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IMPACT OF INDUSTRY 4.0 TECHNOLOGIES ON BUSINESS PERFORMANCE IN THE PHARMACEUTICAL SECTOR OF PAKISTAN

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ABSTRACT

This study examines the impact of industry 4.0 technologies, including Big Data, Cyber-physical systems (CPS), Internet of Things (IoT), and Interoperability on business performance (BP). Primary quantitative data were collected via a structured questionnaire from pharmaceutical firms in Islamabad, Karachi, and Peshawar to assess the adoption and utilization of these technologies on BP. In order to analyze the collected data, Smart PLS was used to examine the relationships between industry 4.0 technologies and BP measures. Based on the analysis, these technologies significantly influence various aspects of business performance, including innovation, productivity and profitability, except BDA has an insignificant impact on profitability and productivity. In addition, the IOT has no impact on innovation, productivity and profitability. This study provides a significant insight for the pharmaceutical sector concerning the industry 4.0 technologies to enhance BP. The findings of this study can be used by the industry stakeholders and pharmaceutical firms to integrate the industry 4.0 technologies in various functions of human resource management, process optimization and strategic *planning to maximize the benefits. In an increasingly digitalized landscape, industry 4.0 technologies adoption can help organizations position themselves in the market for sustained growth and resilience.*

Keywords: *Digital Transformation, Business Performance, Industry 4.0, Cyber-Physical Systems, Internet of Things (IoT), Big Data Analytics.*

INTRODUCTION

Digital technologies are changing organizational dynamics and processes in developed and developing countries. Pakistan is also being affected by these digital technologies. Organizations are moving to opt the technological approach to embrace industry 4.0 advancements such as inclusion of big data analytics (Wamba et al., 2017), cyber-physical systems (Lee et al., 2015), the Internet of Things (IoT) (Zhong et al., 2017), and interoperability (Brettel et al., 2014) in various organizational operations. Thus, digital technologies have revolutionized processes and practices (Westerman et al., 2014). Consequently, digital technology integration in various organizational operations and practices might improve efficiency. For instance, cyber-physical systems (CPS) improve manufacturing processes (Lee et al., 2015), whereas IoT devices monitor and improve the quality outcomes (Li et al., 2020). In addition, interoperability enables the seamless data exchange across the value chain and procedures (Brettel et al., 2014).

IoT can help organizations streamline business processes and ensure that safety and regulatory standards will meet the business and customer needs by responding in real time to fulfill all the requirements (Li et al., 2020; Sareen et al., 2021). On the other side, interoperability seamlessly enables communication among various departments in the pharmaceutical sector to improve the research and development process, manufacturing operations, and marketing to facilitate decision making process. This can be achieved through enhancing collaboration between internal and external partners, as a result, visibility and regulatory compliance can be improved while reducing inventory costs and ensuring quality outcomes (Sareen et al., 2021).

Despite the importance of industry 4.0 technologies for organizations, limited studies exist related to industry 4.0 technologies' impact on business performance indicators, including profitability, productivity, and innovation (Gunasekaran et al., 2017; Schwab, 2017). The implementation and use of Industry 4.0 technologies, such as BDA, CPS, IoT, and interoperability, present unique challenges and opportunities for pharmaceutical companies. However, challenges for the pharmaceutical industry of Pakistan are rising as the landscape becomes more complex with the introduction of new technologies, and demand is increasing. In this scenario, technologies provide a beacon of hope to the industry on many fronts in managing supply chain, human resources, product development, and service delivery. It enables greater efficiency and more innovation within the value chain. Hence, in what way do these digital innovations affect key performance indicators and operational outcomes in Pakistan's pharmaceutical industry?

This indicates a significant knowledge gap regarding industry 4.0 technologies' impact on business performance within the Pakistani context. Therefore, the research objectives of this study assess the impact of industry 4.0 technologies (BDA, CPS, IoT, and interoperability) on key performance indicators, such as productivity, profitability, and innovation, in the Pakistani pharmaceutical sector.

LITERATURE REVIEW

Big Data Analytics Adoption

Big data analytics (BDA) refers to managing and examining large amounts of data. This helps to recognize patterns, relationships, and valuable insights to make informed decisions (Gandomi & Haider, 2015). Thus, digital transformation is reshaping all the major sectors, including pharmaceutical organizations. Digital transformation helps drive efficient operations by managing data across various operations in the pharmaceutical value chain. This aids in monitoring the process in real time to ensure compliance with standards for innovative product development. This will help organizations harness and analyze the data (structured and unstructured) collected from the internal and external stakeholders in order to offer products and services in line with end users' needs. This helps organizations to seize opportunities to optimize pharmaceutical operations from assessment to discovery, development, as well as clinical trials and marketing to meet the organizational goals and customer needs (Wamba et al., 2017). Therefore, BDA can transform the organizational process by examining the data to observe market trends and patterns to forecast the risks and opportunities in the market related to new technologies, products, and competitors. Likewise, it seems to be a strategic approach to be innovative by integrating the data analytics and algorithms and IoT to deliberate and analyze data to forecast utilizing the ample amount of data (Wortmann & Flüchter, 2015). Moreover, organizations must invest to protect the data from potential coercions on the other side for better business performance outcomes (Zhang et al., 2016).

IoT Utilization

The Internet of Things (IoT) comprises of organized devices entrenched with software as well as sensors, actuators, and connectivity (Xu et al., 2014). IoT has become a transformative force across various industries, including pharmaceuticals, to communicate seamlessly between objects, which in turn leads to optimizing processes, enhancing efficiency, and improving decision making (Li et al., 2020). Therefore, IoT implementation in the pharmaceutical sector can help manufacturing, supply chain, and drug development processes by effectively exchanging data. For instance, according to Sareen et al. (2021), in the development of drugs and drug manufacturing, IoT sensors can monitor and control the environmental influences during the procurement of material and production to ensure the quality product is produced complying with the regulatory standards. Additionally, Ding et al. (2020) elaborated that IoT-enabled devices in the pharmaceutical sector can help to monitor the products from the beginning till the end throughout the supply chain to mitigate risk related to counterfeiting by ensuring the timely delivery of drugs to the end users (Li et al., 2020).

Cyber-Physical Systems

Physical systems integration represents a new paradigm in the field of engineering and technology, and it is shifting the organizational processes by enabling the real-time monitoring and mitigation of risk that falls under the category of Cyber-Physical Systems (CPS) (Lee, 2008). Furthermore, Rajkumar et al. (2010) explained that CPS bridges the gap between computation and communication, machines and processes implemented in engineered systems. However, the integration of these components in an engineered system is facilitated through a network of actuators, sensors, and embedded systems to process the real time data in order to mitigate risk and make adjustments in the system to make informed decisions within the organization (Baheti & Gill, 2011). Thus, CPS can transform and revolutionize numerous operations, from the manufacturing of drugs to quality control and supply chain management (Lasi et al., 2014). Accordingly, CPS monitors and controls critical parameters to comply with the regulatory standards in the manufacturing process (Singh et al., 2019), yet also reduces the risk of counterfeiting and ensures the integrity of medicines (Ding et al., 2020) as well as collect and analyze patient data to facilitate personalized treatment plans leading to improve patient outcomes and hence the organizational performance (Lee & Seshia, 2016). The implementation of CPS in pharmaceutical organizations needs an inclusive way by having technological infrastructure, a data integration system, and an intact change management process for improved efficiency (Brettel et al., 2014). So, organizations are now investing in a robust system for developing CPS infrastructure by developing data analytics capabilities to foster the innovative culture and productivity by leveraging transformative technology (Hermann et al., 2016).

Interoperability

Among the major components of digital transformation, interoperability is a vital aspect. It includes the ability of various systems, devices, or applications to acquire, exchange, and communicate data without any interruption (IEEE, 2004). Interoperability ensures the efficient flow of information for collaboration and communication among key stakeholders to make informed decisions (Brettel et al., 2014). According to Sareen et al. (2021), interoperability fosters transparency and reduces error, improving business outcomes such as productivity in operational, business and supply chain contexts. In addition, the inclusion of various dimensions of interoperability in organizational operations can improve the business performance, including technical (the ability to exchange data), semantic (interpret the meaning of data), and organizational (to collaborate effectively among stakeholders) (HIMSS, 2020). However, it requires standardized data, protocols, and a robust governance framework within the organization for efficient implementation (Eichelberg et al., 2019).

Digital Transformation, Productivity, Profitability and Innovation

Concerning business performance (BP), productivity, profitability and innovation are among the most vital indicators. Accordingly, productivity refers to the output produced per employee over a fixed period as per the plan (Syverson, 2011). Productivity seems to be a critical indicator and a fundamental driver considered for BP. In the Pharmaceutical setup, productivity can be measured in various ways, such as drug development speedily to cater to customers' needs, improved output, quality, and customer service. In the realm of technological transformation, acquiring and leveraging technology can amplify the innovation process for process optimization to attain the maximum output using minimum resources (OECD, 2015). Industry 4.0 technologies emerge as a potential way to improve productivity, profitability and innovation in all sectors, including pharmaceutical. For instance, BDA allows organizations to gain insights from the data to make informed decisions in order to streamline the processes leading to improved productivity and performance (Wamba et al., 2017). On the other side, IoT helps to monitor and control the manufacturing process in real time. It enables predictive maintenance as well as lessens the downtime, which in turn optimizes the production efficiency and profitability (Wortmann & Flüchter, 2015), while automation of process can add value to the performed activities, further boosting productivity by inclusion of innovative products (Frey & Osborne, 2017).

Furthermore, profitability refers to the profit margin or return on investment and is seen as a crucial indicator in determining the business performance (Titman & Martin, 2011). According to Ross et al. (2013), profitability is a comprehensive view of a firm's ability to produce profits that surpass its expenses, which shows efficiency in cost management. An organization's main focus is to achieve the profitability goal. This endeavour is influenced by numerous factors such as market dynamics, regulatory environment, innovation and operational efficiency (Kaplan & Norton, 1992). Therefore, digital transformation like BDA, IoT, CPS and Interoperability has presented new opportunities, which in turn enhances profitability and innovation (Gunasekaran et al., 2017; Westerman et al., 2014).

In addition, another indicator of BP includes innovation which encompasses the creation and development of ideas, products and services of a unique nature to gain a competitive edge over others (Pisano, 2015). Innovation in the pharmaceutical sector offers opportunities to develop new drugs, streamline clinical trials, and personalize medicine utilizing BDA (Wamba et al., 2017) and digital technologies (Harrer et al., 2019), leading to transform the process and result in better outcomes such as profitability and productivity (Goyanes et al., 2019). However, limited research exists in this regard. Thus, to fill this gap, following hypotheses were framed. Figure 1 shows the research framework.

H1a: BDA significantly influences Productivity.
H1b: BDA significantly influences Profitability.
H1c: BDA significantly influences Innovation.

H2a: CPS significantly influences Productivity.
H2b: CPS significantly influences Profitability.
H2c: CPS significantly influences Innovation.
H3a: IoT significantly influences Productivity.
H3b: IoT significantly influences Profitability.
H3c: IoT significantly influences Innovation.
H4a: Interoperability significantly influences Productivity.
H4b: Interoperability significantly influences Profitability.
H4c: Interoperability significantly influences innovation.

RESEARCH FRAMEWORK

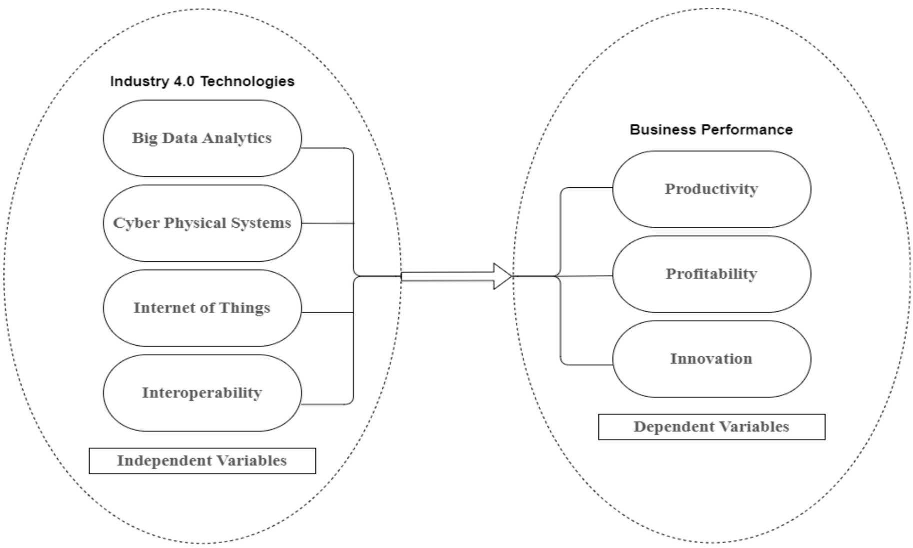

Figure 1: Research Framework

METHODOLOGY

A quantitative research approach was used to examine the influence of industry 4.0 technologies on business performance in the pharmaceutical sector in Pakistan across Karachi, Islamabad, and Peshawar. This includes individuals involved in operations, supply chain, manufacturing, quality assurance, research and development (R&D), and other key departments where digital transformation initiatives are likely to be implemented. A structured questionnaire was used for data collection. The causal element of the research design aims to uncover potential cause-and-effect relationships between industry 4.0 technologies and business performance. A total of 500 employees were disseminated, however, 320 responses were received. After assessment, only 309 responses were appropriate, which have been utilized to generate the results. Smart PLS was used for analysis.

DATA ANALYSIS AND RESULTS

Table 1 shows the demographic details of the respondents.

Table 1: Demographics

Demographics		Frequencies	Percentages %
Gender	Male	170	55.01%
	Female	139	44.98%
Age	Less than 30 years	124	40.12%
	30 to 45 years	98	31.71%
	More than 45 years	87	28.15%
Education	Undergraduate	105	33.98%
	Graduate	95	30.74%
	Postgraduate	109	35.27%
Annual Income	Less than 500,000	134	43.36%
	500,000 to 1,000,000	102	33.01%
	More than 1,000,000	73	23.62%
Position	Junior Staff	109	35.27%
	Mid-Level Management	123	39.80%
	Senior Management	77	24.91%
Department	Operations	34	11.00%
	Supply Chain	130	42.07%
	R&D	48	15.53%
	Quality Assurance	14	4.53%
	Other	83	26.86%
Size of Company	Small: <50 employees	130	42.07%
	Medium: 50-250	126	40.77%
	Large: >250	53	17.15%
Experience	0-5	165	53.39%
	6-10	134	43.36%
	11-15	9	2.91%
	16+	1	0.32%

RELIABILITY AND VALIDITY

Following table presents the reliability and validity analysis for scales used in the study.

Table 2: Reliability and Validity

Construct	Cronbach Alpha	Composite Reliability	Indicator	Outer loadings
BDA	0.857	0.857	BDA-1	0.886
			BDA-2	0.892
			BDA-3	0.867
IOT	0.884	0.885	IOT-1	0.889
			IOT-2	0.925
			IOT-3	0.889
CPS	0.797	0.801	CPS-1	0.833
			CPS-2	0.848
			CPS-3	0.846
INT	0.890	0.890	INT-1	0.920
			INT-2	0.917
			INT-3	0.880
IN	0.734	0.773	IN-1	0.649
			IN-2	0.889
			IN-3	0.875
P	0.731	0.781	P-1	0.886
			P-2	0.865
			P-3	0.653
PR	0.825	0.857	PR-1	0.819
			PR-2	0..71
			PR-3	0.883

As per table 2, there is no issue of reliability and validity. All scales have Cronbach's Alpha values above 0.80, which is well above the acceptable threshold of 0.70, confirming that the questionnaire is reliable and valid as the scales are consistent in measuring the constructs they are intended to measure.

DISCRIMINANT VALIDITY

Discriminant validity was assessed using Fornell-Larcker criterion. As per the criterion, the square root of the Average Variance Extracted (AVE) for each construct should surpass the highest correlation with any other construct in the model. The table below summarizes the Fornell-Larcker criterion results.

Table 3: Discriminant Validity

	BDA	CPS	IN	INT	IOT	P	PR
BDA	0.882	-	-	-	-	-	-
CPS	0.523	0.901	-	-	-	-	-
IN	0.615	0.687	0.843	-	-	-	-
INT	0.588	0.595	0.787	0.906	-	-	-
IOT	0.669	0.797	0.683	0.627	0.812	-	-
P	0.513	0.626	0.825	0.695	0.630	0.808	-
PR	0.401	0.462	0.565	0.516	0.402	0.636	0.859

Another method to assess discriminant validity is through cross-loadings. Each item should load highest on its corresponding construct compared to other constructs. The table below presents the cross-loadings for all items.

Table 4: Cross Loadings

	BDA	CPS	IN	INT	IOT	P	PR
BDA-1	**0.886**	0.466	0.560	0.518	0.569	0.456	0.378
BDA-2	**0.892**	0.476	0.537	0.501	0.583	0.424	0.372
BDA-3	**0.867**	0.441	0.530	0.536	0.620	0.478	0.308
CPS-1	0.479	**0.889**	0.590	0.556	0.768	0.569	0.376
CPS-2	0.484	**0.925**	0.614	0.518	0.744	0.576	0.454
CPS-3	0.451	**0.889**	0.653	0.536	0.645	0.548	0.417
IN-1	0.570	0.540	**0.833**	0.794	0.560	0.613	0.448
IN-2	0.480	0.622	**0.848**	0.611	0.584	0.722	0.477
IN-3	0.496	0.580	**0.846**	0.560	0.584	0.767	0.509
INT-1	0.529	0.547	0.690	**0.920**	0.581	0.645	0.446
INT-2	0.505	0.517	0.697	**0.917**	0.525	0.639	0.468
INT-3	0.562	0.551	0.751	**0.880**	0.596	0.604	0.487
IOT-1	0.706	0.381	0.420	0.437	**0.649**	0.399	0.248
IOT-2	0.509	0.683	0.605	0.554	**0.889**	0.564	0.329
IOT-3	0.482	0.815	0.615	0.530	**0.875**	0.555	0.387
P-1	0.455	0.612	0.758	0.666	0.567	**0.886**	0.480
P-2	0.428	0.508	0.700	0.575	0.569	**0.865**	0.427
P-3	0.358	0.363	0.516	0.408	0.365	**0.653**	0.726
PR-1	0.296	0.306	0.402	0.339	0.278	0.490	**0.819**
PR-2	0.405	0.471	0.557	0.532	0.407	0.570	**0.871**
PR-3	0.310	0.381	0.468	0.420	0.325	0.568	**0.883**

COLLINEARITY STATISTICS (VIF)

Table 5 shows the collinearity statistics. The collinearity statistics (VIF) reveal that all constructs exhibit acceptable levels, as all VIF values are below the critical threshold of 5, which indicates no collinearity issue.

Table 5: VIF

CONSTRUCT		VIF
BDA	BDA-1	2.166
	BDA-2	2.317
	BDA-3	2.002
CPS	CPS-1	2.464
	CPS-2	3.066
	CPS-3	2.323
IN	IN-1	1.507
	IN-2	1.858
	IN-3	1.897
INT	INT-1	3.218
	INT-2	3.138
	INT-3	2.130
IOT	IOT-1	1.200
	IOT-2	2.057
	IOT-3	1.962
P	P-1	1.827
	P-2	1.827
	P-3	1.217
PR	PR-1	1.966
	PR-2	1.674
	PR-3	2.295

PATH ANALYSIS

As per the results, all the proposed hypotheses were accepted as P value is less than 0.05, as mentioned in table 6, except the link between BDA, P and PR along with IOT with IN, P and PR as the P value is greater than 0.05

Table 6: Hypotheses Testing

	Original sample	Sample mean	Standard deviation	T statistics	P values
BDA -> IN	0.135	0.135	0.048	2.820	0.005
BDA -> P	0.033	0.034	0.061	0.539	0.590
BDA -> PR	0.138	0.138	0.072	1.926	0.054
CPS -> IN	0.262	0.264	0.065	4.039	0.000
CPS -> P	0.223	0.223	0.074	3.003	0.003
CPS -> PR	0.301	0.297	0.091	3.328	0.001
INT -> IN	0.513	0.513	0.048	10.741	0.000
INT -> P	0.450	0.448	0.055	8.188	0.000
INT -> PR	0.350	0.349	0.068	5.113	0.000
IOT -> IN	0.062	0.061	0.080	0.771	0.441
IOT -> P	0.149	0.150	0.081	1.834	0.067
IOT -> PR	-0.150	-0.144	0.100	1.502	0.133

DISCUSSION AND CONCLUSION

In this study, we delve to examine the impact that industry 4.0 technologies have on business performance within the pharmaceutical sector of Pakistan. Through empirical evidence in this research, we unravel that industry 4.0 digital technologies stimulate and nurture a culture of innovation within pharmaceutical enterprises (Pisano, 2015). As per the results, BDA significantly affects innovation and has no impact on productivity and profitability. On the other side, CPS and interpretability significantly affect innovation, productivity and profitability. However, IoT has an insignificant influence on innovation, productivity and profitability.

This indicates that leveraging these industries 4.0 technologies can help in transforming the pharmaceutical sector's business performance indicators to achieve operational efficiency and strategic agility to navigate complex market dynamics with resilience and adaptability to innovate (Frey & Osborne, 2017) and improves profitability and productivity within the pharmaceutical sector in an increasingly digitalized landscape (Titman & Martin, 2011).

It is concluded that digital (industry 4.0) technologies significantly affect the business performance indicators in the Pakistani pharmaceutical sector. Through analysis, it has become evident that these technological advancements significantly contribute to fostering innovation and enhancing productivity and profitability. In order to harness the digital transformation benefits, pharmaceutical companies must adopt a comprehensive and integrated approach for technological adoption by taking strategic initiatives through fostering collaboration to nurture talent. It is possible through continuous learning and development programs and perpetually striving for operational excellence, sustained growth, competitiveness, and resilience in the evolving digital technologies.

RECOMMENDATIONS AND LIMITATIONS

In light of this research, pharmaceutical organizations must recognize that the journey toward digital transformation is not a singular event but an ongoing process of adaptation and evolution. Managers must foster a culture of innovation and agility to facilitate the continual exploration and integration of emerging digital technologies within the organizational processes. Furthermore, managers must foster a collaborative environment to interact with external stakeholders to become innovative and more competitive by utilizing information and data. It is possible when a supportive ecosystem is built, which helps in digital transformation.

Additionally, it is imperative to build infrastructure that supports the integration of digital technologies. Ultimately, implementing digital transformation is seen as a strategic move to be proactive in adopting a holistic approach to innovation. In this way, pharmaceutical companies can position themselves as leaders in the digital era, driving positive outcomes for their businesses, leading to a better healthcare ecosystem and society for a more sustainable future.

This research is limited to pharmaceutical companies in Pakistan. Future researchers may conduct this study in other service sectors to broaden the scope of industry 4.0 digital technologies studies. Moreover, this research is limited to examining the role of BDA, IoT, CPS and interoperability on business performance indicators. Future researchers may study the role of artificial intelligence (AI) in optimizing business performance indicators.

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