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The role of artificial intelligence in business transformation: A case of pharmaceutical companies

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ABSTRACT

Artificial intelligence (AI) is of great interest to researchers and practitioners as a means of achieving the necessary progress in the pharmaceutical industry. However, the role of AI and ways of transforming companies are not well studied. The purpose of the paper is to identify exactly how AI affects the key and support business processes of pharmaceutical companies. We offer a qualitative interview study of five large, five medium, and five small pharmaceutical companies. Based on scarce literature on the role of AI in the pharmaceutical industry, we considered which business processes are subject to transform within it and how they do so. We determine that small pharma companies significantly change research and development, master data management, analysis and reporting, and human resource business processes under the influence of AI. Large pharma companies use AI to transform production, sales, marketing, and analysis business processes. In turn, medium-sized companies are in the middle and individually transform their business processes depending on their specialization.

1. Introduction

The modern pharmaceutical industry is characterized by costly and lengthy development cycles of new drugs, as well as price pressures from patients, insurance companies, and states [1,2]. The typical cost of developing a new medicine is estimated at USD 2.5 billion, and this process takes an average of 10–15 years [1]; Chan et al., 2019). These costs start with scanning millions of components in the early stages of research and development (R&D) and finish with the most expensive clinical trials with poorly predictable results. Despite careful preparation, only 12% of clinical trials end in success [2]. All pharmaceutical companies are looking for opportunities to increase efficiency in their business processes for the discovery and development of new products, compliance with the strict rules inherent in the industry, and achieving the necessary financial parameters, among other things.

Medical and pharma industries generate and offer a large amount of digital data, including wearable sensors, electronic medical records, and clinical and genetic data [3]. The more pharmaceutical companies know about the patient, the more likely they are to choose an individual drug and treatment plan that will have the best result. At the same time, the rapid growth of computing capabilities allows companies to form and provide data for processing based on advanced machine and deep learning algorithms, which are the foundation of artificial intelligence (AI) [4,5]. These algorithms include the recognition of existing text and audio materials, the generation of new materials, and subsequent analyses of received data. The increase in IT productivity also launched the formation of numerous AI companies and influenced transformations in the business processes of medium and large pharmaceutical companies that are forced to adapt to new realities [6]. The pharmaceutical industry is the beneficiary due to the lack of bias, reduction of the human factor, and the time to bring new products to the market [2,7].

Researchers believe that Big Data and AI algorithms could become the next step for pharma industry development [5]. The vast majority of pharma companies are aware of the need to use the capabilities of new technologies. However, at present, pharma companies are faced with the task of adapting their strategies and applying new technological opportunities. The digitization of medical data collected from the pharmaceutical industry over decades and subsequent human analysis do not provide a significant increase in industrial efficiency [8]. AI allows real-time processing of patient data, selecting the best candidates for clinical trials, exchanging information with the patient, doctor, provider, and insurance company [9]. AI could become the key to the industry's unsolved problems, such as time and drug development costs. With the support of processing and the analysis of graphic data, text, and voice recordings, AI has the potential for faster and more accurate analysis compared to humans or other technologies.

According to some researchers, pharmaceutical companies have used every traditional opportunity for drug discovery, thereby having already

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picked the "low-hanging fruit," while further research efforts and the formation of stable cash flows require significant investments [1]. Current pharma companies have an unpredictable drug development pipeline and outdated business models that do not contribute to value creation [10]. Therefore, AI could increase efficiency and reduce drug discovery and development costs in the pharma industry.

The core motivation for this study is to explore the increased potential for AI to solve problems in the pharmaceutical industry. We continue studying the role of new technologies in the pharmaceutical and healthcare industries [46,47]. We demonstrated that business models for companies and sources of value formation in pharma and healthcare are often unique and can hardly be compared. However, we found that the majority of pharmaceutical representatives are favorable in the opportunities provided by new technologies such as AI, virtual and augmented reality, robotics, and others. In the majority of cases, existing medical and business studies declare a reduction in the cost and time for drug development as the main advantage of AI in the pharmaceutical industry [5]. However, to our knowledge, there are no studies that analyze the transformation of business processes that are inherent in the pharmaceutical industry under the influence of AI. Therefore, we pose the following research question in our study: "How does AI transform business processes in the pharmaceutical industry?"

To answer our research question, we examine key and support business processes for fifteen companies (five small, five medium, and five large) in the pharmaceutical industry. The result of our analysis reveals an assessment of business processes that transform under the influence of AI depending on the size of the company. We demonstrate that R&D, Master Data Management (MDM), analysis and reporting, and human resources (HR) are significantly changing for small companies. Large companies are more focused on changing processes related to production, sales, marketing, and analysis. In turn, medium-sized companies are transforming business processes depending on the business model and are somewhere in the middle of large and small enterprises. We thereby hope to contribute to the innovation literature and still-scarce research on the role of AI in industry transformation [11–13].

2. Literature review

2.1. Business processes

Business process management, or business process reengineering, studies associations among the management of business processes to improve the performance of business indicators. Internal and external factors, such as the demand for qualified personnel, innovations, and demand changes, form the need for organizational changes in companies [14,53].

In his classic work, Hammer [54] identified the reengineering of business processes using IT solutions as a way to achieve improvements in business performance. Subsequent studies supplemented this definition. For example, Hashem [55] declares that changes in business processes are related to changes in performance indicators, while Baiyere et al. [56] claim a radical change to achieve meaningful results such as price, service, and quality. The majority of authors agree that IT solutions play a key role in increasing productivity and quality, thereby transforming business processes and making companies more successful in the healthcare industry (for example, [15,16].

According to Guha et al. [51], the following steps should be distinguished in changing business processes: project planning, identifying and modeling existing business processes, developing alternatives, changing the current practices to the desired processes, and monitoring and evaluating updated processes for possible further transformations. Subsequently, Radosevic et al. [52] suggested that available resources be considered when transforming business processes; Rao et al. [50] added reasons for project failures in relation to business process changes in the companies; Bertolini et al. (2015) paid attention to the training of managers responsible for changing business processes.

Business process modeling has always been one of the key activities associated with improving the performance of business processes [48,49]. For example, Mendling et al. [17] proposed a study of errors in modeling business processes, the relationship between the complexity of the simulated processes, and the likelihood of success. However, there is some uncertainty regarding the theoretical foundations of business process modeling. As an exception, it is worth noting the work of Mendling et al. [18]; who proposed a sequence of steps for putting business process modeling into practice. These guidelines bring theoretical research into practice and provide strong guidance to practicing managers for implementing business process transformation projects.

Business process reengineering is largely associated with IT capabilities and their impact on society. New technologies based on powerful computing capabilities give a new impetus to the development and adaptation of business. There is a gap in the literature about how specific technologies affect business processes in a particular industry. AI's capabilities are often associated with the pharmaceutical industry; however, researchers pay little attention to this area. Our research closes this gap and demonstrates what kinds of business processes are changing under the influence of AI in the pharmaceutical industry and how they are doing so.

2.2. AI in pharma

Drug development is a long-term process that can be roughly divided into the following main groups: target selection and validation, screening of compounds and optimization of leads, preclinical stages, and clinical trials [19]. AI is a combination of mathematical algorithms and systems that can perform tasks previously available only to humans [20]. The key difference between AI and other automated systems is AI's ability to independently learn and make or recommend decisions for humans [21].

The pharmaceutical industry generates demand for two groups of solutions based on AI. The first group is based on analytical solution systems [22] and includes various types of analysis and predictions of the probability of event occurrence. Such systems are able to offer scenarios with the required resources and can recommend the best for a particular company. AI algorithms allow users to deeply analyze and find the connections between objects and processes that were not previously available for analysis. The second group includes recognition technologies such for speech, snapshots, video, and other unstructured data [5,23]. The software allows users to find existing similar patterns, adapt them for mathematical calculations, and offer recommendations for users.

AI is involved in increasing the efficiency of the pharmaceutical industry [2]. Image processes are used to optimize the search when creating a new drug or other application of already known drugs. Such methods are used to analyze biological, chemical, and medical databases. AI algorithms are used for deep semantic analysis of specialized or open information, for example, scientific articles, conference reports, newspaper articles, genetic databases, and more that could be a source of background information [8]. Any unstructured data on a specific topic could become the basis for training and finding relationships without human intervention. In turn, the processed information serves as the basis for assessing the obtained molecule's potential and effectiveness.

Researchers often highlight the search for drugs for rare diseases as one of the most promising applications of AI in the pharmaceutical industry [7,24]. On the one hand, pharmaceutical companies are less likely to devote resources to drug development if there is insufficient market demand for it. On the other hand, AI is able to select the best candidates for clinical trials. Forming a profile of optimal candidates could significantly reduce the likelihood of failure at the clinical trials stage, the most expensive in the pharmaceutical industry.

Researchers also pay great attention to the role of replacing humans with AI algorithms [25–27]. Social researchers study various prospects

for AI development. On the one hand, there is an opinion that many employees, regardless of industry, could be replaced by algorithms [28]. According to some researchers, the number of new jobs created in the pharmaceutical industry will be significantly less than the number of jobs lost to AI [2]. This approach requires policy makers to work toward maintaining social stability when introducing new technologies. On the other hand, researchers during the last decade suggest that AI-based applications are more likely to complement humans, providing more data for decision-making [29]. Current legislation in most countries does not allow for decision-making without a human presence, especially in relation to human life and health as in the pharmaceutical industry. Moreover, most medical studies suggest that AI can cope with the detection of topologies better than humans, but collaboration between a human and AI is still more productive [30].

3. Method

Given the lack of research on the impact of AI on business processes in the pharmaceutical industry—a fairly new and therefore unexplored area—we chose a qualitative interview study approach as the basis for our research [31]. Conducting qualitative interviews with this approach supports obtaining perceptions, feelings, opinions of the interviewees, and an understanding of existing trends and issues [32]; however, this type of research helps shed light on areas where there is a lack of knowledge, for example in connection with the innovation of technology [33].

Most of the research on the use of AI in the pharmaceutical industry is a single case study [34–36]. In our opinion, this is largely due to the uniqueness of each case, and based on the work of Eisenhardt [37]; single cases are most suitable for expanding the theory and in-depth understanding in the absence of data. The experience of successful AI application is currently underexplored due to the lack of cases related to a novice and growing phenomenon. There are few papers that offer multiple case studies; however, the sample does not exceed twenty cases [38,39]. One explanation is that there are many developers that disguise their services as AI, but they represent conventional or advanced IT solutions. These companies simulate work and provide recommendations without relying on Big Data. The cases of the pharmaceutical companies participating in our project were selected both by the companies themselves through an independent AI development or competition for the integration of AI solutions and through additional recommendations from other market participants. Therefore, we can be sure that the selected cases are exactly correct for the sample, and the information collected is relevant. As a sample, we used companies that are part of Innovative technologies in industry transformation project, which is devoted to new technologies in healthcare and pharma. For this study, we chose fifteen pharma and biotech companies that use or integrate AI capabilities in their business. This methodology for determining the size of the business is taken from Berisha and Pula (2015) and Loecher (2000). See Table 1 for more details.

Additional information about the companies participating in the study and the positions of the interviewees are presented in Table 2.

During the first round of data collection, we sent questionnaires to the contact persons of the selected companies (see Appendix). We took a list of the main and support business processes that are inherent in the pharmaceutical industry based on recommendations by Grüne et al. (2014) and Festa (2018). We asked participants to evaluate the impact of AI on various business processes and highlight those that have not changed due to the use of this technology. We allowed them to choose the value of AI for changing a specific business process from major/minor/not applicable options and to comment on the answer. **We used the concept of practical significance [40] as the basis for our survey proposed in the Appendix and later shown in Table 3. Practical significance is the value of the difference, which can be also known as the effect size. Practically significant are those results that matter in real life; the difference between the values is great [41]. In our cases, a "Major" parameter could be, for example, the 80% change in the personnel responsible for this business process or the selection of new personnel whose functions are atypical for the industry, the abolition of the department, or the total change of the approach to the business process. "Minor" changes were a single addition of new personnel or a new function that made few changes but became typical for the industry. In turn, the "Not Applicable" parameter was used if the respondents do not use AI in the particular business process and are not familiar with the successful experience of such use by other pharma companies. As an alternative, we introduced the "Special Case" parameter, that is, a case that has been implemented within a company and is not typical for the industry but that can bring changes to the pharmaceutical industry in the future and impact the studied business process.** For the analysis and comparison of the obtained data, we used NVivo 12 Pro. The research team formed pivot tables based on the

Table 1
Identification of key parameters of the case companies.

	Operating period, years	Number of employees, people	Revenue, in millions, of EUR/USD/GBP per year
Small companies	<5	<10	<1
Medium companies	5–10	10–25	1–10
Large companies	>10	>25	>10

Table 2
Key information about selected companies for research.

	Type of the company	Country of origin	Contact
1.	Small company 1	France	CSO
2.	Small company 2	UK	CEO
3.	Small company 3	Germany	Founder and CSO
4.	Small company 4	Finland	CEO
5.	Small company 5	Iceland	Founder
6.	Medium company 1	Belgium	Founder
7.	Medium company 2	Sweden	Group leader
8.	Medium company 3	Sweden	CEO
9.	Medium company 4	Spain	CTO and CMO
10.	Medium company 5	Germany	Co-founder
11.	Large company 1	Denmark	Head of AI Department
12.	Large company 2	Switzerland	CEO
13.	Large company 3	Denmark	Project leader
14.	Large company 4	Germany	VP, Product Development
15.	Large company 5	Portugal	CSO

Table 3
The role of AI in business process transformations in the pharma industry.

	Small	Medium	Large
Key business processes			
R&D	**Major**	**Major**	*Minor*
Planning	N/A	Special case	Special case
Procurement	N/A	*Minor*	Special case
Production	N/A	*Minor*	**Major**
Quality	N/A	*Minor*	*Minor*
Sales and marketing	N/A	N/A	**Major**
Storage and delivery	N/A	N/A	Special case
Support business processes			
Master data management	**Major**	**Major**	Special case
Compliance	*Minor*	*Minor*	*Minor*
Legal	N/A	N/A	N/A
Analysis and reporting	**Major**	**Major**	**Major**
Finance and controlling	N/A	N/A	*Minor*
Human resources	**Major**	**Major**	*Minor*
Real estate management	*Minor*	*Minor*	*Minor*
IT services	**Major**	**Major**	*Minor*

answers collected after the first round.

The second round consisted of presentations of the obtained data for the project participants in the framework of individual and group face-to-face online meetings. From our side, we presented pivot tables and clarified the details of the collected information. From the participants' side, interviewees shared information about the market, competitors, and other types (small, medium, and large) of companies. The final value of major/minor/not applicable parameters was obtained if at least four out of five companies in every group agreed with this option.

Our sources of additional information consisted of (1) interviews of other pharmaceutical companies regarding the use of AI in the pharma industry; (2) industrial reports, which assessed the impact of new technologies on the industry; (3) opinions of managers and advisers of business incubators and accelerators, which aim to support and develop technology business in different countries; (4) other available resources, such as the websites of companies and their competitors, news, peer-reviewed publications, and others.

4. Findings

In this part of the article, we present our findings that were identified during the study. Table 3 shows the impact of AI on business process transformations that are specific to the pharma industry.

We will describe in more detail the impact of AI on each of the key and support business processes that are specific to the focal industry and key quotes that were typical during discussions.

4.1. Research and development

Algorithms allow researchers to scan databases of millions of molecules in a matter of hours, while traditional methods would take months and even years. AI cannot develop a drug, however, which may indicate that a particular combination of molecules has a greater chance of creating a drug for a particular disease, **as mentioned by the CEO of Small Company 2:**

> *"Using machine learning methods for R&D is the backbone of our business [target identification]."*

After that, companies may reduce the number of combinations and continue to develop a drug using traditional methods.

Small companies use AI to solve numerous, very narrow tasks by offering services and work results to medium and large companies, for example target identification, generation of novel small molecules, scoring, and others. How small companies get results and increase the likelihood of success in drug discovery and development is the basis of their business and is not subject to disclosure. Medium-sized companies strive to form a R&D conveyor; **see the following quote from the founder of Medium Company 1:**

> *"The approach to R&D of [mid-sized companies] is similar to that of a pipeline. The larger the company, the more projects a company can conduct at the same time."*

These companies are moving away from the principle of narrow specializations and extending their activity to subsequent stages of drug development. Specialized venture capital funds financing drug development could become an important partner for these types of companies. The majority of small companies tend to grow into medium ones and medium-sized companies into large ones. However, both types of the interviewed companies assess the prospects for cooperation with large businesses as low.

Large companies tend to praise the efficiency of internal AI drug development efforts. However, other market participants doubt the correctness of such statements. In most cases, effective internal development of large companies is based on joint work with small innovative companies or the acquisition of these companies. Large companies tend to acquire promising projects in order to gain access to technology or transfer the team to the company. They are also ready to acquire the results of the work of small and medium companies, regardless how they obtain them. All results must be verified and validated by standard procedures that are mandatory for the industry**, as the project manager of Large Company 3 noted:**

> *"We are interested in the result, which will be received and confirmed in accordance with the rules."*

And a representative of Large Company 1 said:

> *"Internal [AI] performance is on par with many other firms, but our management is always open to the market."*

Thus, the development of methods and approaches to conducting AI research has significantly changed for the small companies, has decreased in medium-sized companies, and is almost unchanged in large companies.

Interviewees additionally noted the following new AI opportunities that open to the market in connection with the use of AI capabilities. First, there is the analysis of individual factors for the development of individual treatment plans. Having a treatment process means having the right treatment plan at the right time for the right patient (Link and Saxena, 2014). AI analysis of individual factors of the patient, such as genetic characteristics, history of the formation and development of disease, and environmental factors offers increased chances for the successful development of an individual drug. Managing the patient, accounting for an addiction to the drug, and assessing the current effectiveness of treatment is important for the timely monitoring of a treatment plan. An important factor for successful treatment is also an individual assessment of the compatibility of several drugs for the patient. The obtained structured and unstructured medical data can be processed in real time with AI. In turn, recommendations for the doctor and patient are provided with less time delay. Second, AI plays a role in the development of solutions for rare diseases. Algorithms could increase the chance of developing a drug even for those groups that were previously commercially unattractive to the industry. Solutions for the analysis and care of patients with rare diseases can be demanded by medium-sized pharma companies. AI-based solutions have the ability to significantly increase the effectiveness of clinical trials and the treatment of a particular patient. AI allows companies to select the best candidates for clinical trials through the analysis of collected patient and medical data. The identification of such patients directly increases the effectiveness of drug discovery and development. Moreover, new applications for existing drugs could be found through more accurate patient selection. AI may predict how a potential drug candidate could affect the patient, thereby reducing failure in the most resource-intensive stage of the study: clinical trials. **These areas were especially highlighted and summarized during the discussion by the founders of Small Companies 1 and 3:**

> *"The business model for start-ups is often unique and can transform depending on the market opportunity."*

4.2. Planning

Planning processes have significantly changed in medium and large companies mainly in the clinical trial stages. According to standards of the Food and Drug Administration (FDA), pharmaceutical companies are required to test new drugs for safety and efficiency in controlled samples before they offer products on the market. AI-based applications have the potential to make major changes to standard clinical trials and increase the necessary parameters; **the founder of Medium Company 5 noted:**

"There are trial planning solutions based on machine learning in the market, but it is worth paying more attention to exploring them."

According to the respondents, the reduction in necessary experiments could reach 70% due to an early assessment of the likelihood of success. Small companies are more optimistic in their prognoses, as their business models are based on services to increase the efficiency of drug development.

Large companies have the ability to digitize existing databases that were collected before the mass use of new technologies. Collected and AI-analyzed data allow companies to plan and predict the result at different stages of drug development, especially during the clinical trials. Large companies have an ability to plan sales planning and marketing activities. See the "Sales and marketing" section below.

4.3. Procurement

There is little AI-based procurement software that is successfully integrated into pharmaceutical and other industries. However, many software integrators with a potential for pharma companies offer smart contract management, supply chain management, and AI-based decision-making procurement.

According to the respondents, AI-based procurement solutions may have an advantage over specialists in this industry**, as noted by a representative of Large Company 2:**

"We have an advanced [AI] solution that connects purchasing, sales, and manufacturing. I believe we are the first in this market."

The proposed solutions are able to support decisions in the procurement policy (reduction of manual labor and shortcomings in the supply chain), search for suppliers (optimization of data collection and processing), and ease scaling. AI applications can replace many routine processes and offer decision support, allocating staff time to make strategic decisions in the face of uncertainty. However, at present, AI procurement solutions are based on the speed of data processing. Promising AI solutions have the ability to process structured and unstructured data in real time and provide analytics for decision support.

4.4. Production

There are few examples of successful drug production using AI capabilities by small and medium-sized companies. During the preparatory phase of the study, we expected to see contract and generic manufacturing as representatives of this sample. However, our interviewees doubted there was a need for AI solutions in such cases; **for example, the founder of Small Company 5 noted:**

"*Manufacturing is not typical for small companies operating in the pharmaceutical industry."*

The vast majority of pharmaceutical manufacturing facilities are concentrated in large companies. These companies may use AI-based applications to develop production plans based on available and incoming internal and external information. The recommendations affect the identification of problem areas and defects, the prediction of the equipment load, the optimization of equipment use, and maintenance. **The CSO of Large Company 5 stated:**

"Assessment of demand and production [of drugs] … is based on the forecasts of our analysts and IT solutions [AI-powered]."

Therefore, the main collaboration at the manufacturing stage is concentrated mainly between large companies and third-party AI application developers.

AI-based production and common integrated automation systems differ in their real-time analysis of the situation, their change in workload when changing production tasks, and other unforeseen circumstances. The AI system aims to independently prepare recommendations or make decisions to increase efficiency in the face of uncertainty. The few AI integrations are mainly executed to coordinate existing production systems. For example, image recognition of mobile personnel and equipment increases occupational safety. Successful AI cases include setting changes for a production shift, accounting for the condition of the conveyor, thereby reducing the number of downtime and resource consumption. Interviewees also noted that AI applications can be gradually implemented based on existing production systems, **as noted, for example, by the Head of Department at Large Company 1:**

"There was no need to change the entire ***system and retrain. The new packages were integrated gradually."***

Therefore, there is no need for a sharp reconfiguration of existing business processes, and it contributes to greater controllability and the coordination of business processes.

According to representatives of large companies, technology could become more widespread with a decrease in the need for initial training for the new company. There is a demand for a universal system that could be trained independently while considering the specifics of a particular production.

4.5. Quality control

There is some confusion when discussing the concepts of quality and compliance. Both are important in the drug development industry, but there is a certain difference between them. Quality is the number of parameters that are evaluated by customers and that affect the level of satisfaction from use. Compliance is the rules and requirements that must be followed to complete the FDA registration.

The use of quality control software is common in large companies, less so in medium companies, and rarely found in small companies. **A representative of Large Company 2 added:**

"Our solution tracks user feedback. We ***can respond to emerging trends as needed."***

More often, medium-sized companies start using such programs under the influence of partners or large projects. However, such programs are rarely associated with AI. Most interviewees declare that following the FDA rules is enough to get high-quality drug development standards. For example, it is necessary to document oral and written complaints from consumers. This parameter is especially important at the stage of product testing and is of particular importance for obtaining high quality.

4.6. Sales and marketing

Data mining technologies are in demand for large companies in marketing and sales. A large number of routine events can be automated: filling out calendars, invoicing, etc. However, these activities could be automated without AI capabilities. In turn, AI allows users to personalize activities by a set of parameters, for example the location of the company, the number of employees, their activity, and time spent on the supplier's website. Such data provide unique portraits of customers with similar behaviors, after which the AI software recommends actions for collaboration. Moreover, specialized data allow managers to better understand the decision-making process when purchasing a particular customer or company. A sales manager obtains extra time and offers tools for generating leads and closing deals.

During the interviews, the following areas of AI use in sales for the pharma industry were highlighted. Firstly, there is a demand for market forecasting. Forecasts are based on existing and incoming real-time information and directly affect the loading of production and storage. Secondly, AI-based software evaluates the effectiveness of marketing

channels, correlates them with sales, and allows them to change the company's marketing plans, even in real-time, **as noted during the group discussion by the CEO of Large Company 2:**

> ***"In most cases, sales*** trends ***coincide with forecasts [made by the AI solution]."***

Thirdly, it is possible to evaluate the effectiveness of cooperation with every customer and develop individual plans for their retention. In addition, it is worth noting the capabilities of AI to increase the efficiency of medical representatives. **The head of the AI department at Large Company 1 noted:**

> ***"Our sales team was*** pleased ***with the introduction of the new software. Sales became even more targeted and personalized."***

There are opportunities to assess the likelihood of success in the meeting and to prepare individual materials and samples for the customer. Such solutions are usually integrated into the existing customer relationship management systems of the company.

4.7. Storage and delivery

The stage of storage and delivery involves a large amount of manual labor, which means that there is an opportunity to optimize and reduce costs. The main task of inventory management for any industry is to increase the productivity of warehouse complexes and reduce the cost of processing goods.

Inventory management is primarily interesting for large drug manufacturers. However, the solutions are similar to those in other industries. Modern AI warehouse management systems are based on Pick-by-Light, Pick-by-Voice, and Pick-by-Vision approaches. The most common system is based on Pick-by-Voice, which allows personnel to use voice messages without paper or electronic orders. This is advantageous because it is hands-free and allows for increased concentration on warehouse tasks, **as noted by the CEO of Medium Company 3:**

> *"There are few successful [AI] integrations of warehouse solutions in the industry; nevertheless, this trend is gaining momentum."*

Further reductions in warehouse labor may occur through a combination of AI capabilities and robot control for the preparation of orders. The interviewed representatives of large businesses thought positively about the possibilities of managing complex asynchronous processes in robotic warehouses. Such systems successfully cope with load balancing during the day, they send robots to collect specific orders, monitor the robot charge level, and correct emergency situations. However, the experience of using such systems for the pharmaceutical industry is little.

5. Support business processes

5.1. Master data management

A key aspect of MDM for all business participants is the availability of reliable data for processing. Companies are forced to use significant resources on data cleaning before using it. **According to representatives of Small Companies 3 and 4, as well as those of Medium Company 4, up to 80% of the time is spent cleaning, and only 20% is spent on applying the algorithms.**

Large companies have the ability to create, digitize, and encode data that were collected earlier, including images of pathologies, clinical trial results, and others. However, such activity is not necessarily aimed at obtaining instant benefits. On the one hand, **as mentioned by the CEO of Small Company 2**,

> *"There could be investments in future projects or in the development of the whole industry."*

On the other hand, reliable and structured data could become a basis for cooperation with small and medium-sized companies; **see, for example, a comment from the VP of Large Company 4:**

> *"We collect and structure data for the future … our experience and capabilities allow this."*

Small companies are one of the main consumers of structured data and are interested in obtaining access to it. Representatives of small companies claim that access to such data is one of the most recent causes of innovation in the pharmaceutical industry. Moreover, small companies work with open libraries that were previously inaccessible for analysis by traditional methods. In such cases, the simulation may be characterized as "pulling a needle out of a haystack." However, small companies are more ready to take such a risk.

Medium-sized companies collect and combine data for their own purposes. **A representative of Medium Company 4 noted:**

> ***"We are not sure about the companies offering*** services ***to access the collected data. We rely more on ourselves."***

Such data could be linearly incompatible with each other; therefore, deep neural networks are required to search and extract patterns. According to respondents, such actions are incomprehensible to humans, and the use of other IT resources will take many years. Medium-sized companies may also choose a business model based on the formation and acquisition of data. In this case, the company's reputation will play an important role in business development.

In general, there is an understanding in the market that "data is new money." Various companies generate, process, and use data for their own needs and for the needs of the industry. Businesses of all sizes are interested in cooperation, and the main limitation is trust between the participants. Nevertheless, according to the majority of respondents, the number and size of such projects is growing annually.

5.2. Compliance

Compliance issues were relatively similar among the participating companies regardless of their size. **Representatives of most companies confirmed that there are currently no completely developed AI-based drugs. For example:**

> *"It is prohibited at the moment."* Small Company 2 and Medium Company 3.

Or,

> *"There is always a human who evaluates the results at each stage using standard techniques and acting as an intermediary between [AI] and a drug."* Large Company 3.

At the moment, experiments are a leading factor in the discovery and development of any drug. It is necessary to comply with the strict rules inherent in the pharmaceutical industry in order to confirm the possibility of moving from one stage to another. The surveyed companies state that there is a lack of sophisticated drugs where AI played a major role. The transition to a new stage of drug development or testing requires verification by both the internal forces of the company and external participants, which is used in the vast majority of cases.

5.3. Legal

None of the study participants stated the significant role of AI applications for changing legal procedures in the focal industry. This is largely due to the fact that industrial standards imply a mandatory verification of the data obtained using classical methods.

5.4. Analysis and reporting

AI-based analytics allow companies to study constantly updated data flows from internal and external operations. The processed data could complement decision support in uncertain conditions. **It was mentioned many times in the discussion. For example:**

> ***"Machine*** learning ***is geared towards solving such problems."***

Or

> *"The task of our solution is to find patterns and issue recommendations, that is, analysis and planning in a straightforward form."*

AI analytics provide an opportunity to identify relationships between events that were previously inaccessible to humans. Such information is necessary to work with new and existing customers, form individual offers and recommendations, and forecast at all stages, specifically during R&D, production, and sales. According to respondents, such analytics are also involved in creating an optimal combination of developments, predicting trends in the market, distributing the company's budget, quickly changing the company's strategy, and more.

5.5. Finance and controlling

AI trends in finance and control are formed mainly in large financial organizations around the world. The pharmaceutical industry partly adapts them to their own needs. On the one hand, there is a demand for the dynamic modeling of planning, forecasting, and budgeting processes. On the other hand, the benefits of AI are not entirely clear to market participants. Reliable automated financial processing tools without AI are common and available for integration. Advanced technologies could free employees of financial departments from routine tasks and provide more time for generating ideas. Interviewed pharma representatives foresee an insignificant impact of AI in the finance and control of business processes over the next ten years. However, large companies have noted the potential use of AI in detecting financial deviations in the early stages as well as fraud and malicious operations.

5.6. Human resources

Pharmaceutical companies' business processes change in different ways. For example, large companies create a demand for jobs associated with mass recruitment. Companies may require solutions for the preparation and improvement of the questionnaire, the elimination of discrimination, and the assessment of how attractive the information is for candidates and others. **See, for example, the following comment from the representative of Large Company 5:**

> ***"Finding talents is*** undoubtedly ***important, but how much better is such an AI solution?"***

The formation of salaries is also in demand by large companies. Using a variety of sources, a corresponding database could be formed, and AI offers a system for paying and motivating personnel. Such solutions allow executives to identify the mismatch of position and compensation, which helps reduce the risk of staff leaving and also helps to identify overvalued staff. The system evaluates many parameters in an automatic mode. According to some respondents, a similar project in the classical form with the use of human resources would have already fizzled out in the middle of the project itself.

AI-assisted recruiting could be in demand by companies in the focal industry. The level of subjectivity of a recruiter affects how they form and describe a position, review resumes, conduct interviews, and provide feedback. Most of these tasks could be automated. Companies of all sizes have shown a demand for a skilled workforce. However, finding and assessing qualifications may be challenging. As in other industries, there are many "passive" candidates who are not looking for work but may be suitable for specific tasks. AI solutions allow you to track activity in social networks and professional communities. Next, chatbots could conduct interviews and assess the level of the candidate. An important difference between AI and other bots is the ability to analyze and interpret indirect responses.

In turn, the approach to recruiting and working with personnel in medium and small companies changes the value that these companies offer in the market. **The CSO of Small Company 1 commented:**

> *"In small [pharma and biotech] companies, there are more and more IT specialists. This is a ubiquitous trend."*

And the CTO of Medium Company 4 noted:

> ***"Key IT employees are searched*** around ***the world…. We compete with Apple and Google."***

AI in medium and small companies changes not only the business processes associated with HR but also who is looking for and hiring in companies. The need for classic laboratory personnel is changing in favor of other kinds of personnel. Medium-sized companies can afford to hire qualified and specialized employees. For example, companies form groups of mathematicians who are developing new methods for combining different areas of knowledge using AI algorithms. Other groups of specialists apply these methods to solve existing problems or basic research. In turn, a third group can verify the results obtained by AI to use methods that are common in the pharmaceutical industry. The variety of teams is determined by the tasks that are set by the company and may include methods, applications, and verification of results.

Business processes also change due to the recruitment of employees with different backgrounds. Medium-sized AI-based companies rather slowly increase the number of R&D employees. The key issue is how long it takes to successfully bring together people with different experience and backgrounds. Successful groups within one company may consist of three to five people, for example chemists, biologists, AI specialists, and basic IT specialists, who aim to solve a specific problem. **The following quote comes from a discussion between two Midsize Companies:**

> ***"It becomes a task to teach employees*** who ***hardly understand each other to work together…. I doubt that it was the same in previous years."***

Parallel to the project teams, companies develop infrastructure that contributes to the projects. The staff for the development of new methods and algorithms is unique and recruited internationally. In turn, finding staff who apply the available methods is fairly easy. It is often difficult to progress cooperation among specialists from various fields. Therefore, slow and organic personal growth is inherent in medium-sized companies.

The majority of small companies in the pharma industry are university spin-offs or are founded by former employees of medium and large companies. University spin-offs are usually formed on the basis of master's or PhD graduates at the intersection of such knowledge as biology, chemistry, mathematics, and IT. However, the market forms a different need for specialization. Interviewed representatives are more likely to believe that university graduates should combine different expertise; for example,

> *"Biologists should develop in statistics and chemists in a computational area."* Medium Company 5

In turn, PhDs with a deep specialization in the technical field are in demand. Nevertheless, the respondents were not able to develop a unified strategy and recommendations for the required personnel for five to ten years. On the one hand, there is an opinion that the demand for well-trained laboratory personnel that will cope with automation and AI could grow. On the other hand, the opinion that such specialists will not be needed at all after five to ten years also exists.

Decision-making support of their own personnel is in demand at large companies. However, most AI services are purchased from a third party. There are insignificant HR changes in the structure of the large case companies. As an exception, these may be specialists in R&D formed at the initiative of the company or obtained after the acquisition of smaller companies or specialists in the IT and support departments.

The AI labor market in the pharma industry is changing rapidly, and trends are formed under the influence of new talents and discoveries, which also adds uncertainty and difficulties for making predictions.

5.7. Real estate management

Interviewed company representatives noticed few changes in real estate management processes under the influence of AI, **as the representative from Medium Company 5 noted:**

> ***"IT allows [companies] to reduce facilities costs…. There are doubts that AI will somehow*** significantly ***change this trend."***

In recent decades, R&D processes demonstrated a relocation trend from laboratories to IT, but the need for experimental laboratories is in demand. To a greater extent, independence from such resources is demonstrated by small companies that are more interested in algorithms than in facilities. Medium-sized companies, depending on their specialization, form a certain need for real estate. In turn, large companies are large consumers of real estate services, but AI has not significantly affected them.

5.8. IT services

AI solutions offer new opportunities to expand functionality and increase the productivity of business processes. AI technology has the potential to control and automate time-consuming tasks, such as selecting the optimal combination of proteins and targets, screening new drugs, and more. However, it is worth noting negative scenarios related to AI integrations. New solutions can duplicate each other's functionality, which is one of the key barriers to the development of IT infrastructure in the company. Simultaneously, the role of the IT department is growing in the company. IT managers should constantly study and improve upon new skills to support the IT infrastructure and the smooth functioning of all business processes of the company regardless of its size. IT solutions are service providers based on the company's business objectives**; see the following comment from Large Company 3:**

> ***"Perhaps integrators themselves do*** not ***fully understand exactly how machine learning algorithms makes its prediction. Some uncertainty makes you doubt."***

Companies are raising expectations for new integrations. For example, large companies do not perceive options such as reduced downtime or fast data processing as an advantage. The required standards for making changes to business processes are much higher. Small and medium-sized companies create value around their AI-powered solutions. Changes in business processes are typical of medium-sized companies, while small companies form new business models based on their developments.

6. Summary of results

Pharmaceutical companies, depending on their size, evaluate the role of AI differently in the transformation of business processes. In most cases, the opinions of small, medium, and large companies do not coincide. Small companies are more likely to use AI developments at the R&D stage, while other key business processes remain unchanged or are insignificantly affected by AI. In turn, supporting business processes directly related to R&D are also subject to change. In the case of small companies, support business processes related to data processing, forecasting results, personnel for these functions, and IT services undergo the main changes. Business models for small AI companies are focused on solving narrow problems with the support of algorithms, providing services for larger companies in the industry, and searching for new opportunities to use their know-how. Large companies are more focused on AI capabilities for production management, analysis, forecasting, and sales. An increase in the efficiency of large companies in this industry, even by a few percent, leads to a significant increase in revenue. It is also worth noting that the use of AI capabilities in some areas, for example planning or master data management, could be successfully applied to specific tasks. First of all, this includes predicting the success of clinical trials. This stage is the most resource-intensive, and reducing the probability of failure is very much in demand. MDM is also involved in creating value for the focal industry. Digitization of the accumulated data is in demand for its own purposes, for example training AI algorithms, as well as for cooperation with other companies. In turn, medium-sized companies are somewhere in between large and small companies, and their AI use depends on their specialization, size, and development stage. AI has definitely had an impact on key business processes such as R&D and clinical trial planning. According to the support business processes for the medium companies, it is worth highlighting MDM, analysis, forecasting, and human resources. However, it is difficult to identify any unequivocal priorities in the use of AI for medium-sized companies because it all depends on the particular case. In contrast to small companies, market participants do not always appreciate the investments of large companies in their own AI-based R&D. We want to emphasize that strict industry rules and compliance protocols prevent the accelerated implementation of AI capabilities. All stages developed using algorithms must be verified using traditional methods. Therefore, business processes such as quality or clinical analysis are hardly affected by new opportunities for any type of company.

It is also worth noting the role of other industry participants that influence changes in business processes and procedure transformation. For medium-sized companies, these are investment funds specializing in drug discovery and development. According to respondents, the number of such specialized funds is growing, including those due to the emergence of new technology opportunities. The market is becoming more attractive to new participants that already create value and influence other participants. These types of funds may direct companies to study specific targets and molecules. Moreover, this collaboration contributes to the generation of new data that are in demand in the industry as a whole and by AI companies in particular. Large companies are more likely to collaborate with third-party AI solutions manufacturers and integrators. A major role in successful integration is played by such factors as the company's readiness for the transition and adaptation of new features, as well as the availability of its own databases for training algorithms. In most cases, integrations are based on an individual approach, which could hardly be adapted to another company in the pharma industry. Undoubtedly, such integrations have industrial specificity, which, for example, is associated with FDA standards.

We should emphasize that there are few successfully implemented AI integrations for large pharma companies. The vast majority of pharma companies rarely generated millions of data rows. Thus, the concepts of Big Data do not quite apply to this area. We can argue that the combination of internal and obtained data and processed data in several basic business processes—for example, planning, production, management of warehousing, sales, marketing, and delivery—may be enough for the full use of AI. Such volumes of data can be generated and be in demand for large companies. Partially, the evaluations received from the large companies are more related to the expectations that AI could realize and increase the efficiency of the industry. In turn, small and medium-sized companies are actively using AI for their development. However, it is often doubted that competitors who declare the provision of similar AI services may provide such services. According to some interviewees, competitors can use automated systems and classic approaches to provide pseudo AI services. In such cases, the use of the term AI is more

related to the growing interest of customers in new technologies. In general, large companies are subject to cautious optimism and have some hope for an increase in the use of AI capabilities in the future; small and medium-sized companies create and adapt their business models to new opportunities and consider AI as a paradigm shift in the drug discovery and development industry.

AI has the potential but does not reach the level expected by customers in many business processes, with the exception of R&D. The advantages of AI over existing automated software are not obvious in most cases. Reducing and automating routine tasks is currently available for business. AI can be used as an assistant in decision-making; however, the results of its work should be verified by a human. Full outsourcing of key business processes for medium and large enterprises is unacceptable.

7. Discussion and contributions

The pharmaceutical industry requires efficiency gains and value creation for society. On the one hand, researchers note that humans are reaching their maximum capabilities [1]. The necessary time and financial costs are greater than ever, and the high probability of error reduces the interest of investors and companies in the development of new drugs. On the other hand, it is already generally accepted that innovation is the driving force for the development of companies and industries [42,43]. New technologies represent a chance for the development of those areas and niches that were previously inaccessible. AI and algorithms, according to some researchers, allow for a leap in development [6,11–13,44]. In turn, AI-based innovations are gradually changing the approach to solving complex problems, transforming the resources and processes required for a successful solution, thereby reducing costs and increasing the chances of success [45].

Our key theoretical contribution relates to the impact of innovation, particularly new technologies, on companies' changing business processes. We analyze how and what business processes are changing in the pharmaceutical industry under the influence of AI. The results of our study confirm the current findings of the researchers (Goksoy et al., 2012 [14]; but bring greater insight into changes in key and support business processes of the companies. For example, we agree on the role of AI in R&D and manufacturing [1,8]. However, we specify that, depending on the size of the company, business processes vary from minimum to significant, including non-applicable situations. Some business processes cannot be changed at this time due to strict industry regulations. However, this does not mean that it cannot be applied; rather, it offers room for development and improvement.

The lack of successful integrations affects the promotion of AI solutions. Nevertheless, it was revealed that special cases have been successfully integrated into the market; they are not very common in the industry, but they have the potential to be widespread and significantly change the companies' business processes. Moreover, we confirm the opinion that representatives of the pharmaceutical industry expect an increase in the efficiency of business processes and the industry as a whole under the influence of AI [10,29]. The industry expects that AI will impact areas where human skills are suited to the maximum of their capabilities.

We agree with the opinion of researchers who emphasize the benefits of using AI in the pharmaceutical industry [2,20]. We structure and show exactly how pharma analytical solutions [22] and recognition technologies [5,23] are in demand. Recognition technologies are more in demand at the R&D stage in the pharmaceutical industry, while analytics are more at the production and sales stages (Ombrosi et al., 2019). We are also consonant with the opinion that analytical systems are in demand at the patient interaction stage. The development of individual treatment plans based on the characteristics of patients reduces the likelihood of error and the cost of treatment and also increases the speed of recovery.

Additionally, we consent that AI could become an innovation tool to increase industry efficiency [2,8]. Our analysis demonstrates that most risks are taken by small companies that try to solve issues in the industry due to IT innovation [16]. This finding also applies to rare diseases. The demand for analyzed data is formed mainly by medium-sized companies, who are engaged in analysis, drug discovery, and development either independently or cooperatively with small companies.

We share an opinion with researchers who declare no decline in employment in the pharmaceutical industry [25,26]. The staff of small companies, in most cases, is formed based on their university research; large companies form a small demand for AI specialists. The main consumer of AI specialists is medium-sized businesses. However, medium-sized businesses create a heterogeneous demand for the experience and qualifications of such specialists. These may be specialists with deep knowledge in a certain field or those at the intersection of several areas of knowledge. An additional uncertainty is introduced by the fact that the interviewees could not agree on the demand for specialists after ten years. Their opinions ranged from a complete lack of demand to a significant increase in demand.

Our research also has several practical implications. First, we appeal to the potential representatives of small businesses. We demonstrate to founders and executives that the pharmaceutical industry has a demand for change. Knowledge at the intersection of chemistry, biology, and IT may form a proposal for solving numerous, very narrow problems of the industry. AI can solve problems faster and more efficiently than traditional methods, and even a small reduction in resources can be successful. To start, priority may be given to cooperation with large companies, which are engaged in the digitization of previously collected data. However, founders should be aware of the threats of such cooperation. We also want to emphasize that solutions for key business processes are more specific to the focal industry. In turn, for support business processes, solutions could be adapted from other industries. Therefore, companies that do not have specific knowledge in the pharmaceutical industry have an opportunity to enter new markets.

Second, we also turn to policy makers and universities. The next ten years could generate a boom in the development and application of new technologies. Countries that rely on AI could be faced with a demand for relevant specialists and the absence of an employment decrease in different industries. Moreover, AI solutions may participate in filling vacancies for narrow specialists and decision-making support by inexperienced professionals. Despite some doubts about the demand for traditional pharmaceutical specialists, none of the respondents questioned the need for advanced IT skills for future employees of the focal industry. University programs and advanced research at the intersection of several areas of knowledge will also be a priority.

In addition, the study could be interesting to third-party developers of AI solutions for the pharmaceutical industry. The main consumers of AI solutions could be large companies that are interested in improving efficiency in sales, marketing, production, and inventory management. It is worth noting that solutions for other markets may have a limited impact. Design solutions with the possibility of gradual integration or universal and independently trained solutions could be in demand in the pharmaceutical market.

8. Limitations and future research

This study is one of the first to examine the experience of using AI in the pharmaceutical industry. We find that the pharma industry is not homogeneous, and companies differ significantly from each other, not only in terms of revenue but also in tasks, areas of activity, size and much more. Moreover, the experience of using AI in different pharmaceutical companies cannot always be transferred to other circumstances and adapted to new realities. Nevertheless, we believe that the application of new technologies in the pharmaceutical industry can be an advantage in the company's strategy with a clear understanding of the integration goals.

Our main proposal for further research is to increase the number of

cases of pharma companies that use AI in their business. Even a survey of different representatives of one company's management may allow you to look differently at the studied phenomenon and supplement the collected information. Additionally, comparing the existing experience of other industries and the influence of AI on the business processes of these companies could give a new impetus to the development of the theory. Moreover, such a comparison will help developer and integrator AI companies to consider the new pharmaceutical market as promising, assess their opportunities to increase their business, and change their business model.

9. Conclusion

In recent decades, new technologies have contributed to progress in various areas of life. AI has attracted increased attention from business and society. The pharmaceutical industry is one area where the search for new solutions is associated with significant and very risky investments. Changes in pharmaceutical business processes under the influence of AI play an important role, but it has not been sufficiently studied before. Our research of fifteen pharmaceutical companies allowed us to analyze what kinds of business processes are affected by AI and how. We found that, depending on their size, companies transform the key and support business processes in different ways. Small companies are more focused on using AI to change their approach to R&D and in relation to its business processes. Large companies are changing their business processes associated with marketing, sales, and manufacturing. In turn, medium-sized companies are forced to change their business processes depending on their specialization. At the same time, there are a lack of successful AI integrations in the pharmaceutical industry. Moreover, some of the successfully implemented projects are executed in specific areas and are not well known in the market.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.techsoc.2021.101629.

Credit author statement

Ignat Kulkov: Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Supervision, Project administration

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