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Use of information technology in India's pharmaceutical industry

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Abstract

The purpose of this paper is to understand the role of information technology (IT) in pharmaceutical industry in India and its influence on cost, productivity, compliance and quality of the pharmaceutical products. A questionnaire was developed containing 22 items, which was sent to 400+ pharma professionals working in different functions of 45 different organizations. A total of 111 responses which represented different organizations including manufacturers of sterile drug products, non-sterile drug products, active pharmaceutical ingredients and combinations of these type of products were received and analysed. For ANOVA analysis, respondents were divided into two groups. Based on the IT spending as a percentage of the total budget, the first group included the respondents who confirmed that their organization spent less than 4% of the total annual budget; while the second group included the respondents who confirmed that their organization spent more than 4% of the total annual budget. A significant p-value suggests that there is a statistical difference in Productivity / Cost and Quality / Compliance depending on the IT investments by the firms. Information technology has significant role in the pharmaceutical industry by improving compliance, data integrity and reliability, and overall product quality. Implementation of IT solutions has given immense confidence to the regulators auditing the manufacturing site. This paper contributes to the available knowledge about the pharma industry with specific reference to the Indian pharmaceutical industry. This study also helps to unravel the impact of IT adoption on pharmaceutical organizations' performance parameters.

Keywords: information technology, data integrity, dashboard, compliance, software, pharmaceutical industry, India

1. Introduction

Changes are unpredictable and inevitable in this competitive business environment. Success and growth of any industry / organization including the pharmaceutical industry depend on its rapid acceptability to the

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changing business environment. Many successful organizations have automated their business processes, systems by accepting these changes to capture the information and using it to their advantage.

The pharmaceutical industry is a highly knowledge-based and regulated industry and it involves generation of multiple documents / records at all the stages of manufacturing, packaging, testing and distribution of the drug product. In India specifically, some 20 years back the requirement of documentation was not as stringent as it is today, and therefore, manual documentation work was sufficient to meet expectations of management and regulators. Expectations of different stakeholders are very high nowadays. Hence it has become very complex and difficult to create, execute, archive and retain the manual paper work. Thus the role of information technology has become vital in the pharmaceutical industry.

In order to investigate how the pharmaceutical industry uses and incorporates information technology in their day to day operations of managing the business, authors have developed a questionnaire based on a review of literature, interaction with relevant industry professionals with the objectives of understanding Indian organizations' investment in information technology, and to understand the impact of IT solutions on various performance parameters like productivity, cost, quality, compliance. Pharma professionals working in different organizations including manufacturing sterile drug products, non-sterile drug products, active pharmaceutical ingredients and combinations of these type of products were requested to fill out the questionnaire.

1.1 Overview of the Indian pharma industry

India is among the top five emerging markets globally for pharmaceutical drug products and manufacturers from India are producing drug products / drug substances to supply throughout the world. The Indian pharmaceutical industry is highly fragmented with 24,000 manufacturers. The Indian pharma industry accounts for about 1.4% of the world's pharma industry by value and 10% by volume. The Indian pharma industry has been growing at a compounded annual growth rate (CAGR) of more than 15% over the last five years and has significant growth opportunities. The pharmaceutical industry in India ranks the third in the world in terms of volume and the 14th in terms of value. India's cost of production is nearly 33 percent lower than that of the US. Besides, India has the second largest number of USFDA-approved manufacturing plants outside the US. India has 2,633 FDA-approved drug products, and has over 546 USFDA-approved company sites, the highest number outside the US.

The Indian pharmaceutical industry has contributed immensely to not only domestic but also global healthcare outcomes and continues to play a material role in manufacturing various critical, high quality and low-cost medicines for Indian and global markets. It supplies 50 to 60 percent of the global demand for many vaccines including anti-retroviral (ARV), 40 percent of generics consumed in the US and 25 percent of all the medicines dispensed in the UK. Over the last 5 years, 35 to 38 percent of total ANDAs(Abbreviated New Drug Applications) approved (including 25 to 30 percent of total injectable ANDAs) have been filed from Indian sites. Affordable ARV drugs from India were a major factor in AIDS patients getting better access to treatment. India supplies 30 percent of the annual United Nations International Children's Emergency Fund (UNICEF) requirement.

2. Role of information technology in the pharmaceutical industry

Information Technology (IT) has become an important facilitator for improving the dynamic capabilities of an organization. IT includes the management information systems (Computer, hardware, software,

networks) used to automate and support business tasks and decision making in the organization. Pharmaceutical manufacturers need to implement a comprehensive IT infrastructure to ensure regulatory compliant operations, integrity of data and the quality, safety and efficacy of drug products. Manufacturers need to invest time, resources and effort to build and maintain suitable IT systems. IT tools and software solutions has following roles to play in the pharmaceutical industry:

2.1 Dashboard - information to the management

Real-time information systems are essential for the management of any organization as they allow the continuous and quick display of the data. It is vital that any data generated in the organization should be reviewed and analysed from a business point of view. The gathered data can then be used to create a meaningful dashboard, which in turn can drive effective decision-making. Performance dashboards can be related to quantity, quality or financial details and these management indicators are immediately understood by readers. To make right and meaningful decisions, it is important that information is reliable, up-to-date, complete, and pertinent. Software solutions can create a specific dashboard for each manufacturing site that can support management when making decisions related to product planning, product quality and adverse events. A few such relevant indicators which a dashboard consists of, are listed below:

- Rejection rate
- Deviation rate
- Customer complaint rate
- Confirmed Out of Specification (OOS) rate
- CAPA (corrective and preventive action) effectiveness rate
- Overall equipment effectiveness (OEE)

It is a typical regulatory requirement for the pharmaceutical industry to conduct annual product quality reviews for each product in order to identify underlying trends. Implementation of IT software has ensured that trends of all critical process parameters can be reviewed online and correction can be made in the process during the year as a part of continuous process verification.

2.2 Ease of work

Software solutions have replaced the cumbersome manual work in most industries including pharmaceuticals. Any pharmaceutical company performs various activities, right from the receipt of raw materials to dispatch of the finished products. Being a highly regulated industry, all activities need to be documented and retained during the extended shelf life of the respective product batch, or during the period specified in the organization's data policy.

Manual documentation has following disadvantages.

- Manual & labour intensive work
- Potential of data integrity issues, if real-time recording is not performed
- Possibility of human error while recording e.g. transcription error, calculation error, typo error etc.
- Huge space needed to store documents during the retention period specified in the organization's policy
- Difficult to analyse and review all the information together
- Missing GMP (good manufaturing practices) document may lead to a product recall from the market

Software solutions have made the work easy by overcoming all above listed shortcomings and now the data is available at the click of a button on individual's computer system. Thus it has improved the work efficiency, integrity & reliability of the data, speed of the work and accessibility of the data to the users, decision makers, management and regulators.

2.3 Integrity and reliability of data / records

Integrity of the data generated by any pharmaceutical organization is of fundamental importance to the quality system. Decisions on product quality and final release of the drug product batches are made based on the accuracy of the data. With the introduction of IT software solutions, maintaining the integrity of the generated electronic data is challenging; hence pharmaceutical quality system should integrate the right data governance system as required by regulatory authorities. The efforts and resources allocated to the data governance should be proportionate with the risk related to product quality and patient safety. Pharmaceutical manufacturers and analytical laboratories should design IT systems which provide an acceptable state of control based on the data integrity risk, and should be fully validated with supporting documents.

The United States Food and Drug Administration (USFDA) and the European Medicines Agency (EMA), the regulators of the pharmaceutical industry of the USA and Europe respectively, uncovered serious cases of data integrity breaches during the inspection of multiple pharmaceutical organizations in recent years; which calls for increased emphasis on data integrity. Data integrity breaches have resulted into warning letters (warning issued by the USFDA if serious non-compliances are observed), import alerts (prohibition from exporting products to the US market) and financial penalties to the organization. Individual involvement in wrong doings can result into debarment and imprisonment. Compliance excellence makes good business sense and it is always better to proactively prevent data integrity issues, than trying to resolve issues after their occurrence. It has also been observed in some cases by the investigators that data is being manipulated to achieve the desired results of drug product batches. This is possible because IT solutions lacked well designed controls and review systems were poor in detecting such frauds.

2.4 Compliance to regulations

Data integrity is critical to regulatory compliance. Most of the regulatory authorities have published guidance, spelling out the requirements with respect to computerised systems as mentioned in Table 1.

Table 1. Regulatory requirements for computerised systems in pharma

Name of the agency	Title of the guidance	Scope and application
USFDA	21 CFR Part 11	Applies to records in electronic form that are created, modified, maintained, archived, retrieved, or transmitted under any records requirements set forth in Agency regulations
European Medicines Agency (EMA)	The Good Manufacturing Practices (GMP), Annex 11: Computerised systems	Applies to all forms of computerised systems used as part of a GMP regulated activities

A computerised system is a set of software and hardware components which together helps in making GMP decisions in pharmaceutical firms. Thus, it is essential that any software application used for GMP activities shall be validated and IT infrastructure shall be qualified. These computerised systems have

replaced manual operation, hence there should be no resultant decrease in data integrity, product quality, and process control. There should be no increase in the overall risk related to product quality and patient safety.

Both the USFDA and the EMA use the acronym ALCOA to define its expectations of electronic data as follows :

Attributable	: Who acquired the data or performed an action and when
Legible	: Data can be easily read
Contemporaneous	: Documented at the time of activity
Original	: Written printout or observation or a certified copy thereof
Accurate	: No errors or editing without documented amendments

The regulatory guidance provides clear requirements for effective implementation, control and use of computer systems in GMP-regulated activities. The scope of this guidelines is to regulate software used in the production (e.g. programmable logic controller (PLC) is manufacturing equipment) and implementation of devices in the quality control system (e.g. software that records and maintains the device history record). Methods for record keeping and storage by computer systems must give the same degree of confidence as that provided by paper based systems.

The basic EMA requirement on data integrity originates from the European Union (EU) council directives 2003/94/EC and 91/412/EEC. "The electronically stored data shall be protected, by methods such as duplication or back-up and transfer to another storage system, against loss or damage of data, and audit trails shall be maintained". In addition, the definition of data integrity that the FDA uses for internal training is: "Data are of high quality if they are fit for their intended uses in operations, decision-making and planning. As data volume increases, the question of internal consistency within data becomes paramount". Thus, any IT solution used in the pharmaceutical industry has to be necessarily validated before it is put to use.

2.5 Planning and operations management

IT helps immensely in planning and operations management to falicitate tracking and tracing the products throughout the supply chain, planning and scheduling, supply chain management, barcode labelling for products. Each of these will be discussed below.

2.5.1 Track and trace

Track and Trace (T&T) is defined as the capability to track products throughout the supply chain. The T&T system records information that allows verification of history, location or application. T & T solutions, mainly RFID based, are increasingly used in the pharmaceutical space. T&T has the capability to determine present and past locations of products throughout the supply chain. In today's competitive business environment, T&T has become a necessity and a key differentiator in many industries. Following are the advantages of the implementation of T&T:

- Enhanced pilferage reduction
- Counterfeit prevention and targeted recalls
- Improves supply chain efficiency
- Synchronization
- Product Visibility
- Improved security

The pharmaceutical industry is strongly affected by the counterfeiting of medicines, hence it is very interested in traceability system implementation. Their positive impact on the pharmaceutical supply chain and, in particular, the efficiency of serialization systems has been strengthened by Turkey's experience in the field, which has inspired the most recent regulations in this area. Serialization technology was first introduced by Turkey to combat counterfeiting and reduce fraud. The initiative proved to be a great success. Turkish social security services reimburse pharmacies, through the Ministry of Health for selling drugs. Originally, the number of product units sold was determined by collecting sold carton flaps cut by pharmacists, which was a quite fraud-prone system. After introduction of the T&T system, the supply chain history of any single product unit could be tracked through a governmental repository, and serial numbers could avoid invalid reimbursement. After T&T system implementation, the pharmacist has to share the exact serial numbers of the units sold with the Ministry of Health for the issuance of reimbursement. The government has total control of the medicine quantity that is present in the market and is actually sold to patients, thus cases of fraud have been significantly reduced. This is an example of how serialization is able to improve private companies' competitive advantage, and also contribute to drug safety, security and people's quality of life. Thus, T&T system provides the ideal solution to enhance the efficiency of the supply chain, to reduce theft, to identify counterfeit products and to ensure manufacturers, distributors, retailers, pharmacies and end-users' compliance with the regulatory requirements.

Pfizer's Viagra bottle RFID track & trace solution in the USA is a good example of a well-functioning RFID track & trace solution. Counterfeit drugs are a major problem estimated to cost between 7-10% of global pharmaceutical market revenue. Pharmaceutical companies are not only facing price competition, but they are also seeing counterfeits of their brand products. Counterfeiting is a serious problem for the pharmaceutical brands as it results in direct loss of revenue and indirect loss of brand equity when patients are adversely affected by counterfeit drugs. The challenge of counterfeit drugs must be addressed to ensure future revenue streams, but the solution is likely to need government support to be effectively implemented.

The pharmaceutical industry operates on a global scale, and regulatory compliance across multiple geographies is fundamental to ensure that supply chains remain transparent and safe.

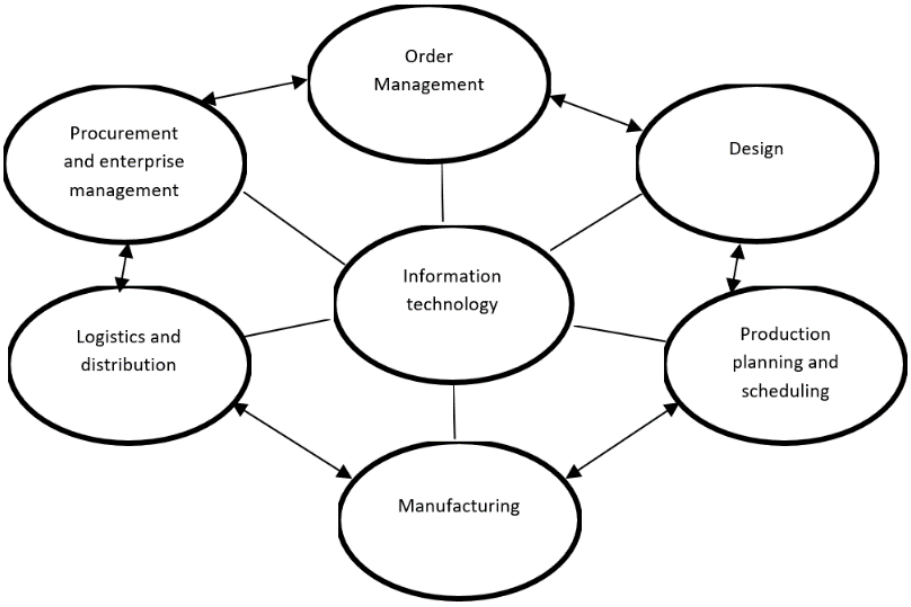
T&T technologies are playing a key role in ensuring the safety of drug distribution networks, in guaranteeing product quality and in managing expiry recalls. T&T systems allow all stakeholders to locate where the product is at any given time and also to see the record of where it had been previously. This is the outcome of assigning a unique identity key to each stock unit during the manufacturing process which then remains with it through the supply chain until its consumption. T&T systems assign unique identification numbers to products. Products that lack identification numbers, or products with unregistered identification numbers, must be treated as counterfeit goods and removed from the market. The unique identifier may be stored in a barcode, electronic product code, radio frequency chip or it may be a long-digit serial number. A reduction in medication errors, automated pharmacy billing, effective control of inventory, effectiveness in product recalls, detection of theft and product diversion are among the advantages offered by the track and trace system. In India, tracking and tracing is implemented only for exported drugs. Based on the benefits of T&T system described above, it is highly recommended that this system be included in the provisions of India's 'Drugs & Cosmetics Act' for incorporating security measures in packaging of pharmaceuticals.

2.5.2 Planning and Scheduling

Any organizations must consistently pursue the five R's, i.e. produce the right product, with the right quality, in the right quantity, at the right price, and at the right time. Correct and timely information is vital for proper planning and scheduling. To meet the requirements as illustrated by the 5 R's, information

technology solutions like database management systems, enterprise resource planning systems, quality management systems and document management systems have become necessary to most pharmaceutical firms (Figure 1).

Figure 1. Role of information technology in the pharmaceutical industry



Proper utilization of resources (material, man and machine etc.) is very important for a successful organization in this competitive era. To stay ahead of the competition, the manufacturer has to deliver quality at a reasonable price. Overhead cost can be reduced by utilising the resources optimally. Monitoring the operating efficiency of manufacturing equipment using software can help to improve the machine's utilization and thus productivity and to reduce overhead cost.

2.5.3 Supply chain management

Nowadays, companies no longer just compete directly with other companies. Rather, their whole supply chains compete with each other. It is equally true in the pharmaceutical industry. A well-managed supply chain offers an additional opportunity to cut operating costs. Therefore, the practice of supply chain management has gained greater importance in recent years in order to develop competitive strategies and ensure the success of organization. Most of pharmaceutical organizations have a separate supply chain management department, which is responsible for production planning, procurement of input material (both raw and packaging materials), timely distribution of drug products, monitoring any shortage of products and determining priorities in order to ensure uninterrupted supply and avoid any penalties associated with late supplies to the customer. Proper planning can also save freight cost, for example if the product is sent through waterways instead of air for export orders. Right information technology tools would strengthen the supply

chain management by integration of various activities, like the billing of input materials, production planning, logistics planning and distribution of products.

2.5.4 Barcoding and scanners

It is essential for a pharmaceutical company to label each incoming material after receiving it in the warehouse. Incoming raw materials hold an "Under Test" label until the quality control laboratory approves or rejects them. If a material meets the specification, "Approved" label is affixed and if it does not meet the specification, "Rejected" label is affixed. These materials are subject to regular retesting, hence again labelling will be done accordingly. Affixing these labels manually, besides being labour intensive, may result in error. With the help of IT solutions, bar code labels are generated which not only reveals the material details (name, code, mfg. date / expiry date etc.) but also the material status (under test, approved or rejected). Because the occurance of manual errors is ruled out, this technology assures the quality of the final drug product.

2.5.5 Warehouse management

Pharmaceutical manufacturing involves the usage of many type of materials (active ingredient, excipients, packaging materials etc.) to produce drug products. These materials are stored in warehouse with proper status labelling. Tracking the location of these materials while following the First in First Out (FIFO) system is a challenging task. To control the operations of fully automated warehouses, sophisticated systems like automated storage and retrieval systems (AS/RS), automated guided vehicles (AGVs) are used. Many other devices such as conveyors, carousels, sortation systems, etc. are commonly used in modern warehouses. A number of computerised system tools are available to assist in the planning of warehouse design and configuration. These systems make overall management in the warehouse easy and error free.

2.5.6 Inventory management system

The cost of materials used in pharmaceutical organization is very high, thus it is essential to have proper inventory management for proper cash flow in the organization. Exessive dead inventory will build financial burden on the organization. Since the raw materials only have a limited shelf life, mismanagement of the inventory can lead to unnecessary financial losses. Proper planning and inventory management can avoid these kind of losses and improve the profitability of an organization. Inventory management software is also helpful for the sourcing of raw materials.

3. Pharma 4.0

Pharma 4.0 is the phenomenon under Industry 4.0 and it represents a move from focusing on production to a fixed specification for a systemized method of continuous evaluation and control. Manufacturing processes are self-adjusting based on running data and the information gathered from systems all around the operation. This concept builds on the principles of Quality by Design (QbD) and Process Analytical Technology (PAT) that started over a decade ago in the industry.

Pharma 4.0 aims to connect human resources, data, and physical machines in a cyber-physical network. In Pharma 4.0, there is no place for nostalgic paper filing. Instead, a virtual value chain relies on seamless, real-time data exchange. Data integrity is high on the priority list of regulators and, considering the enormous amounts of data generated, this can only be achieved by having one single source of truth. The Pharma 4.0

initiative would not only address agility and productivity issues, but also provide quality operations with better instruments to enforce product safety and supply chain security.

There are multiple challenges for companies that do not possess any IT systems / electronic information systems as listed below:

- Ineffective planning
- Unknown manufacturing performance
- Unknown quality performance
- Little visibility into operations
- A focus on releasing the available product based on insufficient or unreliable data
- No information to improve the business

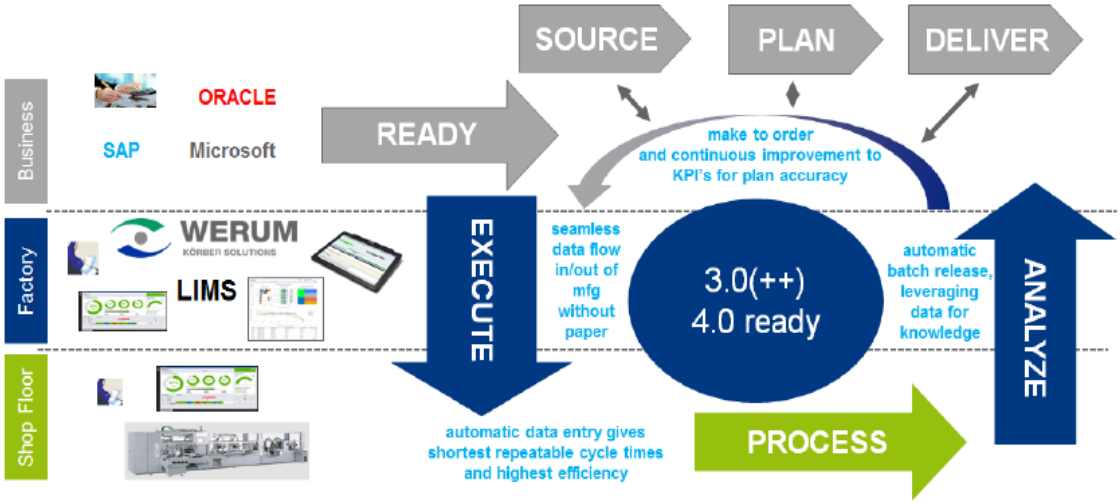
Implementation of IT systems in pharmaceutical production processes will lead to better management of critical product quality attributes and to improved control over critical process parameters. Digitalization will lead to significant reduction in waste due to quality deviation during the manufacturing processes. Implementation of digitalization in different fields (supply chain, production, QA, engineering and IT) of a pharmaceutical factory is based on people-centric thinking that incorporates the following:

- Evolution of the quality management approach from a task-centric to a lifecycle and capabilities point of view to improve agility
- Evolution of qualification and Computer System Validation (CSV) practices through the deployment of American Society for Testing and Materials (ASTM) E2500 for equipment qualification and differentiated approach for enterprise, control and analytical computerized systems
- Science-based risk management for process validation
- Digitalization of the batch release process through the use of integrated computerized system like Laboratory Information Management System (LIMS), Scientific Data Management System (SDMS), Manufacturing Execution System (MES) and Quality Management solutions
- Transformation of production and support maintenance practices to an integrated service model
- A strict respect for GMP predicate rules through careful review of critical decisions

The benefits associated with digitization are many such as improved control, visibility, understanding, prediction and feedback into manufacturing. Ultimately, digitization can enable software to make automatic responses so that higher levels of performance are reached that surpass those achievable with today's manual and semi manual management of operations.

Figure 2 shows an evolved IT landscape where the company has implemented with a top-down approach an Enterprise Resource Planning (ERP) system to make improvements and to automate the wider supply chain processes and connect these in and out of the production sites. At the factory level then Manufacturing Execution Systems (MES) and Laboratory Information Management Systems (LIMS) are in place and integrated into the ERP to manage the production and laboratory operations in a paperless manner for greater efficiency and right first time controls. These systems apply point-of-use checks to ensure correct data, instruction, and sequence of activities and to make the records available for faster review and approval. Figure 2 also shows that once an organization reached an effective basis for Industry 3.0, then Pharma 4.0 ideas can be implemented such as to get closer to processes with human interface devices, IoT sensors for control and tracking, PAT applications for advanced process control, robotics / automation to speed things up and to apply data analysis tools for more insights in our production processes and supply chain operations.

Figure 2. Putting in place basic IT platforms to be ready for Pharma 4.0



4. Electronic softwares in pharma industry

Application of IT in the pharmaceutical industry is essential and common nowadays. The pharmaceutical industry involves multiples stages during the manufacturing of pharmaceutical products right from receiving input material until distribution of the product in the market. Most of the pharmaceutical manufacturers produce different doses of the same drug or different drugs in their manufacturing facility. Therefore, they require a variety of different input materials (both raw material and packaging material) and different production processes for each of the different dosage forms or drug products. Pharmaceutical products are consumed by patients, hence dosage, identity, safety, purity and quality become key attributes. It is a highly regulated industry and involves the generation of various documents at each stage of the production process to create documentary evidence which is verified by the inspectors during the facility audit. Therefore, integrity of the data (records) becomes the key attribute. Use of IT solution / software makes the operation process fast, simple and robust to ensure both consistency of product quality and integrity of the data. There are many software which are used for different purposes in different functions of the organization to replace paper work and automate the workflow. Following are a few examples of software used in the pharmaceutical industry with their respective use shown in Table 2.

Table 2. Software and its usage in the pharmaceutical industry in India

Type of software	Use
Enterprise Resource Planning (ERP)	Material and Operations management
Bardcoding software system	For status labelling of the incoming material

Laboratory information management system (LIMS)	Quality control and analytical documentation management
Quality management system (QMS)	To track & trend all quality systems [e.g. Change control, deviation control, Out of specification investigation, complaints, corrective and preventive actions (CAPAs)] of the organizations
Documentation management system (DMS)	To manage GMP documents like SOPs, Test procedures, specifications and day to day references by users
Learning management system	To train the employees
Attendance management system	To track the attendance of the employees
Building Management system (BMS)	To monitor and control temperature, relative humidity and differential pressure of the processing area / storage areas
Environmental management system (EMS)	To monitor temperature, relative humidity and differential pressure of the processing area / storage areas
Empower / Chromeleon	Software for electronic data management used for chromatographic instruments like High Performance Liquid Chromatography (HPLC), Gas Chromatography (GC), Ultra Performance Liquid Chromatography (UPLC) etc.
Track and Trace software	To track and trace the finished goods in the supply chain

5. Impact of IT in pharma industry

Information technology (IT) has a positive impact on the pharmaceutical industry. This is more so after a few organizations received warning letter / import alert due to data integrity issues identified by the USFDA / EU regulators during their audit of the manufacturing sites. Prior to disclosure of these data integrity issues, most of the companies were having manual system to document the data from laboratory activities and the manufacturing of pharmaceutical products. Employees were found to be involved in manipulating the data into compliance, thereby violating the cGMP norms. Because of such serious non-compliance issues related to data integrity, the FDA imposed a warning and enforced the organizations involved in the scandal to make the necessary corrections to avoid such incidents from repeating themselves in the future. The top four reasons for warning letters were poor quality system, breach of data integrity, poor laboratory control and poor production control. In response, most of the organization introduced software solutions at different stages of the manufacturing, packing and testing process as listed in Table 2. The implementation of these software solutions would ensure that data is attributable (who did what, and when was it done etc.), legible, contemporaneous (recording at the time of activity), original and accurate and thus avoid any data integrity issues. These software solutions meet the CFR part 11 compliance which means it has audit trail for every activity happening during the process. Audit trails make it possible to trace changes that were made to the data records and thus make it impossible to obscure previous entries. Therefore, auditing trails help to ensure the trustworthiness and reliability of the data. There are computer-generated, time-stamped audit trails, for example, date, time, or sequencing of events, who made the changes etc. Audit trails are especially useful when users are expected to create, modify, or delete regulated records during normal operations while using computerised system. To ensure integrity and reliability of electronic records, it is imperative to keep track of all changes made to information related to GMP-relevant records. The use of audit trails makes sure that only authorised additions, deletions or alternations of GMP relevant electronic record are allowed. It allows to reconstruct significant details about manufacturing activities and data collection.

Audit trails or other security methods used to capture electronic activities:

- Must contain any GMP-relevant electronic records
- Should describe when, by whom, and for what reason changes were made to the electronic record
- Original information should not be hidden
- Must be available
- Must be regularly reviewed
- Audit trails can be useful investigative tools to help determine the reliability of the records

Implementation of these software solutions has given much confidence to the regulators.

6. Research survey

In order to investigate how the pharmaceutical industry implements information technology in their day-to-day operations, the authors have interacted with different stakeholders and asked them to formally share their experiences with the use of IT in their respective organizations and the perceived effect on their companies' operations. To generate response, a questionnaire was designed consisting of variables found in the literature, and based on the rich academic and industrial experience of the authors. The questionnaire contained questions related to the use of IT, and how it affects operations including quality, cost, compliance, production etc. The questionnaire was initially reviewed by a close associate from the pharma industry and then sent to multiple pharma professionals within India with a request to respond within the set time limits.

Specifically, the questionnaire had the following three objectives:

1. To understand Indian organizations' investment in information technology
2. To understand the impact of IT use on a company's productivity and costs
3. To understand the impact of IT use on a company's product quality and compliance

7. Data analysis and results

The questionnaire, containing 22 items (Appendix-1), was sent to 400+ pharma professionals working in different functions of 45 different organizations. After a close follow-up, we received 111 responses which represented different organizations including those involved in the manufacturing of sterile drug products, non-sterile drug products, active pharmaceutical ingredients and combinations of these type of products.

To avoid any biased response, multiple respondents were chosen from any single organization to make the responses more representative of that organization. The surveyed organizations were divided into two groups based on their level of IT spending. While closely analyzing the responses, it turned out that some respondents from the same organization had a differing opinion with respect to their company's IT spending. Since IT spending is believed to be an objective fact, it should not vary for different people from the same organization. Therefore, it was decided to eliminate the data of those respondents whose estimation of the total IT spending did not match with the majority of the other respondents for the same organization. As a result, after this elimination, final number of respondents considered for further analysis was 96.

96% of the respondents are working in the organizations whose products are marketed in India and overseas markets (e.g. USA, European countries). The majority of the respondents are experienced in the pharmaceutical industry. 84% of the surveyed organizations had more than 600 employees; 75% of the surveyed organizations had a turnover of more than INR 1000 crores (Table 3).

Table 3. Demographic details of respondents (figures in bracket include % of total respondents)

Respondent's Experience (in years)	Size of Organization (Turnover in INR Cr)	Size of Organization (No of employees)	Product Type Manufactured	Market of Organization
Less than 5 (7.2)	Less than 100 (6.3)	Less than 100 (2.7)	Sterile DP (11.7)	India (2.7)
Between 5 to 10 (18.9)	Between 101 to 500 (9.9)	Between 101 to 300 (5.4)	Non-sterile DP (25.2)	ROW (0.9)
Between 10 to 20 (58.6)	Between 501 to 1000 (9.0)	Between 301 to 600 (7.2)	API (16.2)	India + USA+ EU + ROW (54.1)
Above 20 (15.3)	Above 1000 (74.8)	Above 600 (84.7)	API + Non-sterile DP + Sterile DP (35.1)	USA + EU + ROW (42.3)
			API + Non-sterile DP (0.9)	
			API + Sterile DP (1.8)	
			Non-sterile DP + Sterile DP (9.0)	
			API + Sterile DP (1.8)	
			Non-sterile DP + Sterile DP (9.0)	

DP : Drug Product ; API : Active Pharmaceutical ingredient; ROW : Rest of the world, USA : United States of America; EU : European Union

IT spending in pharma companies in India varies between 1-5% of the total budget. Therefore, the authors formulated the five following options in the survey to cover all respondents:

- IT spend less than 1% of their budget
- IT spend between 1-2% of their budget
- IT spend between 2-3% of their budget
- IT spend between 3-4% of their budget
- IT spend more than 4% of their budget

55% of the respondents indicated that the IT budget in their organization was less than 4% of the total budget and 45% of the respondents said that their company's IT spending exceeded 4% of the total budget for the current financial year. ANOVA (Analysis of Variance) statistical testing was used to understand the differences among the groups with high and low IT spending. The first group included the respondents who confirmed that their organization spent less than 4% of the total annual budget on IT, while the second group included the respondents who confirmed that their organization spent more than 4% of the total annual budget. These groups were created to understand the impact of IT spending by the organization on productivity, cost, quality and compliance.

The following hypotheses were developed and the one-way analysis of variance (ANOVA) was performed to determine whether there are any statistically significant differences between the two groups.

$H1_O$: There is no difference in productivity / cost irrespective of IT investments by the firms
$H1_A$: There is difference in productivity / cost irrespective of IT investments by the firms
$H2_O$: There is no difference in quality / compliance irrespective of IT investments by the firms
$H2_A$: There is difference in quality / compliance irrespective of IT investments by the firms

We used the Statistical Package for the Social Sciences (SPSS) software for analysing the data, results of ANOVA analysis for both hypotheses are as in Table 4.

Table 4. ANOVA analysis results

Hypothesis	P-Value	Result
Productivity / Cost	9.19E-21	P-value is too less suggesting rejection of null hypothesis, that is statistically there is a difference in productivity / cost depending on the IT investments by the firms
Quality / Compliance	1.39E-06	P-value is too less suggesting rejection of null hypothesis, that is statistically there is a difference in in quality / compliance depending on the IT investments by the firms

8. Limitations of the study

Respondents to the survey were from India and did not include pharmaceutical manufacturers from overseas. Further studies can be undertaken to include manufacturers from overseas e.g. the USA, European countries etc. Further research could be undertaken by including data from manufacturers having approval from the USFDA / EU regulatory authority and manufacturers supplying only to the Indian market. The limited sample size may be another limitation of the study. However, we do feel that as the respondents were chosen very carefully, this latter limitation may not have significantly affected our results and findings.

9. Discussion and conclusion

Information Technology (IT) has significant role in the pharmaceutical industry by improving compliance, data integrity and data reliability, and overall product quality. Implementation of software has given immense confidence to the regulators auditing the manufacturing site, especially after they found multiple data integrity issues during their visits to these organizations. Information technology also has a positive impact on the ease of operations, cost and productivity as documentation is replaced by computerised systems. Survey of pharma professionals from organizations located in India has also confirmed that most of the organizations spend more than 4% of their total capex budget in the financial year 2018. Statistical analysis (ANOVA) also confirmed that an IT spending of more than 4% of the total budget has direct impact on productivity, cost, quality and compliance. Pharma professionals have agreed to the implementation of various software like ERP, Quality Management System, Laboratory Information Management System (LIMS), Document Management System (DMS), Learning Management System etc. These software can not only improve productivity and reduce manufacturing costs but can also ensure that quality and compliance are enhanced. This will have a positive impact on all other stakeholders including customers, regulators, vendors and investors.

Kandukuri (2016) reported that use of IT in the pharma sector resulted in the development of new drug delivery systems, improvements in effluent treatment, pollution control, all-round safety standards, improvement in operational efficiency through reduction in batch hours, increase in batch sizes, better solvent recovery, simplification of processes, meeting norms of external regulatory agencies to facilitate more exports, development of products for import substitution, maximum utilisation of indigenous raw materials, product quality improvements, cost reduction, product development, import substitution etc. The continuous upgrade and adoption of new technologies have benefited companies in the form of better production processes, better yields, better quality of the end product and cost reduction. This paper, based on primary data, also supports the findings of Kandukuri.

Blumenthal, a prominent manufacturing execution systems supplier claims, "Our customers are asking us to fill the gap between the business level and automation level. On this operational level, the first focus in pharma manufacturing is the replacement of paper batch recording with an electronic system. Beside the paper replacement, customers are taking a broader approach to many business functions including material flow, quality control and process automation". Our research confirms the observations of Blumenthal.

References

Kandukuri, R. (2016). Role of IT in pharmaceutical industry in India. *Anveshana's International Journal of Research in Regional Studies, Law, Social Sciences, Journalism and Management Practices, 1*(8), 61-65.

Appendix 1. Items in the questionnaire

1.	Do you agree that information technology (IT) has brought transparency between regulators and manufacturers of pharmaceutical industry?
2.	Do you agree that IT has saved time for the employees in the organization?
3.	Do you agree that IT has reduced the manpower?
4.	Do you agree that IT has improved the compliance level in the organization?
5.	Do you agree that IT created platform to compare the quality and operations metrics of different plants within organization?
6.	Do you agree that IT has reduced the paper work at the work place?
7.	Do you agree that Enterprise Resource Planning (ERP) is needed in the pharmaceutical industry for material and operations management?
8.	Do you agree that software LIMS (Laboratory information management system) in the quality control is essential to avoid any potential data integrity issue?
9.	Do you agree that software QMS (Quality management system) is essential to track & trend all quality systems of the organizations?
10.	Do you agree that software DMS (Documentation management system) is essential to refer current version of master GMP document at the work place of employee in the organization?
11.	Do you agree that automation through software would reduce manual errors at all the work places in the pharmaceutical industry?
12.	Do you agree that use of programmable logic controller (PLC) equipped machines in the pharmaceutical industry would produce consistent quality in the drug product?
13.	Do you agree that use of PLC based equipment has reduced generation of product defects and improved the batch yield?
14.	Do you agree that IT is essential for inventory management in pharmaceutical industry?
15.	Do you agree that use of information technology attracts more talent in the organization?
16.	Do you agree that use of training software has improved the knowledge level of employees in the organization?
17.	Do you agree that use of serialization (Track and Trace) software would reduce the counterfeit medicines in market across the globe?
18.	Do you agree that supply chain management software has helped organization in proper planning of drug product manufacturing?

19.	Do you agree that use of data logger and software has been helpful to monitor the temperature during transit of drug product batches?
20.	Do you agree that use of Electronic Batch Record shall avoid data integrity issue?
21.	Do you agree that all electronic data shall be stored directly to the Centralised Server under control of Information Technology (IT) function?
22.	Do you agree that use of various information technology tools has improved work efficiency, increased transparency, reduced manual work and improved product quality in the pharmaceutical industry?