medical equipment supply chains in Kyrgyz educational institutions.

The specific objectives include:

- Identifying the major variables affecting the supply chain performance;
- Establishing contextual relationships among these variables;
- Developing a hierarchical model that explains the causal linkages;
- Deriving managerial and policy implications for the higher-education system.

The research followed the traditional ISM procedure in several stages:

Identification of variables through literature review, expert interviews (with representatives of Kyrgyz universities, Ministry of Education, and suppliers), and content analysis of national procurement regulations.

Development of the Structural Self-Interaction Matrix (SSIM) to establish pairwise relationships among variables.

Transformation of SSIM into the Reachability Matrix (RM) using binary coding rules.

Partitioning of levels to derive a hierarchical model that represents the influence structure.

Development of the ISM diagram, illustrating the flow of influence from the most fundamental (driving) to the most dependent variables.

Table 4.1. Key Variables Influencing the Efficiency of Medical Equipment Supply Chains in Educational Institutions of the Kyrgyz Republic

No.	Variable	Description / Interpretation
1.	Government Policy Support	Refers to the degree of state involvement in regulation, procurement policy, and funding programs for educational and medical equipment logistics.
2.	Financial Availability	Access to financial resources, government allocations, or credit mechanisms that determine the ability of institutions to procure modern equipment.
3.	Import Dependence	The extent to which institutions rely on foreign suppliers and imported technologies, creating vulnerability to global disruptions.
4.	Customs and Certification Procedures	Efficiency of customs clearance, import documentation, and regulatory certification affecting procurement timelines.
5.	Supplier Relationship Management (SRM)	Quality of coordination with domestic and international suppliers, including after-sales service, warranties, and partnership longevity.
6.	Infrastructure Readiness	Availability of appropriate storage, transport facilities, and installation sites within universities and colleges.
7.	Digitalization Level	Adoption of digital tools (ERP, IoT, databases) for tracking, monitoring, and automating supply chain processes.
8.	Staff Competence	Level of qualification and technical training of logistics, procurement, and maintenance personnel in educational institutions.
9.	Maintenance Capability	Presence of service departments and availability of qualified specialists for equipment maintenance and calibration.
10.	Risk Management Practices	Systems for identifying, assessing, and mitigating risks in procurement and logistics operations.
11.	Sustainability Orientation	Integration of environmental and social responsibility principles (green procurement, recycling, energy efficiency).
12.	International Collaboration	Partnerships with foreign universities, donor organizations, and suppliers promoting technology transfer and best practices.

Creating A Structural Self-Interaction Matrix (SSIM)

The Structural Self-Interaction Matrix (SSIM) establishes pairwise contextual relationships among the variables identified in the previous step. Using the approach suggested by Sage (1977), relationships between each pair of factors (i, j) were evaluated to determine the direction and strength of influence.

The following symbols are used to describe the relationship between variables:

- V – Variable *i* influences variable *j* (forward relationship)
- A – Variable *j* influences variable *i* (reverse relationship)
- X – Variables *i* and *j* influence each other (bidirectional relationship)
- O – Variables *i* and *j* are unrelated (no direct influence)

Table 4.2. Structural Self-Interaction Matrix (SSIM) for Key Factors

Factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
F1. Government Policy Support	—	V	V	V	V	V	V	V	V	V	V	V
F2. Financial Availability	A	—	V	V	X	V	V	V	X	V	V	V
F3. Import Dependence	A	A	—	A	O	V	V	V	A	V	V	V
F4. Customs & Certification Procedures	A	A	V	—	X	X	X	X	O	V	X	X
F5. Supplier Relationship Management	A	X	O	X	—	X	X	X	X	V	V	V
F6. Infrastructure Readiness	A	A	A	O	X	—	X	X	X	X	V	X
F7. Digitalization Level	A	A	V	V	V	X	—	X	V	V	X	X
F8. Staff Competence	A	A	A	X	X	X	X	—	X	X	X	V
F9. Maintenance Capability	A	A	V	O	O	X	X	X	—	X	V	X
F10. Risk Management Practices	A	A	A	X	O	X	X	X	X	—	V	V
F11. Sustainability Orientation	A	A	A	O	A	O	O	O	A	O	—	V
F12. International Collaboration	A	A	A	X	A	X	X	X	X	X	A	—

Based on the Structural Self-Interaction Matrix (SSIM) presented in Table 4.2, the next step of the ISM methodology involves converting qualitative directional relationships into a quantitative binary format. This transformation is necessary to formalize the influence patterns among the factors and to prepare the data for level partitioning and hierarchical structuring.

The conversion of SSIM into the Initial Reachability Matrix (IRM) is carried out according to the standard ISM coding rules proposed by Warfield (1974). In this procedure, the symbols V, A, X, and O are replaced with binary values (1 or 0), reflecting the presence or absence of directional influence between each pair of variables:

- V (i → j) is coded as 1 in cell *(i, j)* and 0 in cell *(j, i)*.
- A (j → i) is coded as 0 in cell *(i, j)* and 1 in cell *(j, i)*.
- X (i ↔ j) is coded as 1 in both cells *(i, j)* and *(j, i)*.\
- O represents no direct relationship and is coded as 0 in both cells.

Following these rules, the SSIM was systematically translated into a binary Initial Reachability Matrix, which is presented in Table 5.3. This matrix serves as the foundation for constructing the Final Reachability Matrix (FRM) and subsequently deriving the hierarchical structure of factors within the ISM model.

Table 4.3. Initial Reachability Matrix (IRM)

Factor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
F1	1	1	1	1	1	1	1	1	1	1	1	1
F2	0	1	1	1	1	1	1	1	1	1	1	1
F3	0	0	1	0	0	1	1	1	0	1	1	1
F4	0	0	1	1	1	1	1	1	0	1	1	1
F5	0	1	0	1	1	1	1	1	1	1	1	1
F6	0	0	0	0	1	1	1	1	1	1	1	1
F7	0	0	1	1	1	1	1	1	1	1	1	1
F8	0	0	0	1	1	1	1	1	1	1	1	1
F9	0	0	1	0	0	1	1	1	1	1	1	1
F10	0	0	0	1	0	1	1	1	1	1	1	1
F11	0	0	0	0	0	0	0	0	0	0	1	1
F12	0	0	0	1	0	1	1	1	1	1	0	1

The analysis of the Initial Reachability Matrix demonstrates that the factors F1–F2 exhibit the largest number of direct linkages, indicating their decisive role in shaping all other elements of the supply chain. Factor F1 (Government Policy Support) influences all 11 remaining variables, highlighting the dominant position of state policy in regulating procurement, allocating financial resources, determining certification procedures, managing imports, and creating infrastructural conditions. Similarly, F2 (Financial Availability) exerts significant influence on most factors, reflecting the central role of budgetary resources and financial instruments in ensuring access to modern medical equipment.

Factors F3–F7 display the characteristics of linkage variables: they are influenced by F1–F2, yet they simultaneously affect a large number of other variables. This makes them critical nodes within the system that require priority attention when optimising the supply chain. Changes in these factors produce cascading effects and significantly strengthen or weaken overall system performance.

The dependent variables (F8, F9, F12) demonstrate fewer outgoing linkages, reflecting their reliance on political, financial, and infrastructural conditions. Improvements in staff competencies, equipment maintenance capability, and international collaboration are only possible once strong foundational conditions have been established at the lower levels of the model.

Thus, the IRM confirms the need to prioritize reforms related to policy support, financial mechanisms, infrastructural development, and process digitalization, as these areas drive the functioning of all subsequent variables in the medical equipment supply chain of the Kyrgyz Republic. To obtain the Final Reachability Matrix (FRM), the transitivity rule was applied to the Initial Reachability Matrix. According to the ISM logic, if factor *Fi* influences *Fj* and *Fj* influences *Fk,* then *Fi* is also considered to influence *Fk*, even if this relationship is not directly indicated in the SSIM. All such indirect (transitive) relationships were incorporated into the FRM, resulting in a complete representation of the influence structure among the twelve key factors in the medical equipment supply chain.

Table 4.4. Final Reachability Matrix (FRM) for Key Factors

Factor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
F1	1	1	1	1	1	1	1	1	1	1	1	1
F2	0	1	1	1	1	1	1	1	1	1	1	1
F3	0	1	1	1	1	1	1	1	1	1	1	1
F4	0	1	1	1	1	1	1	1	1	1	1	1
F5	0	1	1	1	1	1	1	1	1	1	1	1
F6	0	1	1	1	1	1	1	1	1	1	1	1
F7	0	1	1	1	1	1	1	1	1	1	1	1
F8	0	1	1	1	1	1	1	1	1	1	1	1
F9	0	1	1	1	1	1	1	1	1	1	1	1
F10	0	1	1	1	1	1	1	1	1	1	1	1
F11	0	1	1	1	1	1	1	1	1	1	1	1
F12	0	1	1	1	1	1	1	1	1	1	1	1

4.2. Partitioning the Reachability Matrix

The partitioning of the Final Reachability Matrix (FRM) represents a critical stage of the Interpretive Structural Modelling (ISM) procedure, as it enables the transformation of a complex web of interdependencies into a clearly defined hierarchical structure. This process allows for the identification of the relative position of each factor within the overall influence system and provides a logical basis for constructing the ISM digraph. By determining reachability sets, antecedent sets, and their intersections, the method objectively allocates variables to specific levels, offering insight into their functional role within the supply chain of medical equipment for educational institutions in the Kyrgyz Republic.

The first iteration of level partitioning involved examining all twelve factors included in the FRM. For each factor, the reachability set (R) consisted of all variables the factor could influence, while the antecedent set (A) included all variables that exerted influence on the given factor. The intersection of these sets (I) was analyzed to determine whether a factor could be placed at the top level. According to ISM logic, if a factor's reachability set is identical to its intersection set, this factor does not influence any variables beyond those that also influence it; therefore, it is designated as a Level 1 factor.

Applying this criterion revealed that three factors—F8 (Staff Competence), F9 (Maintenance Capability), and F12 (International Collaboration)—form the top tier of the hierarchy. These variables are the most dependent, as their effective functioning is shaped by multiple underlying conditions, including policy support, financial availability, digitalization, and infrastructure. Their placement at Level 1 indicates that improvements in staff skills, maintenance systems, and international partnerships cannot be achieved in isolation; they require prior strengthening of foundational drivers.

The second iteration removed these Level 1 factors and re-evaluated the remaining variables. Two factors—F10 (Risk Management Practices) and F11 (Sustainability Orientation)—were identified as Level 2. Although they still depend on several upstream variables, they also exert influence on lower-tier dependent factors. Their position reflects an intermediate role in the supply chain: they are necessary for reinforcing resilience, environmental responsibility, and long-term system stability, yet their effectiveness remains contingent on the availability of adequate resources and supportive institutional frameworks.

During the third iteration, after removing Levels 1 and 2, five factors emerged as Level 3: F3 (Import Dependence), F4 (Customs and Certification Procedures), F5 (Supplier Relationship Management), F6 (Infrastructure Readiness), and F7 (Digitalization Level). These factors form the core linkage layer of the model. Their influence is multidirectional: they impact several dependent variables yet remain strongly influenced by the fundamental drivers. Their placement highlights that operational bottlenecks and systemic inefficiencies in the educational supply chain arise from weaknesses in these interconnected domains. Improvements in digital infrastructure, supplier coordination, import processes, and logistical facilities are therefore essential to stabilizing the entire system.

Finally, the fourth iteration isolated the foundational drivers of the model: F1 (Government Policy Support) and F2 (Financial Availability). These variables exert influence across all other factors and do not significantly depend on downstream elements. Their positioning as Level 4 confirms that policy decisions and financial resources constitute the root of the system's structural integrity. Effective reforms, therefore, must begin with strengthening governance mechanisms, increasing targeted funding, and enhancing strategic planning at the national level.

In summary, the partitioning analysis reveals a clear four-level hierarchy, demonstrating how institutional, operational, and human-capital factors interact within the medical equipment supply chain in Kyrgyz educational institutions. This structured understanding provides a foundation for evidence-based policymaking and targeted interventions aimed at developing a resilient, efficient, and sustainable supply chain.

Table 4.5. Iteration 1 – Reachability, Antecedent and Intersection Sets

Factor	Reachability Set (R)	Antecedent Set (A)	Intersection Set (I)	Level
F1	{F1–F12}	{F1}	{F1}	No
F2	{F2–F12}	{F1,F2–F12}	{F2–F12}	No
F3	{F3–F12}	{F1,F2,F3–F12}	{F3–F12}	No
F4	{F4–F12}	{F1,F2,F3–F12}	{F4–F12}	No
F5	{F5–F12}	{F1,F2,F3–F12}	{F5–F12}	No
F6	{F6–F12}	{F1,F2,F3–F12}	{F6–F12}	No
F7	{F7–F12}	{F1,F2,F3–F12}	{F7–F12}	No
F8	{F1–F12}	{F1–F12}	{F1–F12}	LEVEL 1
F9	{F1–F12}	{F1–F12}	{F1–F12}	LEVEL 1
F10	{F10–F12}	{F1–F12}	{F10–F12}	No
F11	{F11, F12}	{F1–F12}	{F11,F12}	No
F12	{F1–F12}	{F1–F12}	{F1–F12}	LEVEL 1

Table 4.6. Iteration 2 – Reachability, Antecedent and Intersection Sets

Factor	Reachability Set (R)	Antecedent Set (A)	Intersection Set (I)	Level
F1	{F1–F12}	{F1}	{F1}	No
F2	{F2–F12}	{F1,F2–F12}	{F2–F12}	No
F3	{F3–F7, F10, F11}	{F1–F12 except F8,F9,F12}	{F3–F7, F10, F11}	No
F4	{F4–F7, F10, F11}	{F1–F12 except F8,F9,F12}	{F4–F7, F10, F11}	No
F5	{F5–F7, F10, F11}	{F1–F12 except F8,F9,F12}	{F5–F7, F10, F11}	No
F6	{F6–F7, F10, F11}	{F1–F12 except F8,F9,F12}	{F6–F7, F10, F11}	No
F7	{F7, F10, F11}	{F1–F12 except F8,F9,F12}	{F7, F10, F11}	No
F10	{F10, F11}	{F1–F12 except F8,F9,F12}	{F10, F11}	LEVEL 2
F11	{F11}	{F1–F12 except F8,F9,F12}	{F11}	LEVEL 2

Table 4.7. Iteration 3 – Reachability, Antecedent and Intersection Sets

Factor	Reachability Set (R)	Antecedent Set (A)	Intersection Set (I)	Level?
F1	{F1–F12}	{F1}	{F1}	No
F2	{F2–F12}	{F1,F2}	{F2}	No
F3	{F3–F7}	{F1,F2,F3–F7}	{F3–F7}	LEVEL 3
F4	{F4–F7}	{F1,F2,F3–F7}	{F4–F7}	LEVEL 3
F5	{F5–F7}	{F1,F2,F3–F7}	{F5–F7}	LEVEL 3
F6	{F6–F7}	{F1,F2,F3–F7}	{F6–F7}	LEVEL 3
F7	{F7}	{F1,F2,F3–F7}	{F7}	LEVEL 3

Table 4.8. Iteration 4 – Reachability, Antecedent and Intersection Sets

Factor	Reachability Set (R)	Antecedent Set (A)	Intersection Set (I)	Level?
F1	{F1–F12}	{F1}	{F1}	LEVEL 4
F2	{F2–F12}	{F1,F2}	{F2}	LEVEL 4

Table 4.9. Final Level Summary of ISM Hierarchy

Level	Factors	Description
Level 1	F8, F9, F12	Dependent variables: Staff competence, maintenance capability, international collaboration
Level 2	F10, F11	Intermediate factors: Risk management practices, sustainability orientation
Level 3	F3, F4, F5, F6, F7	Linkage variables: import dependence, customs procedures, supplier management, infrastructure, digitalization
Level 4	F1, F2	Driving variables: Government policy support, financial availability

Figure 4.1 presents the conclusive contextual relationships derived from the Final Reachability Matrix (FRM), offering a comprehensive visualization of how the twelve key factors interact within the medical equipment supply chain of educational institutions in the Kyrgyz Republic. This figure synthesizes both direct and transitive relationships identified during the ISM procedure and demonstrates the complex cause–effect pathways that shape the performance, resilience, and overall functionality of the supply system. The diagram serves as a detailed map of influence flows, highlighting the structural dependencies and reinforcing loops that emerge from systemic interactions.

The diagram clearly emphasizes the dominant role of the fundamental driving factors—F1 (Government Policy Support) and F2 (Financial Availability). These factors anchor the bottom of the model and are shown to exert expansive influence across almost all other variables. Their centrality underscores the fact that regulatory frameworks, policy decisions, and budgetary allocations form the foundational conditions upon which all higher-level processes depend. Without adequate policy support and sustained financial resources, improvements in operational capacity, digitalization, infrastructure, or maintenance capabilities are unlikely to materialize. Thus, the strong set of arrows emanating from F1 and F2 supports the conclusion that these drivers must be addressed first in any reform strategy aimed at strengthening educational supply chains.

The cluster of factors situated in the middle of the diagram—F3 (Import Dependence), F4 (Customs and Certification Procedures), F5 (Supplier Relationship Management), F6 (Infrastructure Readiness), and F7 (Digitalization Level)—represents the core linkage layer of the system. The dense pattern of bidirectional interactions between these factors reflects their dual nature: while they are influenced by policy and financial considerations, they also act as essential conduits through which systemic improvements propagate. For example, import dependence and customs procedures directly affect the speed and cost of acquiring medical equipment, while supplier relationships, infrastructure, and digitalization determine the efficiency and transparency of procurement, delivery, installation, and service processes. The visual complexity in this section of the figure aligns with the FRM results, confirming that these linkage variables are critical leverage points for intervention.

The diagram also highlights the intermediate role of F10 (Risk Management Practices) and F11 (Sustainability Orientation). Positioned above the linkage layer, these variables are influenced by operational and infrastructural conditions but, in turn, contribute to shaping higher-level outcomes. Their position reflects the increasing global emphasis on building resilient and sustainable supply chains—particularly important in healthcare education, where uninterrupted access to functional equipment is essential.

Finally, the uppermost section of the figure contains F8 (Staff Competence), F9 (Maintenance Capability), and F12 (International Collaboration), which appear as endpoints for multiple influence pathways. This configuration signals that these factors are the most dependent elements in the system. Competence and training of personnel, effectiveness of maintenance operations, and extent of collaboration with international partners cannot be improved in isolation; their advancement requires prior improvements in digitalization, infrastructure, procurement processes, and risk management. The diagram thus illustrates how high-level outcomes in human capital, service capability, and global integration are shaped by broader structural and institutional reforms.

Overall, Figure 4.1 provides a clear and integrative view of the systemic nature of the educational medical equipment supply chain. It demonstrates how foundational policy and financial drivers' cascade into operational improvements and ultimately support dependent outcomes. This visualization is essential for policymakers and institutional leaders seeking to design comprehensive, evidence-based interventions that strengthen supply chain performance in the Kyrgyz Republic.

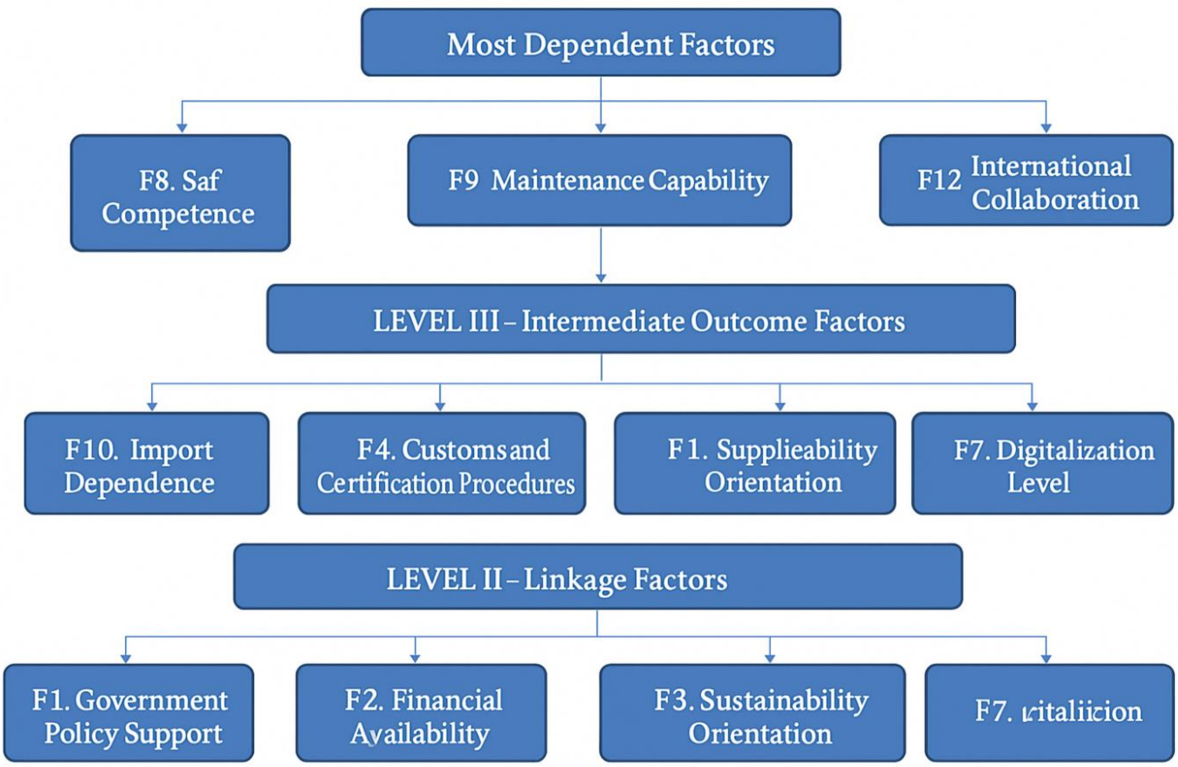

Figure 4.1. Conclusive contextual relationships based on the final Reachability Matrix

Figure 4.2 illustrates the linking contextual ties within the SSCI (Supply Chain Structural Contextual Interactions) framework, offering a comprehensive perspective on how different structural elements of the supply chain system interconnect and mutually reinforce one another. This diagram builds upon earlier ISM and FRM analyses but shifts the emphasis toward the relational mechanics that bind the system together. Instead of focusing primarily on hierarchical layering, Figure 4.2 foregrounds the bridging, mediating, and integrative linkages that determine the coherence, responsiveness, and operational synergy of the medical equipment supply chain in educational institutions of the Kyrgyz Republic.

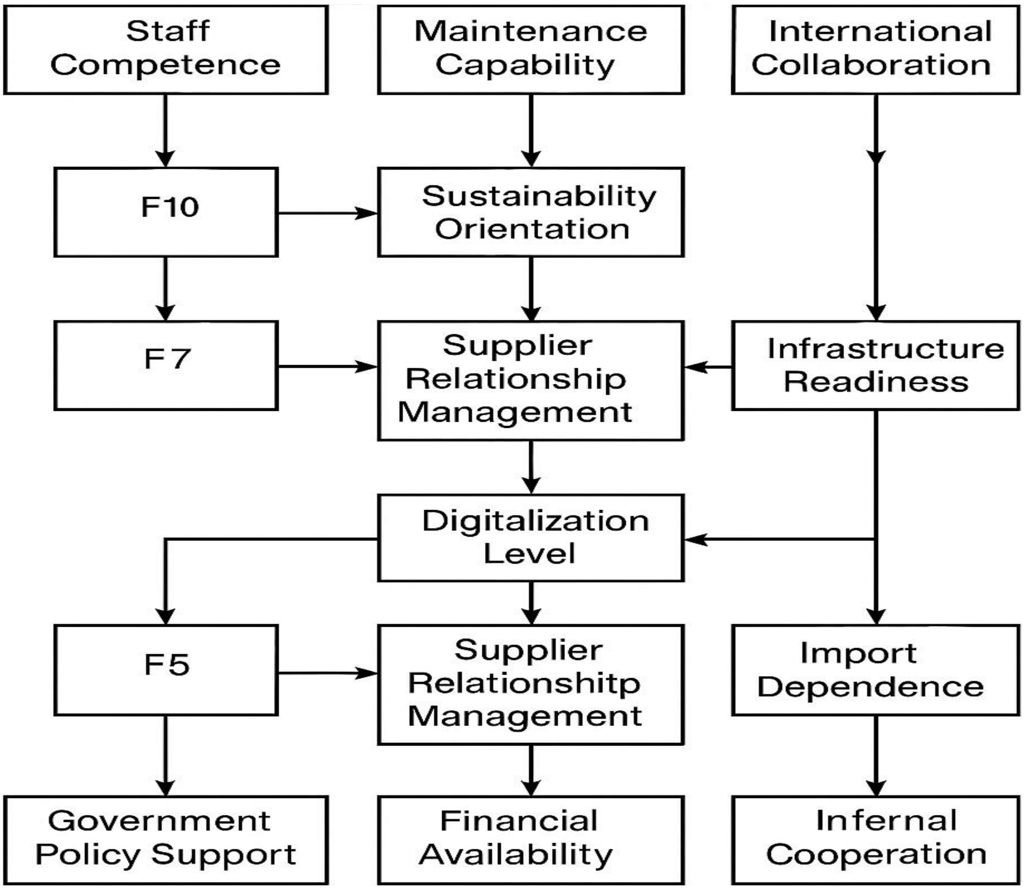

Figure 4.2. The linking contextual ties of SSCI

The first key insight provided by this diagram concerns the role of linkage variables—those factors that simultaneously exert influence and remain strongly influenced by other variables. These are the “active connectors” of the system, shaping and reshaping supply chain dynamics through bidirectional interactions. In the context of the Kyrgyz educational sector, factors such as import dependence, customs procedures, supplier management, infrastructure readiness, and digitalization form the core of these linkage mechanisms. Their positioning within the Figure signifies those improvements in one dimension inevitably reverberate throughout the rest of the system, triggering ripple effects that either promote or hinder the overall efficiency of medical equipment provision. Another significant aspect of the diagram is the way it demonstrates contextual pathways, or sequences of interconnected influences that flow across functional domains. For example, import dependence (SSCI node) may directly affect customs clearance timelines, which in turn shape supplier relationship structures and ultimately influence maintenance capability and staff readiness. These chains of linked contextual ties illustrate that the supply chain is not a linear mechanism but a multidimensional network where constraints in one area cascade into other areas. Such networked interactions highlight the necessity of addressing bottlenecks systemically rather than through isolated interventions. The diagram also underscores the importance of cross-functional alignment, which serves as the backbone of SSCI. Many of the linking ties span across administrative, technological, and organizational domains. This reflects the fact that medical equipment supply chains in educational institutions rely on harmonized decision-making and unified standards across ministries, suppliers, customs agencies, and in-house university logistics. Misalignment between these nodes can dampen the flow of resources, delay procurement, reduce transparency, and weaken the system's resilience. Thus, Figure 4.2 reinforces the idea that supply chain optimisation requires integrated governance.

Moreover, SSCI linking ties emphasize the dual nature of system interactions: forward linkages that drive future outcomes and backward linkages that reflect institutional dependencies. Forward linkages indicate how strategic decisions—such as investment in digitalization or risk management—shape downstream outcomes in maintenance, user readiness, and sustainability. Backward linkages reveal how constraints—such as limited infrastructure or regulatory inefficiencies—limit the system's capacity to improve high-level outcomes. Understanding both types of linkages helps in designing interventions that not only address existing weaknesses but also anticipate future systemic challenges.

Finally, the diagram reflects the dynamic and adaptive nature of the educational medical supply system. SSCI is portrayed not as a static model but as an evolving structure in which linkages may strengthen, weaken, or shift in relevance depending on environmental changes such as policy reforms, technological advancements, external shocks, and international collaboration. This recognition is crucial for policymakers, as it highlights the importance of continuous monitoring and iterative adjustments based on real-world feedback.

In summary, Figure 5.2 provides a deep and multidimensional understanding of the interconnected mechanisms that govern the medical equipment supply chain in Kyrgyz educational institutions. By visualizing linkage relationships rather than hierarchical structures, it highlights the system's dynamic character and the necessity for integrated policy, technological modernization, and operational alignment. This figure therefore serves as an essential analytical tool for diagnosing systemic challenges and designing effective interventions.

4.3. Theoretical Implications

The findings of this study provide several important theoretical implications for the field of SCM, particularly within the emerging context of medical equipment provision in educational systems of developing economies such as the Kyrgyz Republic. First, the research expands the theoretical understanding of the structural dynamics that underpin public-sector supply chains by integrating Interpretive Structural Modelling (ISM) and SSCI contextual mapping. While existing SCM literature predominantly focuses on private-sector optimisation and commercial efficiency, this study demonstrates that public educational supply chains are shaped by fundamentally different institutional pressures, regulatory dependencies, and infrastructural constraints. The proposed theoretical framework therefore contributes to a more nuanced conceptualization of supply chain behaviour in resource-restricted environments.

Second, the study advances theory by identifying a multi-layered hierarchy of drivers, linkage variables, and dependent outcomes. The ISM-based structure clarifies how foundational factors—such as governmental policy support and financial availability—serve as system-level antecedents influencing all subsequent supply chain mechanisms. This hierarchical perspective challenges prevailing theoretical models that traditionally assign equal weight to technological, operational, and managerial dimensions. Instead, the findings emphasize the primacy of institutional forces, suggesting that effective supply chain transformation cannot occur without parallel shifts in governance, regulatory frameworks, and public-sector financing.

Third, the analysis offers theoretical contributions by conceptualizing linkage variables as mediating mechanisms through which systemic change propagates. Import dependence, customs procedures, supplier relationship management, infrastructure readiness, and digitalization collectively form an interdependent network that channels both enabling and constraining effects. The identification of these linkage mechanisms enriches SSCI theory by demonstrating how emerging economy supply chains rely on complex cross-functional alignment rather than isolated interventions.

Fourth, the study introduces a theoretically grounded explanation for the emergence of dependent variables—such as staff competence, maintenance capability, and international collaboration—as outcome indicators rather than isolated operational challenges. These findings reinforce capability-based and institutional theories by showing how human capital development and service competencies represent higher-order outputs that depend on earlier systemic reforms.

Finally, by linking sustainability orientation and risk management practices to intermediate positions within the ISM hierarchy, the study extends theoretical discussions on resilience and sustainable supply chains in the public sector. Unlike private-sector models that treat sustainability as an external or parallel component, this research positions sustainability as a structurally embedded factor shaped by institutional constraints and operational linkages.

Overall, the study contributes to the theoretical development of SCM in emerging markets by presenting a comprehensive, multi-level model that integrates institutional, infrastructural, technological, and human-capital dimensions. The theoretical implications highlight the value of systems thinking, contextual modelling, and hierarchical analysis for advancing SCM theory in the public educational sector.

4.4. Managerial Implications

The findings of this study offer several important managerial implications for administrators, supply chain managers, and procurement specialists involved in providing and maintaining medical equipment in Kyrgyz educational institutions. The ISM hierarchy and SSCI contextual links highlight critical areas where managerial decisions can improve operational efficiency, reduce delays, enhance service quality, and strengthen long-term resilience.

First, the study emphasizes the need for stronger alignment between institutional goals and operational practices. Since government policy support (F1) and financial availability (F2) form the foundation of the ISM model, managers must coordinate procurement plans and budgeting cycles with national education and healthcare priorities, participate in policy dialogues, and advocate for targeted funding.

Second, the influence of linkage factors (F3–F7) shows that mid-level managerial actions have a disproportionately high impact. Optimising supplier selection, improving customs documentation, coordinating with logistics agencies, and implementing digital tracking systems can significantly reduce procurement timelines. Standardized supplier evaluation, long-term vendor agreements, and digital monitoring tools should become routine managerial practices.

Third, the results highlight the importance of institutionalized risk management (F10). Given supply disruptions and high import dependence, managers must establish backup supplier networks, introduce preventive maintenance schedules, and prepare contingency procurement plans. Regular risk assessments and scenario planning can greatly enhance system adaptability.

Fourth, sustainability practices (F11) must be embedded into procurement and lifecycle management. This includes prioritizing energy-efficient devices, applying environmental criteria in tenders, and ensuring responsible disposal of obsolete equipment. Suppliers' ESG compliance should also be considered in vendor evaluations.

Fifth, the dependence of staff competence (F8) and maintenance capability (F9) on other system factors indicates that human-capital investments must be continuous. Managers should support training programs, establish partnerships for capacity-building, and ensure timely certification for technicians and biomedical engineers.

Finally, the significant role of international collaboration (F12) underscores the need for active cooperation with foreign suppliers, donor organizations, and international universities to facilitate knowledge transfer and improve equipment management standards.

In summary, the managerial implications of this study point to the importance of strategic alignment, risk-based decision-making, sustainability integration, and systematic capacity development. Managers must adopt a systems approach, recognizing that improvements in one dimension require coordinated actions across multiple interconnected areas.

CHAPTER V

CHAPTER V. WAYS TO OPTIMISE THE SUPPLY CHAIN OF MEDICAL EQUIPMENT FOR EDUCATIONAL INSTITUTIONS OF THE KYRGYZ REPUBLIC

5.1 A System Dynamics Model of the Medical Device Supply Chain: Economic Optimisation of Deliveries

Model assumptions and prerequisites for Vensim-based simulation

For the system dynamics model developed in Vensim to function properly and generate reliable simulation results, several key conditions and prerequisites must be satisfied.

The model requires the availability of consistent and sufficiently detailed input data. This includes data on budget inflows and expenditures, import volumes, customs duties, delivery times, equipment loss rates, and training capacity indicators. While exact statistical precision is not always possible in system dynamics modelling, the use of realistic ranges and expert-validated estimates is essential to ensure the internal coherence of the model.

The effective operation of the model assumes stable institutional and regulatory conditions over the simulation horizon. Major abrupt changes in customs legislation, procurement rules, or public financing mechanisms may alter causal relationships and require recalibration of model parameters. Therefore, the model is most effective when applied for medium- and long-term scenario analysis under relatively stable policy frameworks.

The model presupposes a minimum level of digitalization and data transparency within the supply chain system. Digital inventory tracking, electronic customs administration, and standardized procurement reporting are necessary to accurately reflect feedback loops related to delivery delays, budget efficiency, and equipment availability. Without such digital foundations, some reinforcing and balancing loops in the model would be difficult to operationalize in practice.

The Vensim model assumes functional coordination among key stakeholders, including government agencies, educational institutions, suppliers, and manufacturers. The model structure reflects interdependencies between these actors; therefore, fragmented decision-making or weak inter-institutional coordination may reduce the practical applicability of simulated policy scenarios.

Proper use of the model requires periodic validation and calibration based on observed system behaviour. As new data become available or as policy priorities evolve, parameter values and structural assumptions should be updated to maintain model relevance and predictive capacity.

Under these conditions, the Vensim-based system dynamics model serves as an effective analytical tool for exploring alternative policy scenarios, identifying leverage points, and supporting evidence-based decision-making in the optimisation of the medical equipment supply chain for educational institutions in the Kyrgyz Republic.

The effective functioning of medical educational institutions in the Kyrgyz Republic depends on timely access to modern medical equipment that is essential for both training and research. However, persistent structural and operational challenges—ranging from procurement and logistics inefficiencies to high dependence on imports and limited public funding—hinder the optimal provision of such equipment. This section analyses the key constraints within the current supply chain and proposes system-level optimisation strategies supported by a system dynamics model developed using Vensim.

Current Challenges in the Supply Chain. The medical equipment supply chain for educational institutions in the KR is characterized by several systemic obstacles.

First, high import dependence represents a major vulnerability, as most medical devices are sourced from China, Russia, Germany, and Turkey. This increases transportation costs, heightens sensitivity to exchange rate fluctuations, and prolongs delivery times.

Second, budgetary constraints limit the ability of institutions to procure advanced and high-quality equipment. Due to insufficient government allocations, procurement cycles often become delayed, fragmented, or significantly reduced in scope.

Third, logistical and administrative inefficiencies—including customs delays, the absence of standardized procurement procedures, and weak coordination among ministries, suppliers, and educational institutions—lead to delivery inconsistencies, shortages, and operational disruptions.

Finally, the sector faces a lack of local service and maintenance infrastructure. Imported equipment frequently cannot be repaired domestically, resulting in long downtimes, increased operational costs, and reduced overall system sustainability.

Supply Chain Optimisation Strategies. To address these challenges, several strategic interventions can strengthen the resilience and performance of the supply chain.

A key priority is the expansion of local manufacturing and assembly capacity. Establishing partnerships with international medical device producers, introducing fiscal incentives, and supporting domestic investors could substantially reduce reliance on imports and shorten lead times.

Equally important is the digitalization of supply chain management. The development of a centralized digital platform for real-time inventory monitoring, implementation of blockchain-based tracking tools for transparent procurement, and the use of AI-based demand-forecasting algorithms can significantly reduce inefficiencies and prevent shortages.

Strengthening public–private partnerships may further enhance system sustainability. Long-term service contracts, leasing schemes, and joint procurement mechanisms offer cost-effective alternatives to traditional acquisition models.

In terms of logistics, improvements may include centralized bulk purchasing, the establishment of regional distribution centers, and simplified customs procedures, all of which reduce costs and accelerate delivery.

Finally, strengthening technical training and maintenance capacity is essential. Developing training programs for technical specialists, creating local service centers, and facilitating technology-transfer agreements can reduce repair times and improve equipment utilization.

Expected Outcomes. The integrated implementation of these optimisation strategies is expected to result in:

- Significant cost reductions through localization, digitalization, and consolidated procurement;
- Improved equipment availability due to more accurate inventory management and efficient distribution;
- Enhanced quality of medical education enabled by access to modern technologies;
- Greater self-sufficiency and resilience of the national education and healthcare systems.

System Dynamics Model: Key Elements and Relationships

To illustrate how these variables interact, a system dynamics model was developed using Vensim. At its core is the stock variable Available Budget, which increases through Budget Inflow (state allocations, grants, donor funding) and decreases through Budget Usage associated with procurement, maintenance, and digitalization activities. The level of Available Budget directly influences Equipment Deliveries, which determine the volume of Available Medical Equipment across educational institutions.

Both Digitalization Level and Local Production Capacity act as reinforcing factors within the system: they diminish costs, improve delivery efficiency, and contribute to higher effective budget availability. Feedback loops—such as the interplay between maintenance expenses and future investment decisions—enable policymakers to assess long-term sustainability under different scenarios.

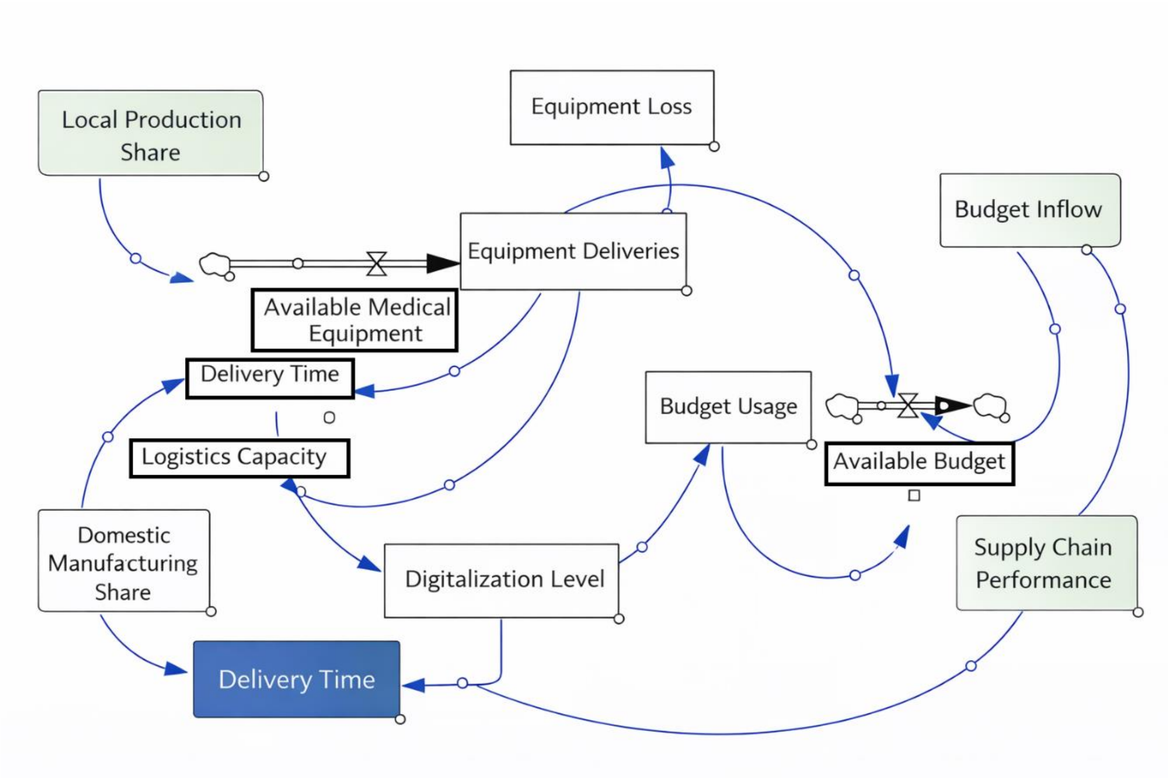

Figure 5.1. System dynamic model of the supply chain of medical equipment for educational institutions in the KR

As shown in Figure 5.1, the system is structured around the central stock variable Available Medical Equipment, which is influenced by inflows (Equipment Deliveries) and outflows (Equipment Loss). The supporting subsystems—including budget allocation, digitalization, logistics capacity, and domestic manufacturing—form reinforcing and balancing feedback loops that determine system behavior over time. This structure makes it possible to evaluate how improvements in budget efficiency, digital tools, or local production contribute to enhanced supply chain performance and greater equipment availability in educational institutions.

Figure 5.2. presents the extended system dynamic model that incorporates customs incentives, administrative digitalization, and local production mechanisms into the supply chain of medical equipment for educational institutions in the Kyrgyz Republic.

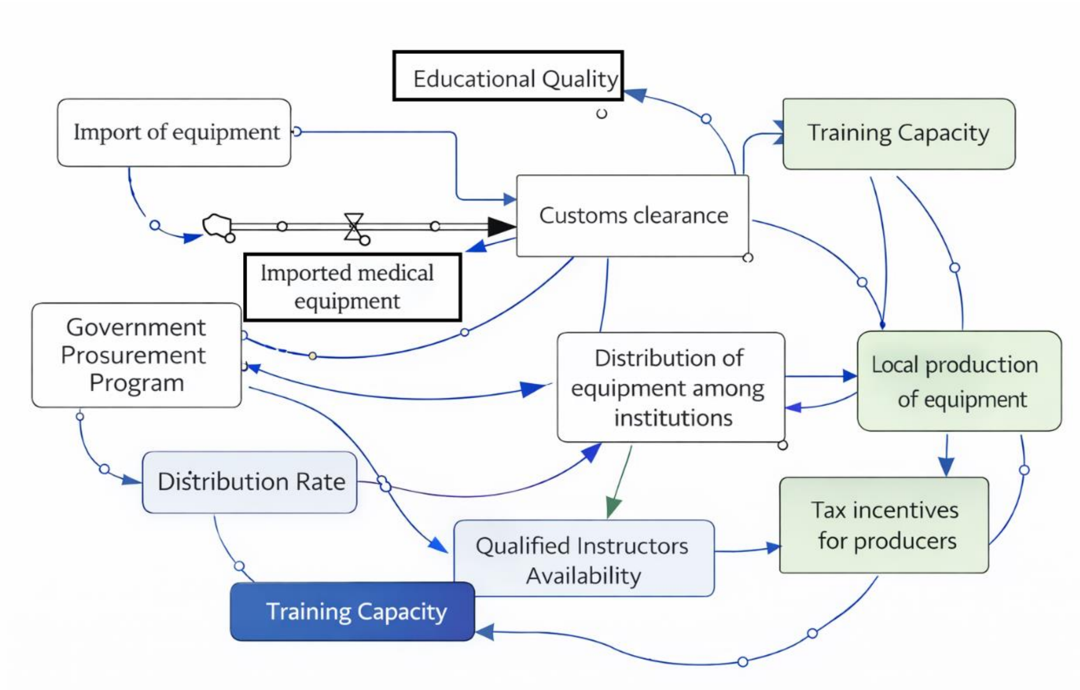

Figure 5.2. Simulation model of the impact of customs incentives and equipment allocation on training capacity and the quality of medical education in the KR

This model expands the earlier structure by integrating institutional and regulatory factors that significantly influence delivery speed, equipment availability, and the overall quality of medical education. The diagram illustrates how customs duties, VAT and excise taxes, electronic administration, tax incentives for producers, and university-specific quotas interact with import flows, distribution processes, and domestic production capacity.

As illustrated in Figure 5.2, the extended simulation model demonstrates how customs incentives, administrative digitalization, and equipment allocation mechanisms jointly shape the training capacity and overall quality of medical education in the Kyrgyz Republic. The efficiency of customs clearance plays a critical role in determining the volume and timeliness of imported medical equipment reaching educational institutions. Lower customs duties, reduced VAT and excise taxes, and simplified clearance procedures accelerate the import flow, thereby increasing the availability of essential devices for training laboratories and simulation centers.

The model also highlights the importance of electronic administration, which improves the speed and transparency of registration and documentation processes. The availability of digital customs systems reduces administrative delays and enhances the predictability of supply timelines. As a result, institutions receive equipment faster, allowing them to expand practical training capacity and improve educational outcomes.

Local production of medical equipment emerges as another significant reinforcing factor. Tax incentives for manufacturers and university-specific customs quotas stimulate domestic production, reduce reliance on imports, and shorten delivery times. As local production capacity grows, educational institutions gain more stable and cost-effective access to necessary equipment, contributing to long-term system resilience.

The interaction of these variables directly influences the distribution of equipment among institutions, which ultimately determines the quality of training resources available to students. Improved equipment distribution enhances practical skill development, supports modern teaching methods, and strengthens the overall educational quality within the medical sector.

Overall, the simulation model underscores the importance of coordinated policy interventions—customs incentives, digitalization of administrative procedures, and support for local manufacturing—in improving the effectiveness of the medical equipment supply chain. By visualizing these relationships, the model provides a basis for scenario analysis and strategic decision-making aimed at advancing medical education in the Kyrgyz Republic.

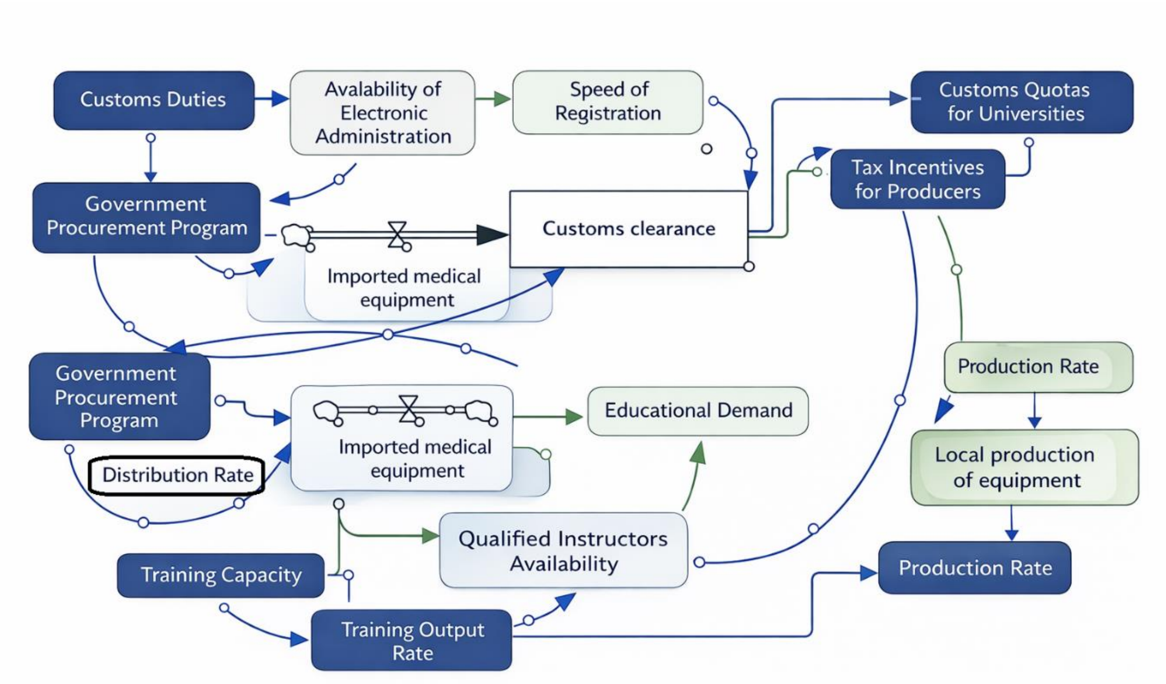

Figure 5.3. Simulation model of the impact of customs regulation and local production on the availability of medical equipment in educational institutions of the KR

As presented in Figure 5.3, this simulation model integrates customs regulation mechanisms, government procurement processes, and local production dynamics to assess their combined impact on the availability of medical equipment in educational institutions of the Kyrgyz Republic. The central flow of the model is represented by the stock variable Imported Medical Equipment, which is influenced by multiple inflows such as import volumes, government procurement programs, and the production rate of domestically manufactured equipment.

Customs duties, electronic administration, and the speed of registration determine the efficiency of customs clearance procedures, which directly affects both the timing and volume of imported medical devices. Enhanced digitalization reduces administrative delays, increases transparency, and accelerates equipment delivery to institutions.

The model also emphasizes the importance of local production of equipment, which acts as a reinforcing factor in improving system resilience. Tax incentives for producers and university-specific customs quotas stimulate domestic manufacturing by reducing production costs and lowering administrative barriers. As local production capacity grows, educational institutions gain more reliable access to necessary equipment, which reduces dependence on imports and shortens delivery times.

Another key component of the model is the variable Distributed Equipment, which reflects the allocation of available devices among universities. This process depends on the efficiency of the distribution rate and the responsiveness of government procurement programs. The availability of medical equipment subsequently affects the Training Capacity of institutions, which is further influenced by the availability of qualified instructors and the level of educational demand.

Overall, the model demonstrates that effective customs regulation, expansion of local production, and improvements in administrative digitalization significantly enhance the availability of medical equipment in educational institutions. This system-wide perspective provides valuable insights for policymakers, enabling them to test alternative scenarios and identify high-leverage interventions to strengthen medical education infrastructure in the Kyrgyz Republic.

The analysis presented in this section demonstrates that the supply chain of medical equipment for educational institutions in the Kyrgyz Republic operates as a complex dynamic system influenced by financial, logistical, regulatory, and technological factors. Using system dynamics and simulation modelling in Vensim, three conceptual models were developed to evaluate the behavior of the system under alternative policy and operational scenarios. This methodological approach made it possible to trace feedback loops, delays, and nonlinear dependencies that cannot be captured through traditional static analysis.

The baseline model (Figure 5.1) shows how the core stock-and-flow structure — centered around available medical equipment, equipment deliveries, and equipment loss — responds to changes in budget allocation, digitalization, and local production. The extended model (Figure 5.2) demonstrates how the introduction of customs incentives and administrative digitalization affects training capacity and the quality of medical education. The third simulation model (Figure 5.3) highlights the systemic effects of customs regulation, government procurement processes, and local production dynamics on equipment availability.

Taken together, the Vensim-based simulation models confirm that effective policy interventions — including digitalization of administrative procedures, fiscal and customs incentives, and the development of domestic manufacturing capacity — can significantly enhance the resilience, efficiency, and responsiveness of the medical equipment supply chain. Strengthening these components will ensure timely access to modern equipment, expand practical training capacity, and ultimately improve the quality of medical education in the Kyrgyz Republic.

5.2. Roadmap for Improving the Supply Chain of Medical Equipment for Educational Institutions of the Kyrgyz Republic

This section presents a strategic roadmap aimed at enhancing the efficiency, resilience, and overall performance of the medical equipment supply chain for educational institutions in the Kyrgyz Republic. The roadmap is developed in alignment with the priorities of the United Nations Sustainable Development Goals (SDGs 3, 4, and 9) and corresponds to the key directions of the National Development Strategy of the Kyrgyz Republic for 2018–2040, which emphasizes digital transformation, human capital development, improved public service delivery, and modernization of national infrastructure.

The roadmap is structured into short-term, medium-term, long-term, and strategic measures, enabling a systematic and phased modernization of the medical equipment supply chain in line with the needs of the medical education system.

Phase I: Short-Term Measures (1–2 years)

Stabilisation and Building a Digital Foundation (Aligned with SDG 3 "Good Health and Well-being", SDG 4 "Quality Education", SDG 9 "Industry, Innovation and Infrastructure", and the digital development goals of the National Development Strategy of the Kyrgyz Republic for 2018–2040)

1. Enhancing transparency and coordination in procurement:

- Establishing a unified digital platform for the procurement of medical equipment by all medical universities.

- Standardizing procurement procedures and bidding documentation in accordance with the principles of openness and accountability outlined in the National Development Strategy of the Kyrgyz Republic for 2018–2040.

2. Initial digitalization of the supply chain management process

- Implementing electronic systems for equipment inventory, condition monitoring, and renewal planning.

- Transitioning to electronic customs clearance to accelerate deliveries and reduce administrative costs, consistent with the Strategy's priority of building a "digital state".

3. Optimisation of customs procedures

- Introducing accelerated customs clearance ("green corridor") for educational medical equipment.

- Reducing administrative barriers for the import of essential equipment through simplified procedures, in line with the Strategy's objectives of improving the business environment and enhancing investment attractiveness.

Phase II: Medium-Term Measures (2–4 years)

Process Integration and Increased Efficiency (Aligned with SDG 4 "Quality Education", SDG 8 "Decent Work and Economic Growth", SDG 9 "Industry, Innovation and Infrastructure", and the goals of strengthening competitiveness, logistics development, and digital transformation under the National Development Strategy of the Kyrgyz Republic for 2018–2040)

1. Development of logistics and service infrastructure

- Establishing regional distribution centers for storage, repair, and delivery of medical equipment, in accordance with the Strategy's priorities for infrastructure modernization and regional development.

- Introducing centralized procurement mechanisms to reduce costs and increase the efficiency of budget utilization.

2. Expanding the use of advanced digital technologies

- Implementing AI-based tools for demand forecasting, equipment renewal planning, and logistics optimisation.

- Applying blockchain technologies to ensure transparency and accountability across all supply chain operations, supporting the Strategy's goal of accelerating digitalization of the national economy.

3. Strengthening public–private partnerships (PPP)

- Engaging private companies in equipment servicing and maintenance infrastructure.

- Developing leasing models and joint procurement programs for high-cost medical equipment, consistent with the Strategy's objective of promoting effective PPP mechanisms.

Phase III: Long-Term Measures (4–7 years)

Developing Domestic Production Capacity and Enhancing System Resilience (Aligned with SDG 8 "Economic Growth", SDG 9 "Industry, Innovation and Infrastructure", and the Strategy's goals for industrial development and building an innovation-driven economy)

1. Support and incentives for domestic manufacturing

- Introducing tax exemptions, subsidies, and preferential conditions for local manufacturers of medical equipment.

- Reducing customs duties on components and materials for domestic production, supporting import substitution in line with the National Development Strategy for 2018–2040.

2. Building a professional workforce

- Establishing educational programs in biomedical engineering at leading universities.

- Creating a national network of equipment maintenance and repair centres, supporting the Strategy's focus on human capital development and modernisation of vocational education.

3. Strengthening supply chain resilience

- Reducing dependency on imported equipment by increasing the share of domestically produced devices.

- Developing a national supply chain management system integrating universities, suppliers, manufacturers, and government agencies.

Phase IV: Strategic Outlook (Beyond 7 years)

Building a Self-Sufficient and Innovative Medical Technology Ecosystem (Aligned with SDG 3, SDG 4, SDG 9 and the long-term objectives of the National Development Strategy of the Kyrgyz Republic for 2018–2040 concerning innovation, technological development, and export growth)

1. Development of a national medical equipment ecosystem

- Forming a complete domestic production cycle of medical equipment—from design and assembly to maintenance and technological innovation.

- Entering the Central Asian market as an exporter of selected categories of medical devices, supporting the Strategy's objectives for economic competitiveness and export diversification.

2. Continuous improvement through simulation modelling

- Applying system dynamics (Vensim) to support planning, forecasting, and evaluation of policy interventions.

- Updating the roadmap and procurement strategies annually based on modelling results, consistent with the Strategy's principle of "data-driven decision-making".

3. Improving the quality of medical education

- Ensuring all medical universities are equipped with modern laboratories, simulation centres, and up-to-date training devices.

- Enhancing practical training, research capacity, and international academic cooperation.

Table 5.1. Roadmap for Improving the Supply Chain of Medical Equipment

Phase	Key Measures	SDG Alignment	Alignment with the National Development Strategy of the Kyrgyz Republic 2018–2040
Phase I (1–2 years)	1. Creation of a unified digital procurement platform. 2. Standardisation of procurement procedures. 3. Introduction of digital inventory systems. 4. Transition to electronic customs clearance. 5. Implementation of a 'green corridor' for educational equipment. 6. Reduction of administrative barriers for imports.	SDG 3, SDG 4, SDG 9	Digital transformation, improved business climate, transparency and accountability of public services.
Phase II (2–4 years)	1. Establishment of regional logistics and service centres. 2. Centralised procurement mechanisms. 3. Use of AI for demand forecasting. 4. Application of blockchain for transparency. 5. Development of public–private partnerships.	SDG 4, SDG 8, SDG 9	Logistics development, digital economic transformation, increased competitiveness.
Phase III (4–7 years)	1. Tax incentives and subsidies for domestic producers. 2. Reduction of customs duties on components. 3. Introduction of biomedical engineering programmes. 4. Development of regional service and repair centres. 5. Creation of a national supply chain management system.	SDG 8, SDG 9	Industrial development, human capital strengthening, innovation-based economic growth.
Phase IV (7+ years)	1. Formation of a national medical equipment ecosystem. 2. Export of selected medical technologies. 3. Use of system dynamics modelling (Vensim) for planning. 4. Data-driven policy development. 5. Modern equipment for all medical universities.	SDG 3, SDG 4, SDG 9	Innovative economy, export development, improved quality of medical education.

CONCLUSION

The dissertation research, dedicated to the analysis and improvement of supply chains of medical equipment for educational institutions of the Kyrgyz Republic, allowed to reveal in depth the specifics of logistics processes in the field of medical education, identify systemic barriers and justify practical directions for their elimination.

The results of the study confirmed that the effectiveness of medical personnel training in the Kyrgyz Republic largely depends on the quality and reliability of supply chains of medical equipment to educational institutions. Providing universities with modern simulators, laboratory and diagnostic equipment and teaching aids is not only logistical, but also a strategic task of national importance, directly affecting the sustainability of the health care system.

The analysis of the current state showed that the existing medical equipment supply model suffers from institutional fragmentation, non-transparent public procurement procedures, high import dependence, insufficient digitalisation of processes and lack of systematic forecasting of needs. Particular attention was paid to the legal and regulatory framework, including tender procurement procedures, where barriers to efficiency and quality of supplies were identified.

Comparative analysis with international practices (Germany, China, USA, India) revealed current trends in medical device supply chain management, including:

- Utilizing smart logistics concepts with the integration of IoT and RFID technologies,
- Digital transformation of supply chains (e-procurement, SCM platforms),
- Implementation of sustainable sourcing principles (green and sustainable supply chains),
- Using blockchain technology to increase transparency of processes.

In the context of contemporary challenges - pandemic, import dependence, digital inequality and institutional fragmentation - the topic acquires not only scientific but also applied significance.

The study achieved the following main results:

1. A conceptual model of the supply chain of medical equipment in the education system was developed, including the main logistical links: demand planning, procurement, transport, installation, technical support and disposal. The model was adapted to the realities of the Kyrgyz Republic.

2. For the first time the typology of barriers in supply logistics for educational institutions was carried out in the following areas: institutional, financial and economic, logistical, technological and personnel. The necessity of

reforming the regulatory and legal framework and simplifying procurement procedures was substantiated.

3. practical recommendations were proposed to optimise procurement processes, including transition to a centralized electronic platform e-Procurement, introduction of KPIs for logistics operations, use of equipment demand forecasting tools taking into account the specifics of educational programs.

4. A comparative analysis of international experience (Germany, China, USA, India) was carried out, based on which the following areas for the adaptation of best practices were proposed: digitalization of supply chains, sustainable logistics planning, mechanisms of public-private partnership in medical education.

5. The necessity to integrate sustainability approaches into medical equipment logistics through equipment life cycle criteria, environmental standards of suppliers and sustainable disposal was substantiated.

By implementing strategies such as localization, digitalization, public-private partnerships and streamlining customs procedures, the CD can significantly improve the efficiency and sustainability of medical equipment procurement.

Effective application of these measures will result in:

- Reduced procurement costs and logistical delays.
- Increasing the availability of modern medical equipment in educational institutions.
- Strengthening local manufacturing and service capabilities.
- Increased co-operation between government, private sector and international suppliers.
- Closer alignment of national policies with international trade rules to ensure smooth import and export of medical devices.

In conclusion, optimising the medical equipment supply chain is critical to ensuring high quality medical education and research in the Kyrgyz Republic. If these strategies are properly implemented, the Kyrgyz Republic will be able to create a more sustainable, cost-effective and stable medical equipment supply chain, which will ultimately contribute to the development of the health and education sectors.

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APPENDIX 1

A questionnaire for medical students to assess their opinions and experiences related to the educational process and simulation technologies in education:

Questionnaire for medical students
Personal data (optional):
1. ***Your year of study:*** __________
2. ***Your specialization (if applicable):*** __________

Section 1: Overall satisfaction with the educational process
1. How satisfied are you with the quality of education at your university?

- Very satisfied / Satisfied / Average / Dissatisfied / Not at all satisfied
2. Rate the availability of educational materials and resources.
3. How prepared do you feel for practical work after completing the courses?
4. Do you think that the teachers spend enough time explaining practical skills?
5. How often do you get the opportunity to work with real patients?

Section 2: Evaluation of Simulation Training
6. Have you participated in simulation training?
- Yes / No
7. How would you rate the level of realism of the simulators you have worked with?
8. How often do you participate in simulation training during the academic year?
9. Do you find that simulation training helps you develop practical skills?
10. What types of simulators do you most often work with (mannequins, virtual reality, computer simulations, etc.)?
11. Are you satisfied with the frequency of simulation training?
12. What aspects of simulation training do you find most useful?

Section 3: Practical Training
13. Do you find that practical skills training is adequate for your specialization?
14. What proportion of your time do you spend practicing practical skills compared to theoretical training?
15. Do you feel confident in performing manipulations after simulation training?
16. What types of manipulations or procedures would you like to practice more often?
17. Do you think it is important to use virtual reality in teaching?

Section 4: Interaction with teachers and supervisors

18. How often do teachers provide feedback after simulation sessions?
19. Do teachers sufficiently explain mistakes made on simulation trainers?
20. Rate the competence of teachers in using simulation equipment.

Section 5: Evaluation of conditions and resources

21. Are you satisfied with the state of simulation laboratories and equipment at your university?
22. Are there enough simulators for all students in your course?
23. How often did you have to wait for your turn to work with a simulator?
24. What improvements would you suggest for simulation training at your university?
25. Do you feel that the simulation training prepared you for real practice?