The Impact of Logistics Systems' Digital Transformation on the Development of Healthy Cities

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***Abstract*—The development of smart cities is a response to the need to integrate the interests of various stakeholder groups in order to ensure a high quality of life for residents. In this regard, the city's logistics system plays a pivotal role in supporting the operation of public services, including healthcare. Healthy cities serve as hubs for healthcare systems. These hubs generate complex logistical needs that require the integrated management of material, information, and knowledge flows. This article aims to determine the impact of logistical conditions and digital transformation processes on the smart development of healthy cities. The study proposes a knowledge management concept for the city's logistics system to improve the efficiency of flows related to medical and health facilities. This concept emphasises the importance of stakeholders' participation in these flows and their role in gathering and sharing knowledge. It also considers the function of a coordinator responsible for integrating knowledge from various sources. A review of literature and empirical research confirms that digital transformation is a key factor in supporting smart urban development for health. Key features of organisations acting as knowledge coordinators and methods of acquiring tacit knowledge - the foundation for building resilient and sustainable urban logistics systems - were also identified.**

Keywords: healthy cities, knowledge management, digital transformation, healthcare logistics, resilient urban systems.

I. INTRODUCTION

A smart city should cater to diverse stakeholder groups while maintaining a strong focus on ensuring a high quality of life. In this context, the city's logistics system plays a pivotal role in providing the infrastructure necessary for the operation of essential public services, particularly healthcare. This article aims to determine the impact of a city's logistics system on smart urban development for health, and to conceptualise a knowledge management model that supports adapting logistics systems to the specific needs arising from urban healthcare systems. The article proposes a knowledge management concept that integrates knowledge generated by the city and its stakeholders into the logistics system.

The developed concept emphasises the importance of the role of stakeholders involved in the movement of people and goods in healthy cities. It also highlights their function as coordinators responsible for integrating knowledge from dispersed sources, as well as their role in the processes of gathering, processing and sharing knowledge. Additionally, particular attention was paid to identifying sources of explicit knowledge and methods of acquiring tacit knowledge. The following research questions were formulated in this context:

Q1. What elements of the digital transformation of a city's logistics system support smart urban development for health?

Q2. What characteristics should an organisation acting as a knowledge management coordinator in the logistics system of a healthy city have?

Q3: What are the sources of open knowledge, and how can closed knowledge be acquired for knowledge management purposes in the logistics systems of healthy cities?

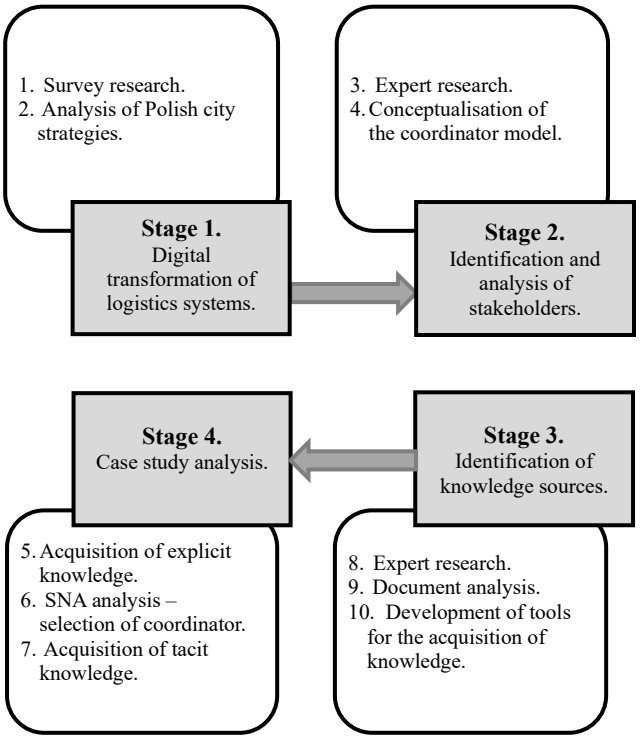

Figure 1. Research methodology.

These questions required a systematic review of the literature, integrating the concepts of 'healthy cities' and the 'smart city' approach, as well as the issue of the city's logistics system. The methodology combined stakeholder identification and role definition with open knowledge source

analysis and tacit knowledge acquisition tool development. This methodology enabled the development of a coherent knowledge management concept for a city's logistics system. The empirical part consisted of a case study conducted in one of the 62 cities covered by the study. This city was chosen because it fulfilled the attributes of a "city for health". The article concludes with a discussion of the results and findings.

II. LITERATURE BACKGROUND

Health issues have become the foundation for the development of modern urban centres. This approach aims to stimulate social, economic and environmental progress, while prioritising the quality of life of residents, which has a direct impact on their physical and mental well-being [1]. In 1988, the WHO launched the Healthy Cities programme, which has since evolved into a global initiative [2]. The concept of a healthy city is based on the fundamental values of the right to health and well-being, peace, social justice, gender equality, solidarity, social integration and sustainable development, and involves placing health, social well-being, equality and sustainable development at the centre of local policies, strategies and programmes. The Healthy Cities initiative is guided by the principles of health for all, universal health coverage, intersectoral governance for health, health in all policies, community participation, social cohesion and innovation [2]. These principles align well with the concept of smart cities, which have the potential to promote health and wellbeing.

Logistics systems play a key role in developing healthy smart cities. The evolution of these systems towards 'green' approaches that prioritise environmental issues, as well as sustainable systems that address social and economic concerns, helps create efficient, effective and inclusive urban environments [3]. One of the main dimensions of smart cities is smart mobility, which is also part of the logistics system. In this regard, strategies must be developed to meet current and future mobility needs in urban centres [4]. Researchers highlight the connection between various mobility options and the development of healthy smart cities. Cycling and walking are identified as solutions that are more resistant to pandemics, enabling safe travel and providing additional benefits in terms of physical activity, mental health and sustainable development. Furthermore, pedestrian-friendly neighbourhoods have been found to reduce stress [5]. These issues align with the concept of the 15-minute city. This concept can contribute to reducing transport emissions and noise pollution, promoting active modes of transport, reducing inequalities (including health inequalities) and building resilience to future epidemics and threats from climate change [5]. The ability to walk or access public transport, combined with reduced dependence on cars, mitigates the effects of climate change [6]. Access to reliable public transport is an important factor in potential urban social disparities, which translate into inequalities in access to medical services [5]-[7].

In summary, it should be emphasised that climate change has been identified as one of the main threats to public health. Furthermore, equal access to health and social care in cities must be improved. Additionally, good health is both a consequence of and a prerequisite for sustainable development [7].

III. RESULTS AND DISCUSSION

In accordance with the stages presented in Figure 1, the conceptualisation of a knowledge management system that integrates medical mobility needs with the conditions of the city's logistics system, with a distinct role for a central coordinator, was carried out.

The first stage of the research involved identifying key stakeholders in the city's health logistics system. These included medical facilities, residents, local government units, scientific and research units, uniformed services, organisations involved in medical waste management and logistics companies. A search was then conducted among these stakeholders for an entity capable of acting as a knowledge management system coordinator. This coordinator would be responsible for integrating dispersed knowledge resources and initiating the development of logistics solutions that meet cities' health needs. The proposed model assumes that the coordinator should possess strong relational skills. The coordinator acts as a centralised intermediary with a large number of relationships, which are more numerous and important than those of other network participants. This assumption was verified using Social Network Analysis (SNA), which identifies entities of key relational importance within a given system.

The second assumption of the model is that it combines high relational skills with knowledge and experience in technology development. The knowledge management system's purpose is not only to collect information, but also to identify the city and medical facilities' needs and link them with the possibilities of meeting these needs by developing technologies that support the flow of people and goods in the city. Due to the scientific nature of the knowledge management system and the need for continuous improvement, the coordinator should be an organisation with the necessary expertise, analytical skills and technical resources. While the attributes of the coordinator are universal in terms of the model, their practical implementation depends on the potential of a particular city.

In an empirical study investigating the impact of digitalising logistics systems on smart urban development for health, Zabrze was selected as a case study from among the 62 cities analysed in the study's initial stage. Zabrze has extensive medical facilities and significant academic potential. It is home to the Silesian University of Technology and the Medical University of Silesia, among others. The Silesian University of Technology has two key departments in Zabrze: Biomedical Engineering and Organisation and Management. These departments have significant experience in medical technology, ICT, logistics, and knowledge management. The Faculty of Organisation and Management is also associated with the Transport and Logistics Observatory, which collects and analyses information on the development of logistics technologies in the Silesian Province.

Analysis of social networks confirmed the Silesian University of Technology's high relational competence within

the network connecting the city's logistics system stakeholders with medical facilities. Notably, the European HealthTech Innovation Centre (EHTIC), which operates within the Faculty of Biomedical Engineering and involves employees from both the Faculty of Biomedical Engineering and the Faculty of Organisation and Management (including the Department of Logistics), was found to act as a bridge between key network clusters. These clusters include medical facilities, medical waste management organisations, logistics companies, municipal administration units, and uniformed services. Based on this, it was assumed that EHTIC could coordinate the developed knowledge management system concept as an entity capable of integrating knowledge, initiating cooperation between stakeholders, and supporting the intelligent development of the city's health logistics system.

Further research showed that such systems involve highly dispersed explicit and tacit knowledge among numerous stakeholder groups. This fragmentation of information and knowledge resources poses a significant challenge to the effective management of urban flows, particularly in health-oriented cities where the requirements for reliability, response times and safety are high. Implementing innovations in urban logistics systems facilitates the acquisition and processing of data, particularly that related to traffic intensity, transport times, and various types of disruption in urban transport systems. Intelligent transport systems play a special role in this regard.

The data necessary for the sustainable management of urban flows for health comes from many sources and is characterised by varying rates of change over time. Consequently, the frequency of collection and updating is not uniform and must be adapted to the nature of the analysed phenomenon. Table I presents examples of data collection mechanisms.

TABLE I. DATA ACQUISITION MECHANISMS IN THE CITY LOGISTICS SYSTEM FOR HEALTH

Data type	Source and method of collection	Frequency of collection
Deviations in collective transport	Public Transport Authority	Once a month
The amount of medical waste generated in medical facilities	Medical facilities (aggregation of data reported to UTK)	Once a year
Traffic intensity in road transport	Intelligent Transport Systems (ITS)	Every day (5 measurements during the day)
Environmental pollution	IoT sensors	Every day (5 measurements during the day)
Availability of parking spaces near medical facilities.	Urban systems	Once a month (summary)
Intensity of specialist vehicle traffic (e.g. ambulances, blood and organ transport vehicles).	Central Statistical Office, data from medical facilities	Once per quarter
New technologies in passenger transport	Analysis of industry documents and expert studies	Once a year
New technologies in freight transport	Analysis of industry documents and expert studies	Once a year
New ICT technologies in logistics	Analysis of industry documents and expert studies	Once a year

As with data, the process of acquiring knowledge requires the adaptation of acquisition mechanisms to the type of knowledge and stakeholder. In a city's health logistics system, explicit knowledge primarily concerns formally defined processes, procedures, and transport demand, while tacit knowledge encompasses the decision-making conditions, preferences, and experiences of stakeholders that cannot be observed directly. The knowledge acquisition mechanisms are presented in Table II.

TABLE II. KNOWLEDGE-GATHERING MECHANISMS IN THE CITY LOGISTICS SYSTEM FOR HEALTH

Kind of knowledge	Type of knowledge	Stakeholder group	Method of acquisition
The transport needs of residents	Explicit knowledge	Inhabitants	Surveys
Demand for transport by various modes	Explicit knowledge	Logistics companies	Operational data analysis
Factors that determine the choice of transport method for passengers	Tacit knowledge	Inhabitants	Surveys
Assessment of communication exclusions	Tacit knowledge	Inhabitants	Surveys
Assessment of digital exclusion	Tacit knowledge	Inhabitants	Surveys

The concept of knowledge gathering requires the design of appropriate research tools to enable systematic acquisition of knowledge. The current stage of research on the knowledge management system involves identifying and acquiring tacit knowledge using tools developed in earlier analysis stages. Empirical research enables the identification of individual stakeholder group needs, as well as the assessment of the city's logistics system's current potential in the context of health services. Based on this, key barriers and development challenges for the logistics system that determine its ability to support the effective flow of people and goods in the city for health purposes can be identified.

IV. CONCLUSION

For intelligent urban development to promote health, the concepts of the healthy city, the smart city and sustainable logistics must be systematically integrated within a coherent knowledge management architecture. Analyses have shown

that a city's logistics system is a key part of its health infrastructure.

The developed concept of a centralised knowledge management system with a dedicated coordinator role has provided a theoretical and empirical basis for integrating the explicit and tacit knowledge resources generated by various stakeholder groups. The effectiveness of the digital transformation of urban logistics systems for health has been demonstrated to depend not only on the implementation of technologies such as ITS, IoT and analytical tools, but also on the capacity for institutional coordination, effective knowledge transfer and the formation of lasting network relationships between entities in the public sector, academia and industry.

The case study confirmed that it is possible to appoint a knowledge management system coordinator given high academic potential and developed medical infrastructure.

The study's focus on a single case limits its scope. Another limitation is the dynamic nature of digital transformation, which implies the need to continuously update the adopted model assumptions.

Further research should include comparative analyses of cities with varying levels of logistical and digital development, as well as empirical verification of the long-term impact of transforming logistics systems on reducing health inequalities, strengthening the resilience of cities' logistics systems and achieving sustainable development goals.

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