Redesigning of Smart Manufacturing System based on IoT: Perspective of Disruptive Innovations of Industry 4.0 Paradigm

Bhaveshkumar N. Pasi, Subhash K. Mahajan, Santosh B. Rane

Abstract: Manufacturing plants are working with limited efficiency and productivity. These manufacturing plants can become more efficient, productive and smarter by adopting the enabling technologies of Industry 4.0. In this research paper, keyword based literature review is carried out. Purpose of this research paper is to use IoT based framework in assembly line of small scale transformer manufacturing industry located in Mumbai, India to illustrate the effect on efficiency, productivity, and safety. Finally, reliability and effectiveness of IoT framework is determined by performing paired t-test hypothesis testing. IoT framework for assembly line of small scale transformer manufacturing industry has capability to optimize parameters such as cycle time, rejection rate, and productivity. This research has been performed by considering only the assembly line. However, other manufacturing processes of small scale transformer manufacturing industry can also be improved by implementing developed IoT framework.

Keywords: Industry 4.0, IoT Framework, Smart Manufacturing System..

I. INTRODUCTION

Lately, the revolution in manufacturing technology is a concern for the entire world. Management of manufacturing is become more effective and smarter because of new technologies [1], [2]. Visibility in manufacturing is improved radically by using Industry 4.0 enabling technologies such as data analytics, Internet of Things, 3D printing, etc. Now a days, organizations are looking for sustainability features in their commercial events [3], [4]. Then again, ventures are confronting issues to satisfy the consistently changing requests of clients alongside affirming a practical evolvement in business. Industry 4.0 based idea allows to coordinate ecological security, control activities and procedure wellbeing [5], [6], [7]. As a result of Industry 4.0 activities, a manufacturing framework can be changed into a smart manufacturing framework. This makes fabricating framework progressively adaptable, prudent, and naturally amicable [8]. In the course of recent years, the Internet of Things (IoT) and digital physical systems ideas have improved mechanical industries frameworks [9]. For a top to bottom comprehension of 4th industrial revolutions, it is huge to know past three industrial revolutions. The primary mechanical insurgency gives the preparation to industrialization [10], [11], [12]. The subsequent upset gives the preparation to Power and develops the idea of 'hard computerization'. The third upheaval gives the basis to PCs and develops the possibility of 'adaptable computerization'. The fourth industrial transformation furnishes the preparation to Industry 4.0 with a use of current data and correspondence innovation and associated with a combination of modern robotization, information arranges, and propelled fabricating advancements like brilliant creation, human-PC cooperation, 3D printing, remote activities, and so forth [13], [14].

A. Internet of Things (IoT)

Definition of the Internet of Things is different for the different person. It alludes to connecting any gadget with an on and off switch to the internet [15], [16], [17]. This comprises mobile phones, Bluetooth based headsets, refrigerator and air conditioner, coffee vending machines, washing machines, lamps, etc. The IoT is a huge linkage of connected "things" (which also includes people). IoT is alluded as the overall system which allows the correspondence between individual to-individual, individual to-things and things-to-things, by giving idiosyncratic rareness to each and everything [18], [19].

Due to an increase in competition among manufacturing industries, it is important for manufacturers to rethink about their manufacturing operations and develop effective factory management i.e. smart manufacturing [20], [21]. In smart manufacturing, focus is on to improve assets utilization by using IoT-driven data analytics. IoT - driven data analytics combines new and old data which gives the high degree of flexibility and decision-making capability to manufacturing workers [22], [23], [24]. Due to the Internet of Things, every element of production can be visualized in the generation procedure and group level checking is being supplanted by unit-level observing [32], [33].

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This is the beginning of smart manufacturing. IoT is an idea that gives a thought regarding how we live and how we work [34], [35]. Advancements dependent on IoT is getting more worth due to the wide accessibility of broadband Internet, decrease in the expense of associating, generation of gadgets with Wi-Fi abilities and decrease in innovation cost [36], [37].

Therefore, in this research article an IoT based framework is designed and developed for assembly line of transformer manufacturing industry and its importance is determined.

B. Smart Manufacturing

Smart manufacturing deals with capturing and analysis of shop floor data, logistics data and supply chain data in real-time [25], [26]. Smart manufacturing covers different aspects such as product design and development, factory processes, supply chain, and demand management. Smart manufacturing allows enterprises to have full visibility and real-time tracking of investments in assets, advancements in the business/process, capitals, and products which optimizes supply and demand [27], [28]. The incorporation of proactive and autonomic investigation abilities in shrewd assembling makes shrewd assembling an astute and self-recuperating condition which can figure troublesome issues, create/adjust activities and pleasure clients. Smart manufacturing combines connectivity technologies, the cloud and Big Data analytics. Connectivity technologies allow taking active and precise decisions related to business by linking factory automation assets to end-user apps [29], [30], [31].

II. LITERATURE SURVEY

A. Industry 4.0

The idea of "Industry 4.0" was introduced by Hanover Messe in 2011. Industry 4.0, can be comprehended as the "savvy fabricating" or "coordinated industry" can impact the entire business as far as items are planned, produced and conveyed and so forth. Industry 4.0 offers increasingly powerful intends to control the production framework contrasted with the conventional concentrated framework [38]. As of late, Industry 4.0 dominatingly illuminating the forthcoming transformations of the assembling business scene, particularly in the created economy [39].

As of late, because of high challenge in the manufacturing field, producers are compelled to acknowledge current mechanical advancement and procedure developments [40]. The procedure developments like six sigma, lean, kaizen, Just-in-time when coupled to present day data innovation based Industry 4.0 activities lead to a manageable culture in assembling. This will advance new reasonable patterns in the manufacturing condition in creating economies [41]. Industry 4.0 permits mechanical frameworks to build up a worldwide digital physical system of machines and equipment for better information trade and control [42]. This overall digital physical system would be amazingly adaptable and more intelligent prompts a brilliant industrial facility. This further improves the all-out exhibition of the entire business by improvising every business movement like plan, material and machine necessities, item lifecycle and production network the board and so forth [43]. Industry 4.0 innovations permit the continuous observing and controlling of indispensable creation parameters, for example, generation status, vitality utilization, progression of materials, clients' requests, and providers' information. Industry 4.0 and manageability has become the ongoing creating strings for assembling for improving the efficiency and advancing an increasingly supportable culture [44]. Industry 4.0 is thought to be another business outlook that can help business associations and society to move towards manageable improvement [45].

B. Internet of Things (IoT)

As of late, it is seen that advancement is viewed as one of the principle factors influencing organizations' endurance. Notwithstanding, the confirmed certainty is that the high challenge among production ventures has speeded up the pace of development as far as its discovering, execution, presentation, and dispersion into the market [46]. This has set off a strengthening self-energized circle that has propelled organizations to consistently improve items and administrations to advance a superior exhibition. Presently a days, to accomplish higher efficiency, higher caliber, and lower generation costs different ICT advancements are utilized [47].

Headway of Internet-based innovations has prompted the arrangement of new methods of reasoning for manufacturing and new types of association, for example, virtual associations, remote production, PC incorporated manufacturing frameworks, and Internet-based production [48]. For instance, "design anywhere, manufacture anywhere" is another strategy for production which offers design and manufacturing information over different stages and foundations. Ongoing investigations show progressively adaptable and progressed robotized producing framework will be created due to data situated and information driven innovations [49]. Thusly, manufacturing innovation is should be incorporated with a network framework and to work in "circulated situations".

The upsides of Internet-based arrangements, (for example, cloud-based design) inside manufacturing environments are distinguished as far as versatility with the interest and of adaptability in conveying and tweaking arrangements [50]. Cloud-based structure alludes to an assistance arranged, organized, item advancement model in which administration customers can design items or administrations and reconfigure production frameworks [51]. Effective execution of Cloud-Based Manufacturing (CBM) will give focal points, for example, increment in the creation lines productivity, diminish item lifecycle costs, improvement in business-to-business (B2B) connections and advancement in asset portion [52]. Subsequently, this condition offers a composed method to store, incorporate, oversee and control the two information and procedure from production to circulation. In this way, Internet-based innovation by supporting B2B incorporation, thus, influences the working execution regarding cost-cutting, quality, adaptability, and conveyance execution [53].

III. RESEARCH GAPS

A. Traditional Manufacturing Systems vs. Industry 4.0

Fig. 1 shows the 'gaps' between existing manufacturing frameworks and the Industry 4.0. To compare research gaps with Industry 4.0 initiatives cellular manufacturing cell, automatic assembly line, FMS, CIM, and reconfigurable manufacturing system are involved.

Many research scholars and companies are working on the topic of industry 4.0. It has been found that existing manufacturing system has not attained Industry 4.0 level. The capability of flexibility can be achieved by the digitized single-station automated cell. The computer-integrated manufacturing system is preferred over the current automated assembly system because current automated assembly system cannot be standardized.
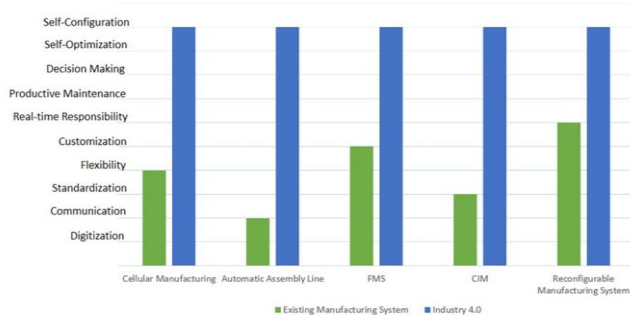
Fig. 1.Traditional manufacturing systems vs. Industry 4.0

B. Research Gaps in IoT

From ongoing examination papers, it has been discovered that the majority of the papers included confined substance about current earlier investigations and talk about the hypothetical foundation of the issues. It has additionally been discovered that a large portion of the exploration papers are dreary in nature. The current research papers barely examine the avoidance systems for the requirements related with the Internet of Things. The majority of the earlier strategies are practically comparative and no essential results could be determined for the redundant idea of execution. It can likewise be seen that dominant part of the current examinations don't talk about the benchmark systems subsequently it will be hard for the future specialists to comprehend what is the proficient procedure to be received for proceeding with the exploration in the field of Internet of Things (IoT).

IV. PROBLEM STATEMENT

During the survey of the small scale manufacturing industries in Mumbai MIDC area, it is found that industries are facing the challenge to reduce long setup and changeover times. Because of long setup and changeover times, products are often produced in batches. Due to batch production inventory cost, work-in-progress inventory and quality problems are increased. Also, lots of space required for production and more labors are required to move items from one stage of the batch process to another. Therefore, the facility cannot meet the demand. Hence, objective of this research work is to study the current assembly process of transformer manufacturing industries and redesign the assembly line by using IoT based technology. This research

work will demonstrate applicability and benefits of the IoT based technology in the assembly process of transformer manufacturing industries. The research will work as an example to other similar facilities to benefit from the lessons learned and the methods used in this study.

V. RESEARCH METHODOLOGY

Fig. 2 shows the research methodology flow diagram for research work. The literature review is completed by searching some keywords along with their combinations such as – IoT framework; smart manufacturing; Industry 4.0; transformer manufacturing industry; smart manufacturing and challenges. Electronic database such as Scopus and Google Scholar are explored to search above mentioned keywords. During literature survey, research articles written in English only are considered.
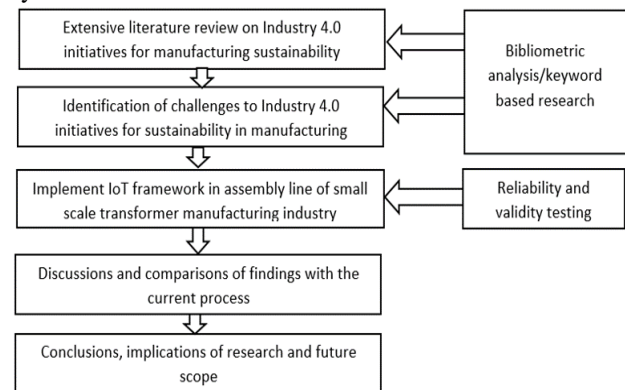

Fig. 2.Research methodology flow diagram

VI. PROPOSED IOT FRAMEWORK

The production information is gathered, put away, handled, and investigated by means of big data technologies. Subsequently, the level of production process can be fundamentally raised. As appeared in fig. 3, the IoT based production structure comprises of four modules, in particular, the production module, the information driver module, the constant screen module, and the issue handling module.

Production module obliges various types of production exercises. It comprises of an assortment of data frameworks and production assets, which can be outlined as man-machine-material-environment. The contributions to this module are raw materials and outputs are finished components. During the info yield change process, different information is gathered from human administrators, production hardware, data frameworks, and modern systems.

Information driver module gives the main thrust to IoT based production all through the various phases of the production information lifecycle. As sources of info, the information from the production module is transmitted to cloud-based server farms to be additionally broke down. Subsequently, express data and significant proposals misused from various types of raw information are utilized to coordinate the activities (e.g., item structure, production planning, and production execution) in the production module.

The ongoing checking module and issue handling module are likewise both controlled by the information driver module.

Constant screen module helps in tracking the production process in real time. Driven by the information driver module, this module is empowered to investigate the constant running status of production facilities. Subsequently, manufacturers can stay up to date with changes in the production procedure, in order to build up the ideal operational control techniques. The production procedure can be balanced in correspondence to explicit item quality deformities. Accordingly, the constant screen module can make the production facilities run all the more proficiently.

Issue handling module capacities to distinguish and foresee developing issues (e.g., hardware issues or quality deformities), prescribe potential arrangements, gauge arrangement viability, and assess potential effects on other production exercises. The proactive support empowered by this module will improve the smooth working of production processes.
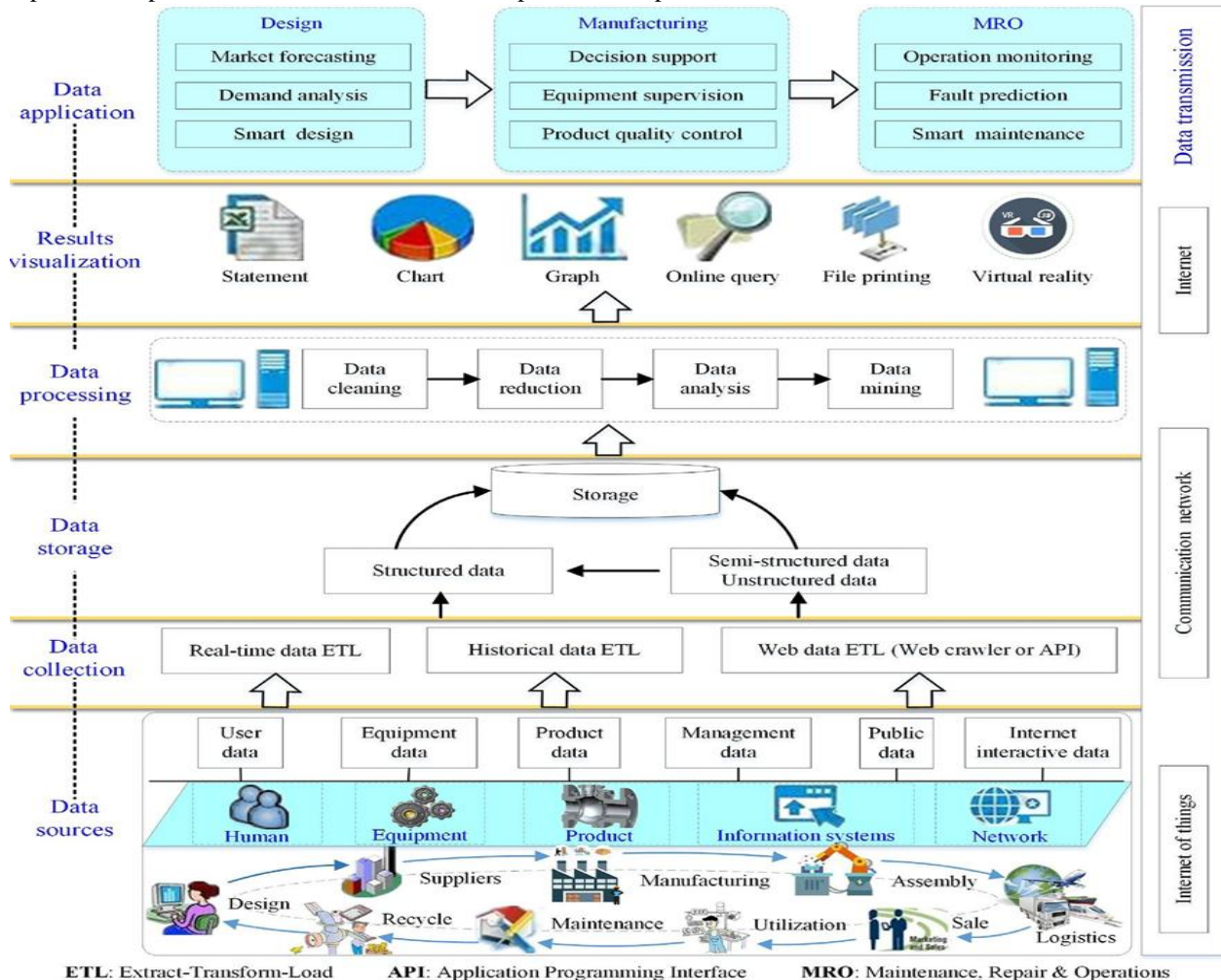
Fig. 3.IoT based framework for manufaturing line

A. IoT Enablers

RFID and QR codes utilizes electromagnetic fields to naturally distinguish and follow labels appended to objects. The labels contain electronically-put away data. RFID is one technique for Automatic Identification and Data Capture (AIDC).

Smart devices are an electronic gadget, for the most part associated with different gadgets or systems by means of various remote conventions, for example, Bluetooth, Wi-Fi, 3G, and so on., which can work somewhat intuitively and self-sufficiently. A few prominent sorts of brilliant gadgets are cell phones, phablets, smart watches, and smart speakers.

M2M interface alludes to coordinate correspondence between gadgets utilizing any interchanges channel, including wired and remote. It can incorporate modern instrumentation, empowering a sensor or meter to convey the information it records to application programming that can utilize it.

Enterprise application is a huge programming framework intended to work in a professional workplace. It comprises of a gathering of projects with shared business applications and authoritative displaying utilities intended for unmatched functionalities.

Big Data Analytics is the perplexing procedure of looking at enormous and shifted informational indexes to reveal data including shrouded designs, obscure relationships, advertise patterns and client inclinations that can assist associations with settling on educated business choices. Enormous information examination is a type of cutting edge investigation, which includes complex applications with components.

B. IoT Barriers

In IoT framework, a lot of information is created which is known as the Big Data. Subsequent to moving this enormous created information through the cloud, the information investigation would be finished and the valuable data is delivered. In IoT based savvy production lines, the entire manufacturing plant is interconnected, observed and controlled remotely. Issue is this permits conceivable passage focuses for digital assaults. Digital security is one of the most indispensable and most requested highlights of an IoT framework.

Firms are facing problems because existing employees are not accepting IoT based technology. Employees feel insecure about their jobs and responsibilities. This barrier could be outshined if the management educates their employees for the new smart systems.

So as to execute new innovations effectively and embrace any sort of thoughts then the company's interior elements ought to be adaptable and light-footed. Otherwise, implementation of new technologies almost impossible or risky.

VII. CASE STUDY

A. Existing System

The transformer manufacturing industry has a make-to-order facility. This means the facility only starts to manufacture the desired product once the customer has placed the order. From an industry reference guide book it is found that the production line produces 67 different varieties of products. Each one of the 67 different types of instrument transformers can be made to whatever ratio the customer desires as long as it does not interfere with the functionality and design of the product. Due to the long setup and changeover times, products are often produced in batches. Producing products in batches should be avoided whenever possible because it increases inventory carrying cost, increases work-in-progress inventory, and increases quality problems. Producing in batches is also undesirable because the facility only has a certain number of molds for the casting process and it leaves factory workers and casting machinery sitting idle while waiting for the molds to cycle through the casting operations. In this research work to overcome above-mentioned difficulties, IoT based assembly line is developed for transformer manufacturing industry.
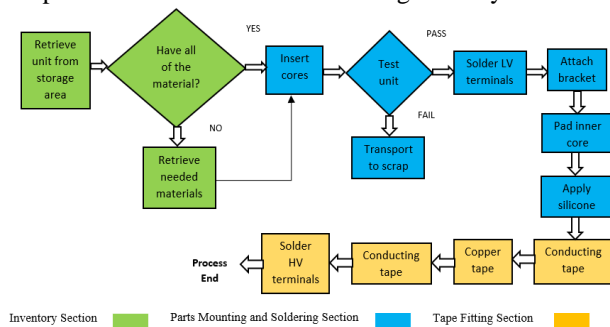

Fig. 4.Assembly line (before improvement)

B. IoT based Proposed System

Fig. 5 shows the IoT based mechanical production system which shows the building blocks of an IoT framework and how they are associated with gather, store and process transformer assembly line data.

A proximity sensor detects the presence of objects into the specified zone and converts it into the signal which can be easily read by a user. As shown in figure 5, the signal given by job order board will be sensed by a photoelectric sensor. If the product is in red color bay line then it gives an alarm to project leader and indicates that the job is complete and available in inventory. Also, the master production schedule will be updated automatically. If the product is in yellow color bay line then it gives an alarm to platform operator and indicates that to collect material from a shop as per checklist and take the material to a platform where job order is green. If the product is in green color bay line then it gives an alarm to project leader and indicates that the job is in process.
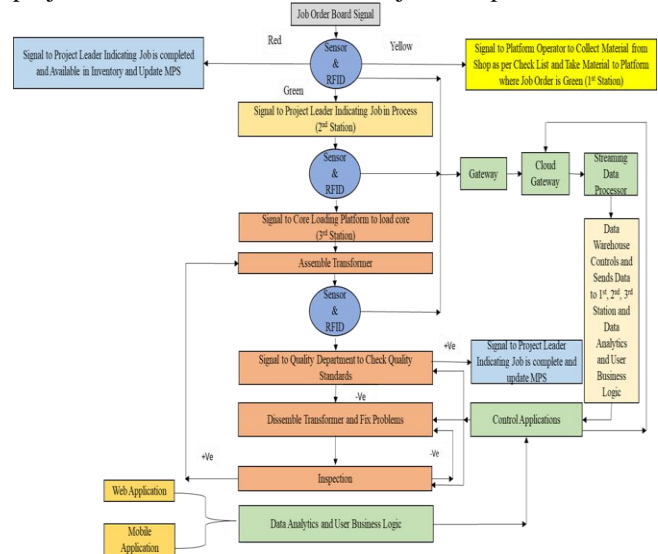

Fig. 5.IoT based assembly line (after improvement)

Assembly line works all the more effectively with RFID. It utilizes the innovation to recognize and arrangement parts on a mechanical production system of transformer industry, screen and track work in process, guarantee right instrument utilization, follow the historical backdrop of parts, and monitor completed item. Utilization of RFID empowers the venture administrator to rapidly get and find parts all through the sequential assembly system and produce cost reserve funds. RFID diminishes the recovery time of parts being gathered. Information goes from things to the cloud. A portal gives availability among things and the cloud some portion of the IoT arrangement, permits information preprocessing and separating before moving it to the cloud and transmits control directions going from the cloud to things.

Cloud gateway encourages information compression and verifies information transmission between field portals and cloud IoT servers. It additionally guarantees similarity with different conventions and communicates with field portals utilizing various conventions relying upon what protocol is supported by gateways.

Separated and preprocessed information required for important bits of knowledge is put away in an information distribution center. An information stockroom contains just cleaned, organized and coordinated information.

Likewise, information discount stores setting data about things and sensors. As appeared in figure 5, the information distribution center offers data to all procedure.

Control application sends programmed directions and cautions to actuators. As appeared in figure 5, control applications send directions to quality and testing departments. The directions sent by control applications to actuators can be likewise moreover put away in an information distribution center.

User applications are part of an IoT framework which empowers the association of clients to an IoT framework and gives the choices to screen and control their savvy things. With a portable or web application, clients can screen the condition of their things, send directions to control applications.

Close by with gadget the executives, it's essential to give authority over the clients approaching an IoT framework. User management includes distinguishing clients, their jobs, get to levels and proprietorship in a framework. It incorporates such alternatives as including and expelling clients, overseeing client settings, controlling access of different clients to certain data, just as the consent to play out specific tasks inside a framework, controlling and recording client exercises and then some.

Security is one of the top worries in the web of things. Associated things produce colossal volumes of information, which should be safely transmitted and shielded from digital lawbreakers.

VIII. LABOUR PRODUCTIVITY ANALYSIS

A. Labour Productivity in Storage Section

The labour Productivity in storage Section of assembly line is analyzed. Fig. 6 presents the time in minutes required to perform the activities in storage section.

- Before IoT, for labour 1 normal time was 1.70 Minutes. After improvement normal time is 1 minute to complete assigned job of checking request bill issued by assembly line in-charge.
- Time required to complete the activity of searching the transformer winding core in the storage section before improvement was 5.44 Minutes. After IoT framework implementation, time required is 3.4 minutes.

| LABOUR RESPONDENTS IN STORAGE SECTION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Before IoT	1.7	5.44	0.7	2.8	4.55	1.08	2.06	1.26	3.28	1.95	2.09	1.17	2.22	2.08	2.51
After IoT	1	3.4	0.2	1.4	2.25	0.52	0.97	0.4	2.1	0.92	1.14	0.47	1.2	1.4	1.25
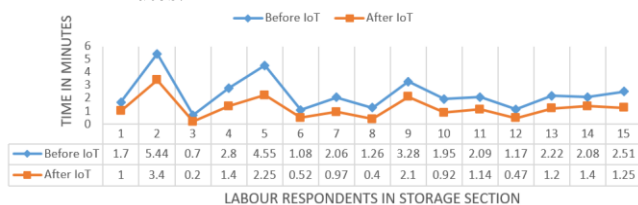
Fig. 6. Time required to complete the activities in storage section

- Labour 3 performs the activity of searching of transformer winding wires. Previously, time required by labour 3 to perform the activity was 0.70 Minutes but after IoT implementation it is 0.2 Minutes.
- Before improvement, time required by labour 4 was 2.80 Minutes to complete the activity of searching of soldering wire materials. After IoT framework implementation, time required is 1.4 minutes.

- Before IoT, time required by labour 5 was 4.55 Minutes to perform the activity of searching of LV terminals but after implementation of IoT framework time required by the worker is 2.25 Minutes.
- Labour 6 performs the activity of searching of HV terminals. Without IoT framework, time required by labour 6 to perform the activity was 1.08 Minutes but after IoT framework implementation time required is 0.52 Minutes.
- To perform the searching of transformer bracket, time required by labour 7 before IoT implementation was 2.06 Minutes. After IoT framework implementation time required is 0.97 Minutes.
- Labour 8 performs the activity of searching of silicone material. Before IoT, time required by labour 8 to perform the activity was 1.26 Minutes. After IoT framework implementation, time required is 0.4 Minutes.
- Before IoT framework manufacturing, time required by labour 9 is 3.28 Minutes to perform the activity of searching of conducting tape. After implementation of IoT framework, time required is 2.1 Minutes.
- Previously, time required by labour 10 was 1.95 Minutes to compare and verify searched parts with the request bill. Now, it is 0.92 Minutes.
- Labour 11 performs the activity of cleaning the parts. Time required by labour 11 to perform the activity was 2.09 Minutes. After IoT, time required is 1.14 Minutes.
- Labour 12 performs the activity of transporting the winding core and wires from storage section to the assembly line. Earlier, time required by labour 12 to perform the activity was 1.17 Minutes. Now, it is 0.47 Minutes.
- Labour 13 performs the activity of transporting semi-assembled parts from storage section to the assembly line. Earlier, time required by labour 13 to perform the activity was 2.22 Minutes. Now, it is 1.2 Minutes.
- Labour 14 performs the activity of transportation of insulating tape, LV, and HV terminals to the assembly line. Previously, time required by labour 14 to perform the activity was 2.08 Minutes. Now, it is 1.4 Minutes.
- Before IoT, time required for labour 15 to perform the activity as system operator i.e. to enter the required information related to the parts received on the assembly line from storage section was 2.08 Minutes. After improvement, time required is 1.25 Minutes.

B. Labour Productivity in Core Mounting Section

Fig. 7 presents the time in minutes required to perform the activities in core mounting section.

| LABOUR RESPONDANTS IN CORE MOUNTING SECTION	1	2	3
Before IoT	9	12	10
After IoT	5	7	6
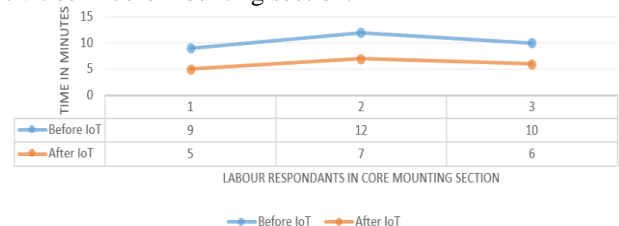
Fig. 7. Time required to complete the activities in core mounting section

- Before implementation of IoT framework, time required by labour 1 was 9 Minutes to complete his assigned job of core mounting and winding the wire on core. Now, it is 5 Minutes.
- Previously, time required to complete the activity of core mounting and winding the wire on core for labour 2 was 12 Minutes. Now, this activity is reduced to 7 Minutes.
- Earlier, for labour 3 normal time was 10 Minutes to complete his assigned job of core mounting and winding the wire on core. Now, it is 6 Minutes.

C. Labour Productivity in Testing Section

Fig. 8 presents the time in minutes required to perform the activities in testing section. Number of respondents are 3.
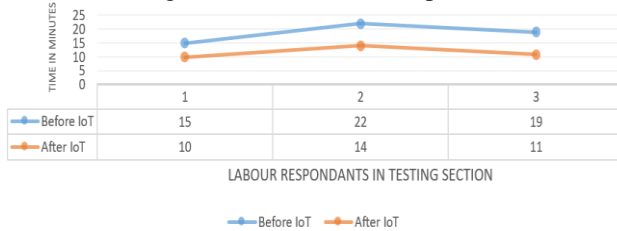
Fig. 8.Time required to complete the activities in testing section

- Before IoT framework implementation, time required by labour 1 was 15 Minutes to complete his assigned job of testing the transformer with core and wires. Now, it is 10 Minutes.
- Time taken by labour 2 to complete the activity of testing the transformer with core and wires was 22 Minutes. Now, it is 14 Minutes.
- For labour 3 normal time was 19 Minutes to complete his assigned job of testing the transformer with core and wires. After implementation of IoT framework, time required is 11 Minutes.

D. Labour Productivity in Solder and Tape Section

Fig. 9 presents the time in minutes required to perform the activities in solder and tape mounting section. Number of respondents are 3.
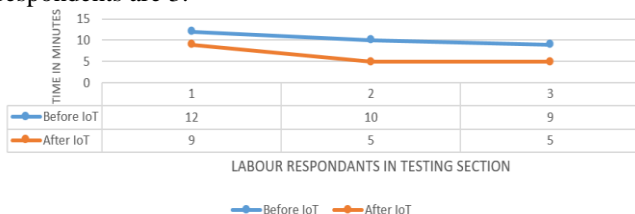
Fig. 9.Time required to complete the activities in solder and tape mounting section

- Before IoT implementation, time taken by labour 1 was 12 Minutes to complete his assigned job of soldering of HV terminals. Now, it is 9 Minutes.
- Time required by labour 2 to complete the activity of soldering of LV terminals was 10 Minutes. Now, it is reduced to 5 Minutes.
- For labour 3 normal time was 9 Minutes to complete his assigned job of tape mounting. Now, it is 5 minutes.

IX. HYPOTHESIS VALIDATION

A. Labour Productivity in Storage Section

Null hypothesis,
H0: There is no significance difference between mean time before and after IoT ($\mu 1 = \mu 2$)
Alternative hypothesis,
Ha: Mean time before improvement is more than mean time after IoT ($\mu 1 > \mu 2$)
Level of significance (α): 5%

Table- I: Paired t-Test for Storage Section

	Variable 1 (Before IoT)	*Variable 2 (After IoT)*
Mean	2.326	1.241333333
Variance	1.6580257	0.687112381
Observations	15	15
Pearson Correlation	0.9753857	
Hypothesized Mean Difference	0	
df	14	
t Stat	8.1919862	
P(T<=t) one-tail	5.19E-07	
t Critical one-tail	1.7613101	
P(T<=t) two-tail	1.038E-06	
t Critical two-tail	2.1447867	

For right tailed test, P value (= 5.19E-07) < α (=0.05) therefore reject null hypothesis. It means that mean time value before improvement is higher than mean time value after IoT.

B. Labour Productivity in Core Mounting Section

Null hypothesis,
H0: There is no significance difference between mean time before and after IoT ($\mu 1 = \mu 2$)
Alternative hypothesis,
Ha: Mean time before improvement is more than mean time after IoT ($\mu 1 > \mu 2$)
Level of significance (α): 5%

Table- II: Paired t-Test for Core Mounting Section

	Variable 1 (Before IoT)	*Variable 2 (After IoT)*
Mean	10.3333333	6
Variance	2.33333333	1
Observations	3	3
Pearson Correlation	0.98198050	
Hypothesized Mean Difference	0	
df	2	
t Stat	13	

P(T<=t) one-tail	0.00293257	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.00586515	
t Critical two-tail	4.30265273	

For right tailed test, P value (= 0.00293) < α (=0.05) therefore reject null hypothesis. It means that mean time value before improvement is higher than mean time value after IoT.

C. Labour Productivity in Testing Section

Null hypothesis,

H0: There is no significance difference between mean time before and after IoT ($\mu1 = \mu2$)

Alternative hypothesis,

Ha: Mean time before improvement is more than mean time after IoT ($\mu1 > \mu2$)

Level of significance (α): 5%

Table- III: Paired t-Test for Testing Section

	Variable 1 (Before IoT)	*Variable 2 (After IoT)*
Mean	18.6666666	11.6666666
Variance	12.3333333	4.33333333
Observations	3	3
Pearson Correlation	0.93471954	
Hypothesized Mean Difference	0	
df	2	
t Stat	7	
P(T<=t) one-tail	0.00990197	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.01980394	
t Critical two-tail	4.30265273	

For right tailed test, P value (= 0.0099) < α (=0.05) therefore reject null hypothesis. It means that mean time value before improvement is higher than mean time value after IoT.

D. Labour Productivity in Solder and Tape Section

Null hypothesis,

H0: There is no significance difference between mean time before and after IoT ($\mu1 = \mu2$)

Alternative hypothesis,

Ha: Mean time before improvement is more than mean time after IoT ($\mu1 > \mu2$)

Level of significance (α): 5%

Table- IV: Paired t-Test for Solder and Tape Section

	Variable 1 (Before)	*Variable 2 (After)*
Mean	10.3333	6.333333
Variance	2.33333	5.3333
Observations	3	3
Pearson Correlation	0.94491	
Hypothesized Mean Difference	0	
df	2	
t Stat	6.92820	
P(T<=t) one-tail	0.01010	
t Critical one-tail	2.91998	
P(T<=t) two-tail	0.02020	
t Critical two-tail	4.30265	

For right tailed test, P value (= 0.0101) < α (=0.05) therefore reject null hypothesis. It means that mean time value before improvement is higher than mean time value after IoT.

X. RESULTS AND DISCUSSIONS

Implementing IoT based technologies will benefit the transformer manufacturing's assembly line by increasing the capacity of the system, increasing system flexibility, and increasing the system's overall quality. The production line will also be benefited from a decrease in work-in-process inventories, a decrease in lead time, and a decrease in manufacturing associated waste.

With an increase in global demand for products related to the power industry, transformer manufacturing organizations need to take advantage of this situation by producing their products more effectively and more efficiently. Therefore, IoT based smart manufacturing system has been the important area of research. Many of the power device manufacturing firms have offshored their production to the low-cost countries which results into lower product cost, therefore, competition among manufacturing industries are increased.

IoT centers on mass-customization and robotization of manufacturing production which permits the makers to bring back the production to their nations of origin in light of the fact that these new advancements are making the advantages of offshoring obsolete. Notwithstanding, it is discovered that production organizations are still during the time spent learning and comprehension of how the IoT can improve their own generation.

Table- V: Comparative Statement Before and After IoT

Parameters	Before IoT	Benefits After IoT
Reject Rate After Assembly	Reject rate was approx. 25%.	Reject rate is decreased up to approx. 10%, yielding dramatic monthly savings
Non value added activity time (NVA)	Percentage NVA was 33.33%.	Percentage NVA is 11.06%.
Assembly Efficiency	Assembly efficiency was approx. 49%.	Assembly efficiency is increased up to approx. 67%.
Accident During Assembly Process	An accident during the assembly process was 02 numbers in a day.	Chances of accidents are reduced by approx. 70%.
Work-In-Progress Inventory	WIP was high.	Work-In-progress inventory is reduced by approx. 20%.
Changeover/Down Time	It was high because of batch production.	Downtime is reduced by approx. 50%.
Percentage Utilization of Tools and Fixtures in Assembly	Utilization of tools and fixtures in the assembly line was approx. 85%	Utilization of tools and fixtures are increased up to approx. 95%.
Scrap Reduction	Scrap in the assembly line was 5%.	Scrap in the assembly process is reduced to zero.

XI. CONCLUSIONS

It is found that IoT will disrupt the assembly line of transformer manufacturing industry. IoT develops a fully automated system of devices which replaces the traditional production process. IoT should be adopted by transformer manufacturers as a long-term investment and to avail benefits a large majority of transformer manufacturers should start using the IoT. To gain the competitive edge and strong position in the market every transformer manufacturer must implement IoT based technology.

LIMITATIONS

The outcomes acquired in this research work are restricted and excessively centered on a transformer producing industry. Equivalent outcomes can't be accomplished if a similar research strategy is applied to an alternate industry or for an alternate innovation. Thus, an earlier overhaul of the exploration approach is exhorted.

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