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LOSSES IN PHARMACEUTICAL SUPPLY CHAINS: CHALLENGES IN EFFICIENT VACCINE DISTRIBUTION AND UTILIZATION

Oksana Pozniak, Valentina Khmylievska, Ishimwe Marie Jeanne. *“Losses in Pharmaceutical Supply Chains: challenges in efficient vaccine distribution and utilization”.* The article is devoted to the research the problems that arise in pharmaceutical vaccine supply chains. Slow vaccination leads to global economic losses, and the lack of free access to vaccines in many developing countries is a problem not so much in the economic category as in the cost of human life category, which is confirmed by the research of the International Monetary Fund (IMF) and the United Nations (UN). Pharmaceutical vaccine supply chains are subject to special organization and flow management requirements to avoid waste. In the context of the Covid-19 pandemic, bottlenecks inevitably arise that lead to economic, social, human losses, potential and real losses of vaccines and an increasing pressure on reverse logistics. The main bottlenecks at each stage of the supply chain have been identified, which indicate a shift in the main problems in the pharmaceutical supply chain to the distribution and last mile logistics. A detailed analysis of the vaccine distribution system in the city of Kiev was carried out with the help of sites that cover information on used vaccines and losses based on the types of vaccination points of different forms of ownership. Vaccination sites were ranked according to the degree of effective use of vaccines. As a result, the problems of insufficient information support of the vaccination campaign by government agencies were identified, which leads to the loss of vaccines. The role of the state in solving these problems was assumed by public organizations. To accomplish these tasks, an interactive vaccination map was launched, which makes it possible to find the nearest vaccination point, see how many vaccinations were given in a particular medical institution and how many vaccine doses were potentially lost. For the study, empirical research, data analysis and synthesis, expert assessments and generalization methods were used. Calculated the amount of real and potential monetary losses from vaccines that have been disposed

of. Recommendations on the use of innovative tools such as Blockchain to prevent potential and manage existing problems in pharmaceutical vaccine supply chains were provided.

Keywords: pharmaceutical supply chain, vaccine, COVID-19, losses, distribution and last mile logistics, Blockchain.

Оксана Позняк, Валентина Хмилевська, Ишимбе Марі Жанна. «Втрати у фармацевтичних ланцюгах постачання: проблеми ефективного розподілу та використання вакцин». Стаття присвячена дослідженню проблем, що виникають у фармацевтичних ланцюгах постачання вакцин. Обґрунтовано, що повільна вакцинація призводить до глобальних втрат економіки, а в умовах відсутності вільного доступу до вакцин у багатьох країнах, що розвиваються, проблеми втрат - це не стільки економічна категорія, скільки категорія ціни людського життя. Отже, до фармацевтичних ланцюгів поставок вакцин пред'являються спеціальні вимоги організації та управління потоками, щоб уникнути втрат. Однак, в умовах пандемії COVID-19, неминуче виникають "вузькі місця", що призводять до виникнення економічних, соціальних, людських втрат, потенційних і реальних втрат вакцин і зростаючого навантаження на зворотну логістику. Визначено основні "вузькі місця" на кожному етапі ланцюга поставок, які вказують на переміщення акцентів основних проблем у фармацевтичних ланцюгах поставок до сфери дистрибуції та логістики "останньої милі". Проведено детальний аналіз системи дистрибуції вакцин у місті Києві за допомогою сайтів, які охоплюють інформацію щодо використаних вакцин та втрат за кожним типом пунктів вакцинації. Проведено ранжування пунктів вакцинації за ступенем ефективного використання вакцин. Для проведення дослідження були використані емпіричні дослідження, аналіз та синтез даних, експертні оцінки та методи узагальнення. Підраховано суму реальних та потенційних грошових втрат від вакцин, що були утилізовані. Наведено рекомендації щодо використання інноваційних інструментів, таких як Blockchain, для запобігання потенційних та управління існуючими проблемами у фармацевтичних ланцюгах постачання вакцин.

Ключові слова: фармацевтичний ланцюг поставок, вакцина, COVID-19, втрати, розподіл та логістика останньої милі, Blockchain.

Оксана Позняк, Валентина Хмилевская, Ишимбе Мари Жанна. «Потери в фармацевтических цепях поставок: проблемы эффективного распределения и использования вакцин». Статья посвящена исследованию проблем, которые возникают в фармацевтических цепях поставок вакцин. Обосновано, что медленная вакцинация приводит в глобальным потерям экономики, а в условиях отсутствия свободного доступа к вакцинам во многих развивающихся странах, проблемы потерь - это не столько экономическая категория, сколько категория цены человеческой жизни. Следовательно, к фармацевтическим цепям поставок вакцин пред'являются особые требования организации и управления потоками, чтоб избежать потерь. Однако, в условиях пандемии COVID-19, неизбежно возникают "узкие места" которые приводят к возникновению экономических, социальных, человеческим потерям, потенциальным и реальным потерям вакцин и возрастающей нагрузке на обратную логистику. Определены основные "узкие места" на каждом этапе цепи поставок, которые указывают на смещение основных проблем в фармацевтических цепях поставок в сферу дистрибуции и логистики последней мили. Проведен детальный анализ системы дистрибуции вакцин в городе Киеве с помощью сайтов, которые охватывают информацию по использованным вакцинам и потерям исходя из типов пунктов вакцинации разных форм собственности. Проведено ранжирование пунктов вакцинации по степени эффективного использования вакцин. Для проведения исследования были использованы эмпирические исследования, анализ и синтез данных, экспертные оценки и методы обобщения. Подсчитано сумму реальных и потенциальных денежных потерь от вакцин, которые были утилизированы. Даны рекомендации по использованию инновационных инструментов, таких как Blockchain, для предотвращения потенциальных и управления существующими проблемами в фармацевтических цепях поставок вакцин.

Ключевые слова: фармацевтическая цепь поставок, вакцина, COVID-19, потери, распределение и логистика последней мили, Blockchain.

Introduction. The losses caused by the coronavirus are difficult to fully assess since they caused a complete restructuring of the entire global ecosystem of humanity. According to IMF forecasts, the losses of the world economy have amounted to \$ 3.5 trillion and in the next 5 years will increase by another \$ 5 trillion. [12]. According to the World Bank, at least 88 million people will cross the poverty line in the wake of the pandemic crisis, and income losses due to education problems will reach \$ 10 trillion. [16]. Inflation and higher commodity prices and global transportation costs now add another 1.5% to annual inflation. Unemployment, which led to a decrease in the income of the population, had a negative impact on retail trade, aviation, the restaurant business, and tourism. Entire spheres of small business were closed forever, which further increased unemployment and the need for financial support from the population, as a result of an increase in state budget spending. In addition, the costs for the formation and management of pharmaceutical supply chains, medical support for patient care, re-equipment of medical institutions, financial support for staff work, and vaccination are constantly increasing.

Events have made it clear that it is a common problem and that the pandemic will not end anywhere until it ends everywhere. The only way out, according to the IMF chief specialist Gita Gopinath, is to actively vaccinate the world's population. Accelerating vaccination of the world's population remains a top political priority, after which large-scale testing and investment in disease treatment should be pushed. Fewer than 5% of developing countries are now fully vaccinated, compared with about 58% of those in the richest countries. According to the forecast of the Organization for Economic Cooperation and Development, slow vaccination slows down the country's economy and the development of all industries [15].

So, in countries whereby the middle of 2022 the vaccination level of the population

will not reach 60%, the cumulative decrease in GDP will be \$ 2.3 trillion in the period from 2022 to 2025. Asia will suffer the largest cumulative losses among regions due to slow vaccination - by \$ 1.7 trillion. But in terms of the size of the economy, sub-Saharan Africa will suffer the most significant losses - 3% of the projected GDP for 2022–2025 [11].

Slow progress in global vaccination and the spread of new viral mutations will result in weaker recovery and greater job losses. Governments need to ensure that all necessary resources are used to roll out vaccinations as quickly as possible around the world to save lives, preserve income and control the virus. A more determined international effort is needed to provide low-income countries with the resources they need to vaccinate their populations - both for their own benefit and to accelerate global recovery from the crisis, economists emphasize [15].

Since the world is now divided into those who have free access to vaccines and those who do not, the problem of reducing losses in pharmaceutical supply chains in the distribution system and efficient use of vaccines is not only an economic problem but also a problem of human survival.

Analysis of recent research and publications. The impact of the covid-19 issues on the pharmaceutical industry and pharmaceutical supply chains has led to the emergence of many kinds of research, provided by individual scientists and groups of researchers, companies, and international organizations such as WHO and the EU.

WHO developed "Guidance on developing a national deployment and vaccination plan for COVID-19 vaccines" (2020) [8]. This document is intended to guide national governments in developing and updating their national deployment and vaccination plan (NDVP) for COVID-19 vaccines. The guidance is built upon existing documents and the core principles of the WHO Strategic Advisory Group of Experts (SAGE) values framework for the allocation and prioritization of COVID-19 vaccination,

the prioritization roadmap, and the Fair allocation mechanism for COVID-19 vaccines through the COVAX Facility and will be continually shaped by the vaccine-specific recommendations.

The Organization for Economic Co-operation and Development (OECD) provide research "OECD Policy Responses to Coronavirus (COVID-19) Using trade to fight COVID-19: Manufacturing and distributing vaccines" (2021) [14] that discusses trade and trade policy considerations underpinning access to the final and intermediate goods needed to effectively produce, deliver and administer COVID-19 vaccines. It focuses on the international aspects of the vaccine supply chain, discussing the sourcing, production, distribution and need to expedite international border crossing and transportation (including in the context of the cold supply chain).

The group of researchers in collaboration with the Center for Global Development provided the survey "A Path to Resiliency: Mitigating the Impacts of COVID-19 on Essential Medicines Supply Chains" (2021) [2]. The paper highlights that data-driven approaches should be considered to make supply chains more robust, solutions must account for the political and institutional landscape, price surges benefit the wealthiest, and local solutions are often needed to manage global shocks.

Another group of researchers analyzed short and long term impacts of COVID-19 on the pharmaceutical sector (2020) [4]. According to their survey, short-term impacts of COVID-19 pandemic includes demand changes, regulation revisions, research and development process changes and the shift towards tele-communication and tele-medicine. In addition, industry growth slowdown, approval delays, moving towards self-sufficiency in pharm-production supply chain and trend changes in consumption of health-market products along with ethical dilemma could be anticipated as long-term impacts of COVID-19 pandemic on pharmaceutical sector in both global and local levels.

Pharmaceutical Industry Consultant Keith Coleman and Anne Marie Gaffney (2021) identified factors affecting the resilience of pharmaceutical supply chains and provided guidance on how to overcome challenges and manage risks in the COVID-19 environment [17].

DHL, as a leading logistics provider, has teamed up with McKinsey & Company as an analytics partner to publish a white paper on building a resilient supply chain for vaccines and health products during Covid-19, aligning the interests of all market players and defining future crises in the field. health care. The importance of this study is that it identifies pain points that lead to losses in pharmaceutical supply chains [6].

According to the International Air Transport Association (IATA), currently, about a quarter of the vaccine cargo gets degraded due to shipping-related oversights, such as pallets being left out of cold storage for too long. Additionally, about 20% of the temperature-sensitive vaccine shipments also deteriorate during transportation. A COVID-19 vaccine comes with certain prerequisites in terms of temperature and shelf life. Hence, it is crucial to have a robust supply chain management with real-time logistics [3].

The range of publications that identify the problems of the impact of coronavirus on all spheres of human life, and the pharmaceutical industry, in particular, are not limited to the publications reviewed. New ones are added to the existing problems, with which methods of struggle and prevention have not been developed yet. Therefore, the authors draw attention to the insufficient number of researches in the field of ineffective organization of the vaccine distribution system, which leads to vaccine losses, economic losses, potential human losses, and an increasing burden on reverse logistics.

Objectives statement. The purpose of this article is to identify the root causes of problems in Pharmaceutical Supply Chain and specific problems in the vaccine distribution chain that lead to inefficient use of existing

stocks and an increased burden on reverse logistics.

Basic material and results. Producing a medicine is only the first step towards getting it to the patient who needs it. The pharma industry, with its stringent requirements for product security and stability, has one of the most complex logistical chains in the world today. High-tech logistics are not just an expense, they are an investment in better access to medicines, and – used efficiently – they can bring down overall healthcare costs and improve patient care [7]. This becomes especially relevant in the context of the global covid-19 pandemic.

Getting vaccines to where they are needed requires a debugged subjective-streaming interaction in Pharmaceutical Supply Chain because lives can be at stake if anything works less than perfectly. WHO says it is critical that "no weak link exists in the supply chain" [5] and all processes in PSC must be organized without gaps, lack of transparency, and traceability. Although logistics is only one step in the pharma supply chain, these shipping processes can represent nearly 40 percent of total operating expenses [9].

Therefore, it is very important for each country, when shaping the vaccine delivery chain, to prioritize the most important areas that need to be addressed (by industry, regulators, and other key stakeholders) to create a sustainable and reliable drug value chain that faces unprecedented pressures and crashes. It is also critically important to review the structure of the value chain, evaluating each step to see where there is a chance of failure and to determine where more flexibility is needed. This approach makes it possible to identify bottlenecks at each stage of the pharmaceutical supply chain based on [1,6], which are shown in Figure 1.

At the beginning of the covid-19 pandemic, the main problems were concentrated in the production sphere, since there were not enough components for the

production of vaccines, demand exceeded supply, etc., then as the market was saturated with vaccines from different manufacturers, problems in pharmaceutical supply chains shifted to the sphere of transport and logistics services, among which the main ones were highlighted and reflected in fig.1:

1. Transportation and consolidation in sourcing country:
 - Local quality checks and non-steady supply;
 - Transportation capacity bottleneck;
 - Limited transparency with high variance in quality.
2. Inbound transport:
 - Limited and volatile freight capacity;
 - Extraordinary time pressure.
3. Inbound transport:
 - Limited and volatile freight capacity;
 - Extraordinary time pressure.
4. Custom and regulation:
 - Lack of coordination fast track;
 - Supplier certification and qualification;
 - Frequent import regulation changes and country variations.
5. Quality check:
 - Substantial amount of disqualified products due to arrival-only quality check.
6. Warehousing:
 - Limited storage capacity and lack of routine;
 - Suboptimal SKU formats and imprecise product information;
 - Lack of expertise and sophistication in storage of different types of vaccine.
7. Distribution and Last Mile:
 - Limited transparency on stock levels and demand;
 - Challenging transportation planning and carrier management;
 - Disruption of any of the connected components can lead to potential drug delays;
 - High demand and delay in procurement can result in shortage of stock and lead to potential increase the number of cases;

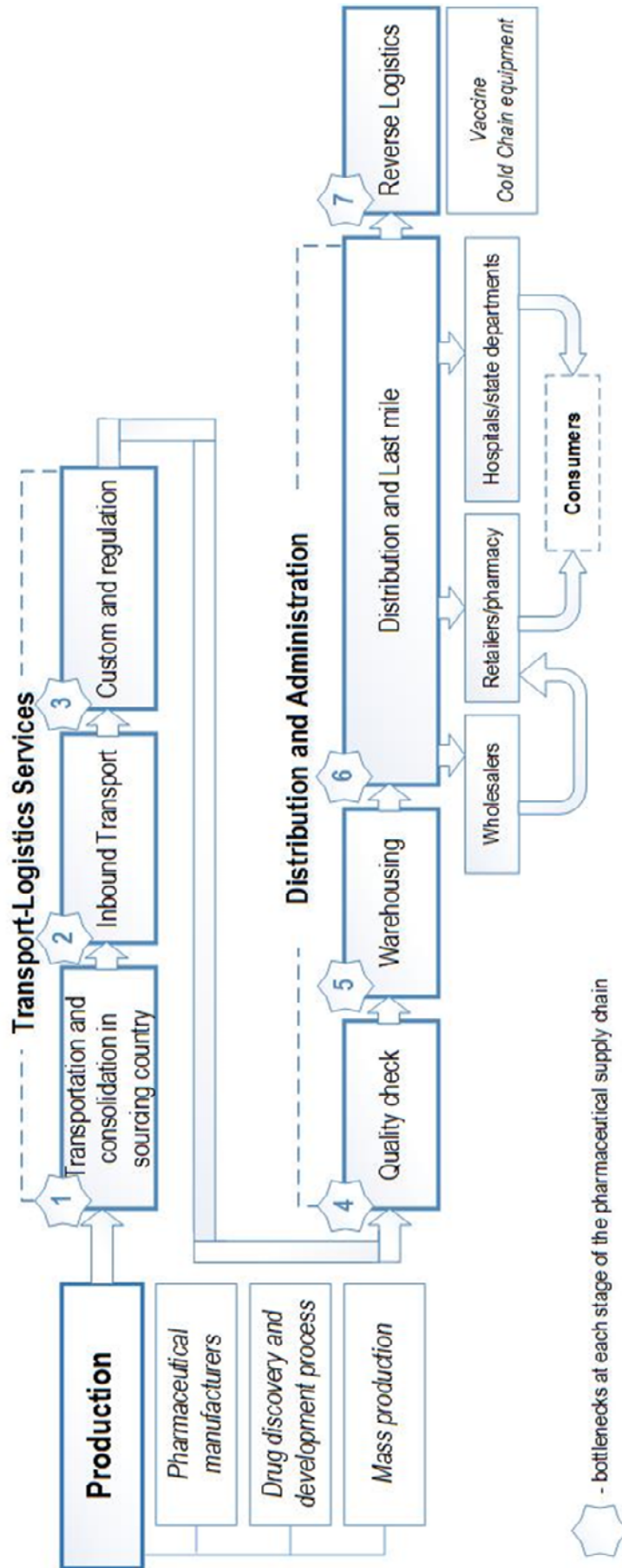


Figure 1 –Bottlenecks in Pharmaceutical Supply Chain

Source: developed by the authors

- Increase in number of patient and high demand for vaccine are contributing to short-term supply shortages;
- Violation of storage conditions for vaccines;
- Lack of Cold Chain equipment for vaccine`s storage;
- Lack of traceability of vaccine storage conditions at all stages of the supply chain;
- Ineffective information campaign that has led to an increase in the number of unused vaccines with shelf life;
- Information flow management problems in the field of vaccine availability and vaccine residues at each vaccination site.

8. Reverse Logistics:

- Problems in returning Cold Chain equipment;
- Disposal of expired vaccines;
- Disposal of unused vaccines.

It should be noted that the main problems in pharmaceutical supply chains have moved to the last part of the chain - distribution and logistics of the last mile. This is due to the fact that manufacturers and operators of the logistics services have balanced and agreed upon the main problems and conflicts in export-import activities. The involvement of state institutions in Ukraine in the regulation of the distribution of vaccines among vaccination points, which at the moment cannot be considered effective, leads to large losses of vaccines.

According to the official data of the Ministry of Health of Ukraine, there is the following data on the number of disposed of vaccines [13]:

- 500 thousand doses of AstraZeneca coronavirus vaccine due to expiration date;
- 34,036 doses of Pfizer vaccines due to thermal disturbance when shipped in early summer;
- potentially 800 thousand doses of AstraZeneca (both the first and second doses) are disposed of due to the expiration date in November.

At the moment, the Ministry of Health cannot name the exact number of disposed of vaccines. But even based on these data, it is possible to calculate the losses of the state from the disposal of a given volume of vaccines. If we take the cost of the Pfizer vaccine, which ranges from \$ 15.5 to \$ 19.5, then the sum of losses will be from \$ 527 558 to \$ 663 702. The losses from 500 thousand doses of AstraZeneca coronavirus vaccine amounted to \$ 2.4 million if we take the cost of \$ 4.8, potential losses from 800 thousand doses of AstraZeneca will amount to \$ 3,840,000. That is, the real losses of the state of Ukraine ranged from \$ 2,927,558 to \$ 3,063,702. If we add potential losses, the amount will double.

There are many subjective and objective reasons, but the failure of the informational vaccination company, the lack of an information base for informing the population about the existing vaccination sites, the availability of vaccines in them in a real-time system, informing the population registered in "Diya" in real-time about the possibility of making a vaccine (especially this relevant for the AstraZeneca vaccine). The role of the state in solving these problems was assumed by public organizations.

To fulfil these issues, the public organization "Anti-Corruption Headquarters", with the support of the French Embassy in Ukraine, has launched an interactive vaccination map. Everyone can find in this map the nearest vaccination point, see how many vaccinations a particular medical facility has received and how many doses of vaccine are potentially lost.

Moreover, this information was used for analyzing the effectiveness of certain channels - vaccination points. Based on this data [10], information about vaccination points of all forms of ownership in the city of Kyiv, that displays the effectiveness of each vaccine distribution channel within the logistics of the last mile was summarized in table 1.

This information characterizes the activities of each vaccination point for

October 2021, before mandatory vaccination for certain groups of the population of Ukraine was introduced. The proportion of unused (lost) vaccines for each vaccination point was calculated using the following formula: the number of unused (lost) vaccines for each vaccination point is divided by the total number of unused (lost) vaccines and multiplied by 100%. The largest share of this

indicator is among individual entrepreneurs, who have 6 times more vaccines disposed of than used ones. The second place in the ranking of ineffective vaccination points is taken by private enterprises providing medical services in Kiev, where the number of disposed vaccines is 2.5 times more than those used.

Table 1 - Analysis of vaccine losses, depending on the type of vaccination point in Kyiv

№	Type of an enterprise	Number of vaccinated	Number of unused (lost) doses of vaccines	Share of unused (lost) vaccines, %
1	Municipal non-profit district enterprises, providing medical services in Kyiv	96 481	10 449	10,83
2	Municipal non-profit enterprises of the executive committee of the Kyiv city Council (Kyiv city State Administration)	5 505	665	12,08
3	State institution "TERRITORIAL MEDICAL ASSOCIATION" of the Ministry of Internal Affairs of Ukraine in Kyiv region	4 178	182	4,36
4	Individual entrepreneurs providing medical services in Kyiv	104	656	630,77
5	Limited liability companies providing medical services in Kyiv	2 118	2 512	118,60
6	Private enterprises providing medical services in Kyiv	82	208	253,65
	Total	108 468	14 672	

Source: compiled by the authors

The performed calculations show the inefficiency of non-governmental vaccination point, information on the location of which was not communicated to potential consumers of their services. This applies not only to non-state vaccination points. The problem of wide information coverage of the vaccination company has not yet been resolved, and when opening vaccination centers, the logistic principles of flow management are not taken into account, which leads to losses.

The ranking of the vaccination points of the population, according to the degree of vaccine loss is shown on the following chart (Fig. 2).

The solution of the problems that were mentioned above cannot be postponed, since it is too early to talk about the end of the pandemic. Therefore, it is necessary to think about using innovative tools for managing flows, primarily informational ones. It is proposed to use Blockchain-based solutions for managing secure databases to manage the COVID-19 vaccine supply chain. Implementing this technology, along with Internet of Things (IoT) solutions such as real-time monitoring and asset tracking, can ensure a successful vaccine deployment.

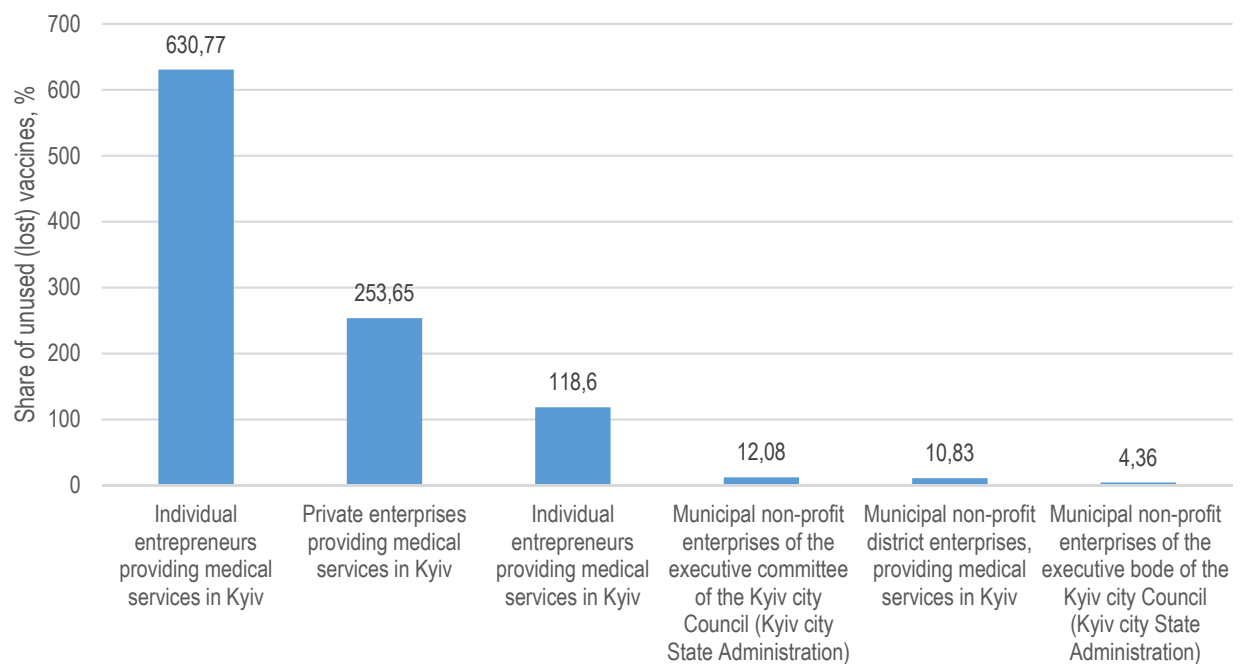


Figure 2 – Vaccination points ranking by ineffective vaccine use

Source: compiled by the authors

As shown in Figure 3, combining the two technologies has a synergistic effect, that is, one technology enhances the impact of the other on the efficiency of the pharmaceutical supply chain. Moreover, their use in such

large-scale events can ensure the optimal use of resources to save precious lives without compromising quality and safety standards, which are fundamental principles of the state's humanitarian policy.

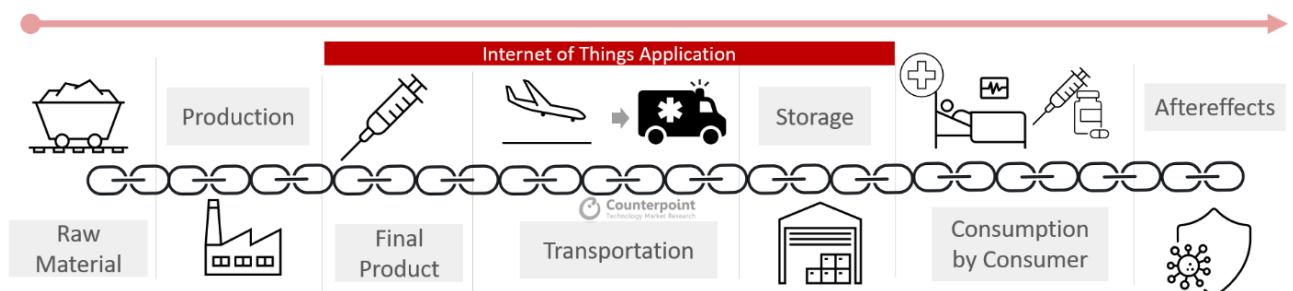


Figure 3 – COVID 19 Vaccine Supply Chain based on Blockchain and Internet of Things [3]

Since some companies, and even countries, have already begun implementation Blockchain technology to optimize supply chain processes, it can be assumed that the introduction of this technology to manage processes in vaccine supply chains could lead to the same results. Among the main potential positive results, especially in distribution and last mile logistics, are the following:

1. Support direct or indirect communication protocol for secure real-time

monitoring of the vaccine in transit as well as at the source and destination.

2. Transparency of the standards that are followed at every stage, by creating an exact copy of the registry at every node of the network.

3. Transparency of processes in the vaccine supply chain.

4. Ensuring the identity of health care workers, maintaining medical records and tracking the effects of treatment.

5. Monitoring health centers to check for cases when employees use their authority or compromise their responsibility.

6. Using IoT sensors embedded in trays or boxes for cooling vaccines together with a communication module to collect and analyze data on lighting, humidity and temperature and transmit them to the vaccine distribution authority.

7. Protect data that is sent to a Blockchain system in the cloud, or cryptographic printing that combines NFC chips with a Blockchain to track and protect distribution.

8. Monitoring information about urgent requirement for pallet-sized cooling boxes embedded with temperature sensors in distribution and last mile logistics and information about movements of these instruments via reverse logistics.

Conclusions. Challenges in the pharmaceutical vaccine supply chain are linked to the course of the Covid-19 pandemic. In the early stages, when the vaccine was just being developed, the main problems in the supply chain were in ensuring the production of necessary components, which were mainly shipped from Asian

countries. With the advent of vaccines on the market, there was a problem with the formation of the necessary infrastructure to ensure the delivery of vaccines, since there is a certain temperature regime for each vaccine. After saturation of the market with vaccines, the problem of efficient regional distribution of vaccines turned into a solution to the problems with the distribution of vaccination in each settlement and the last mile logistics of, reverse logistics. In research has been found that problems exist at every stage of the pharmaceutical vaccine supply chain and affect not only the efficiency of the entire supply chain, but also the economy, humanitarian policy, and most importantly, the lives of people. Identifying problems allows to develop certain standards for their solution, and the use of new technologies, such as Blockchain and the Internet of Things, give an opportunity to bring flow management in pharmaceutical supply chains to a completely new level, which makes it possible to avoid unnecessary losses, such as vaccine losses, economic losses, potential human losses, and an increasing burden on reverse logistics

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