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An Empirical Study to Examine the Role Smart Manufacturing in Improving Productivity and Accelerating Innovation

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ABSTRACT

Smart Manufacturing (SM) is the vividly exaggerated and prevalent application of networked information-based tools throughout the manufacturing life cycle of a product. It comprises real-time integrated computational resources, demand-driven supply network; and broad-based manpower association. ICT driven Smart factories helps in improving productivity and accelerating manufacturing innovation. Several reports are there that are dealing with the practical and operational features of SM, but the role of SM as a dynamic element in improving productivity and accelerating innovation is not considered fully. Recognising the significance of role of SM in improving productivity and accelerating innovation, an empirical study has been carried out & presented in this paper with the purpose of attaining supplementary cognizance.

***Keywords*--** Manufacturing Intelligence, Smart Manufacturing, Flexible Manufacturing System; FMS, Smart Manufacturing Execution System; SMES, Productivity, Innovation

I. INTRODUCTION

Smart manufacturing is knowledge enabled and ICT plays a vital role in improving manufacturing intelligence, developing novel business prototypes and technologies. Manufacturing intelligence (MI) comprises of the real-time understanding, reasoning, planning and management of all aspects of the enterprise manufacturing process and is facilitated by the pervasive use of advanced sensor-based data analytics, modeling and simulation. Small, medium and large manufacturers will depend on college level training and skills and the manufacturing workforce will re-distribute throughout the supply chain, advanced technology suppliers, innovation and start-up companies[32][33][34]. SM responds as a synchronized, performance-oriented enterprise, minimizing energy and material usage while maximizing environmental sustainability, health and safety and economic competitiveness. ICT have been applied to optimize individual unit processes, but Smart Manufacturing (SM) systems that integrate manufacturing intelligence in real-time across an entire production operation remain rare in large companies, and virtually non-existent in small and medium size organizations. Real time management of energy consumption is a perfect example of the contradiction between the potential benefits and barriers to the implementation of SM technology. Clearly there is a recognized interest and a base of literature on flexible and adaptive enterprise wide optimization and decision making [35][36][37][38][45].

A key aspect of the SM Platform is performance metrics. The pervasive internet availability of the data and information about the manufacturing process opens untapped opportunities for radically improving manufacturing productivity and innovation. SM provides a standard protocol for building the internet modeling, simulation and data analytic applications that put the manufacturing internet data into actionable forms. An industry driven SM Platform will provide and manage the protocols and standards for data and the plug and play standards for internet applications. Smart manufacturing fundamentally depends on networked-based information technology, modeling and simulation. In raising the level of abstraction, smart manufacturing is seen as a new enterprise operating model in which demand-dynamic economics, active, performance-driven management, and broad-based innovation are achieved by using technology to distribute global business and operating intelligence throughout the enterprise to the local point of decision. Greater operating complexity and resiliency involve greater levels of automation, while greater strategic management and innovation require a new, involved workforce making decisions that drive performance and objectives, and not tasks. Predictive modeling and simulation are used to explicitly manage risk and uncertainty [37].

Productivity is the relationship between the quantity of output and the quantity of input used to generate said output. It is basically the measure of the effectiveness and efficiency of the organizations in generating output using the resources available. By laying a strong foundation of productivity, organizations will be able to enhance their organizational systems and processes to achieve sustained business excellence in the long run. In the quest to achieve business excellence, organizations need to adopt a holistic productivity management system to manage their organization's productivity journey in a systematic manner. Productivity measurement is thus an important communication tool to share current performances relative to the goals and/or standards that the organizations have established. It provides an objective basis to recognize and reward both individual and team contributions to the productivity effort in the company through the application of a productivity gain sharing scheme. Moreover, productivity measurement could also help to identify the learning and development needs of employees so that the competency of the workforce can be further enhanced. With a productivity measurement system, SMEs can execute and compute their performance results in both quantitative and qualitative terms, thereby gaining a complete understanding of their productivity improvement status over time.

Innovation in manufacturing process entails modification in the method of production. The alteration in the procedure can be a result of amendments within the company or across the value chain. The aim of such innovation can be to reduce the turnaround time, enhance the product quality, trim the cost of production, achieve the flexibility of customising the product as per customer demands as well as reap other benefits that result into better product competitiveness. Management innovation is a change introduced in a firm's management principles to improvise any area of business activity. Innovation in manufacturing process can be outbound as well – by involving other stakeholders engaged in the production process. The Indian manufacturing sector has been incorporating various technologies to serve the varying needs of the diversified Indian customer base. For instance, the Indian market on a macro level is divided into urban and rural, with the factor of differentiation being the purchasing power of customers, which is lower in the latter group. Thus, the manufacturing sector is introducing products to capitalise on the large untapped price-sensitive Indian market. The Technology and Innovation for the future production will focus on technologies that, both individually and in combination, are reshaping the way we make things. It will assess the impact of these technologies and develop innovative and unique insights and tools to help governments and companies better understand ongoing and future technology-driven transformations, inform investment and policy decisions and foster a common understanding among stakeholders. Efforts so far have been directed towards five key ICT-enabled technologies.

II. REVIEW OF LITERATURE

The exhaustive literature reviewed for this paper in mentioned in the tabular form in Table I which includes the author(s) name, year and the key findings by the researcher(s) in the previous years.

TABLE:1 SUMMARY OF LITERATURE REVIWED

Author(s), Year and Key Findings
Draper, 1984), (Van Brussel, 1994), (Goldman, Nagel, & Preiss, 1995), (Koren&Ulsoy, 1997), Van Brussel, Wyns, et al., 1998), (Mehrabi et al., 2000). suggested that the need for novel manufacturing control systems that are able to manage production change and disturbances, both effectively and efficiently, and has lead to the creation of concepts such as "flexible manufacturing", "holonic manufacturing", "agile manufacturing", and reconfigurable manufacturing". All these approaches aim to incorporate increased levels of flexibility, reconfigurability, and intelligence into manufacturing systems in order to meet highly dynamically marked demands[6][39][40][41][42].
(Mehrabi, Ulsoy&Koren, 2000). suggested that the rapid changes in process technology demand production systems that are themselves easily upgradeable and into which new technologies and new functions can be readily integrated.[42]
(Mahalik, 2003; Neumann, 2007) suggested that most manufacturing systems are physically distributed over a plant site, so that their embedded system components will also be physically apart. In order to be able to interact and synchronize while meeting stringent timing requirements, real-time industrial communication protocols must be employed, so that a timely communication occurs.[43].
Morel et al. (2005) suggested that "Only a form of technical intelligence that goes beyond simple data through information to knowledge and is embedded into manufacturing systems components and within the products themselves will play a prominent role as the pivotal technology that makes it possible to meet agility/reconfigurability in manufacturing over flexibility and reactivity"[23].
(Mařík& McFarlane, 2005) found that in many industrial scenarios, conventional centralized and hierarchical approaches can be inadequate-especially under conditions of disruption and long-term change – to cope with the high degree of complexity and practical requirements for robustness, generality and reconfigurability in manufacturing plant control as well as in production management, planning and scheduling[48].
The study of Shin (2006); Teoh et al.(2008) shows that, to recognize the factors affecting ERP operation in organisations there has been widespread study to carry out the objective. Eventually, this will improve the likelihood of getting elevated gains time saving, cost reduction, value and effectiveness [28][30].
The study of Mekid, Pruschek and Hernandez (2009); Isermann 2011) tells that the production tasks that can be controlled and monitored with ICT are increasing in number as well as difficulty; allowing rapid production with improving precision[17][22].

Sanders (2011) suggested that use of computer enabled technologies improves interactions and enable equally "smart manufacturing" and "smart supply-chain design"— so that the right suppliers may get the right product [26].
Iorio(2011) proposed that the better use of ICT in manufacturing acquaintances the design phase of a component to the bigger assembly manufacturing system to the use of finished goods [16].
Apulu and Latham (2011) found that ICT plays a strategic role in the management of organization to gain competitive advantage amongst organizations in the fast globalizing environment [3].
(Mekid, Pruschek and Hernandez 2009; Isermann 2011) found that in recent years, the tasks that can be monitored and controlled with information technology are increasing in number as well as complexity; these increases are enabling high-speed production with increasing accuracy.[22]
(N.N. 2013) suggested that Industrial production of the future will be characterized by the strong individualization of products under the conditions of highly flexible (large series) production, the extensive integration of customers and business partners in business and value-added processes, and the linking of production and high-quality services leading to so-called hybrid products"

III. DEVELOPMENT OF MEASUREMENT CONSTRUCT

The theory and categorization of smart manufacturing, productivity and innovation have been explored and examined with insights from the existing literature in this section. The measurement constructs that have been developed are further used in analysis for developing the different relationships.

Smart manufacturing(SM)

The chase for manufacturing innovation and improved productivity has compelled entire manufacturing segment to get on a variety of SM endeavour. SM incorporates a properly implemented, monitored and evaluated cluster of integrated hard and soft technologies, which can enhance the functional effectiveness and efficiency of the firms. SM can be described as a collection of computer-related technologies which includes Smart Manufacturing execution system (SMES), Manufacturing Intelligence (MI), Flexible Manufacturing Systems (FMS), Enterprise Resource Planning (ERP) and other advanced manufacturing techniques (AMT). Previous studies have depicted SM as a multidimensional construct which includes the use of 'hard' machine-related aspects: robotics, CNC hardware, CAD/CAM, etc.; and 'soft' reduction techniques etc. In an earlier research it was found that empirically derived three separate dimensions of SM: invent & design, manufacturing and administration. Design incorporated a blend of design and development methodologies such as computer aided design, computer aided engineering, computer aided manufacturing, computer-aided process planning and the usage of Computer Numerical Control equipment. SM comprises manufacturing techniques viz. Flexible Manufacturing System, Manufacturing Intelligence, real-time process control systems manufacturing execution system and robotics; whereas the managerial aspect comprises Enterprise resource planning, information & communication technology and decision support systems. A researcher examine that which manufacturers plan and schedule their production using MRP, MRPII or ERP systems how and to what extent they are affected by uncertainty. Results show stable delayed supply performance, supporting the argument that there is a shortage of supervision and acquaintance on how to tackle uncertainty in SMEs in the UK. Another researcher examined the concern of the strategic fit between AMT and its impact on performance in developing countries. They develop their framework by using survey data collected from 125 manufacturing firms. In one more research, an extensive variety of literature on the investment rationalization of AMT. They delivered an up to date and widespread viewpoint of the topics surrounding the problem of investment rationalization of AMT and gave some direction for future investigation.

Productivity

Productivity refers to average degree of the competence of production. It can be measured as the proportion of output to inputs used in the manufacturing process, i.e. output per unit of input. The use of ICT not only increases overall productivity in the plant by increasing communication speed and efficiency, it also preserves quality by better managing processes [46]. Productivity is the relationship between the quantity of output and the quantity of input used to generate that output. It is basically a measure of the effectiveness and efficiency of your organization in generating output with the resources available.

Productivity is defined as a ratio of output to input:

Productivity = Output / Input

Essentially, productivity measurement is the identification and estimation of the appropriate output and input measures.

Measures of Output

Output could be in the form of goods produced or services rendered. Output may be expressed in:

- Physical quantity
- Financial value

Measures of Input

Input comprises the resources used to produce output. The most common forms of input are labour and capital.

Innovation

Innovation refers to changing processes or creating more effective processes, products and ideas. It can translate an idea or invention into a good or service that creates value or for which customers will pay. If the manufacturing leads towards decentralized production, more distributed, supply-chain management and innovation will provide even more [26]. The successful innovations across multiple sectors in manufacturing the key types of innovation can be classified under the following categories:

1. Innovation in sourcing
2. Innovation in manufacturing processes
3. Management innovation
4. Innovation through technology

Innovation in sourcing

New components, new suppliers or an improved deal with the existing suppliers could improve products and profits significantly. A number of companies have integrated the suppliers into the manufacturing processes to ensure online visibility on inventory at various stages and quality control. E-auctions and reverse auctions to manage material costs are other examples of increasing efficiency in procurement.

Innovation in manufacturing processes

Companies can innovate in the way products are developed or manufactured, either within the firm or across the supply chain. Such innovations are termed as 'Process Innovation'. It is typically aimed at garnering competitive advantage through improved quality, reduced costs or reduced *time-to-market*. Several automotive companies, today, use the collaborative product development to shorten their new product development cycles, in collaboration with Tier I suppliers.

Management innovation

Management innovation refers to innovation in management principles and processes that will eventually change the practice of what managers do, and how they do it. Typically, such innovations have long lasting impact on the organization. Innovation in Business model falls under this category.

Innovation through technology

Technology has been a tremendous driving force for innovation in businesses; especially in the recent times. Many breaks through concepts and development in businesses have been primarily driven by the development of new generation technology. New materials could improve products or their packaging and present action. Over the past few decades, there has been a growing concern globally about the fast depletion of global resources and the need to conserve them for the future. These include both natural and human resources. Another key concern is the need to control pollution and to safeguard the environment. These have also been the key drivers for innovation in developing greener technologies and manufacturing practices; for example: development of electric/ hybrid vehicles. Such innovations typically take time to gain acceptance and become commercially successful; as the long-term advantages offered by the technology are not immediately evident to consumers. Hence, companies that innovate in these areas need to have a long-term view.

IV. RESEARCH METHODOLOGY

The results of detailed survey conducted in various manufacturing enterprises in the northern region of India covering the states of Punjab, Haryana, Himachal Pradesh, Rajasthan, Uttar Pradesh, Delhi and Union Territory of Chandigarh have been presented, analyzed and discussed. The survey has been limited to those medium and large scale manufacturing enterprises of the northern region, which are in process of acquiring, developing or utilizing smart manufacturing for improving productivity and accelerating innovation. The survey has been conducted to determine the role in smart manufacturing for improving productivity and accelerating innovation.

As this study is an empirical one, it was determined to review the medium and large scale manufacturing organisations of North India, which are in the course of implementing smart manufacturing at different levels, using structured mailed questionnaires. The questionnaire was designed to find out the current status of different aspects of the organisation. The reliability of the constructs and their measures were obtained and correlation analysis, canonical correlation and multiple linear regression, were employed to predict the results.

A. Reliability of item measures

Item measures for smart manufacturing, productivity and innovation were adapted from existing scales. Individual item measures were developed that are posited to impact manufacturing informatics in the study and are shown in Table II as psychometric properties of measures. This approach is consistent with previous research studies that employ single-scale items for manufacturing variables. A 1–5 (very low/very high) Likert-type scale has been employed for all item measures in the questionnaire.

The reliability of the scale was obtained through the reliability analysis for finding out the value of Cronbach's alpha for all the measuring instruments. Cronbach's alpha is calculated for each scale, as recommended for empirical research in operations management. Table II shows Cronbach's alpha values calculated for scales used. Cronbach's alpha value for each scale is greater than 0.85, which is considered adequate for exploratory research.

TABLE:2 CRONBACH'S ALPHAFOR INDEPENDENT AND DEPENDENT VARIABLES

Dependent Variable	**Description**	**Cronbach's Alpha**
PDV	Productivity	0.958
INN	Innovation	0.868
Independent Variable	**Description**	**Cronbach's Alpha**

Dependent Variable	Description	Cronbach's Alpha
SM	Smart Manufacturing	0.890
FMS	Flexible manufacturing system	0.926
MI	Manufacturing intelligence	0.937
SMES	Smart Manufacturing Execution System	0.958

B. Data collection and design of questionnaire

The collection of data was done in three phases. In the initial phase thorough consultation with manufacturing supervisors in certain plants of different organisations was carried out, to verify the validity of the questionnaire and sample structure features. The aim is to validate that responses were based on accurate elucidation of the questions. In the next phase, a final planned survey questionnaire comprising 126 questions was prepared and mailed to 400 respondents. In the final phase, a reminder with a replica survey was sent to all non-respondents of the initial mailing. One hundred and twenty four responses were received, having a response rate of 26%. This response rate matches fit with the response rates for studies in operations management (Handfield and Pannessi, 1995; Suarez et al., 1996). A comparison between the respondents to our first and second mailings revealed no significant differences in terms of organisation size or respondent level. After eliminating the unusable responses, only 104 responses were finalized for further usage. The breakdown of responses from the manufacturing organisations comprises automobile and heavy earth-moving machinery organisations (16), mechanical sub-assembly organisations (50) – consumer goods manufacturer (20) and process organisations (18). Among the 104 (100%) respondents, 16% were the automobile manufacturers, 48% industries were the automobile component manufacturers, 19% industries were consumer goods manufacturers and remaining 17% were process industries. The industry-wise breakup is shown in figure 1.

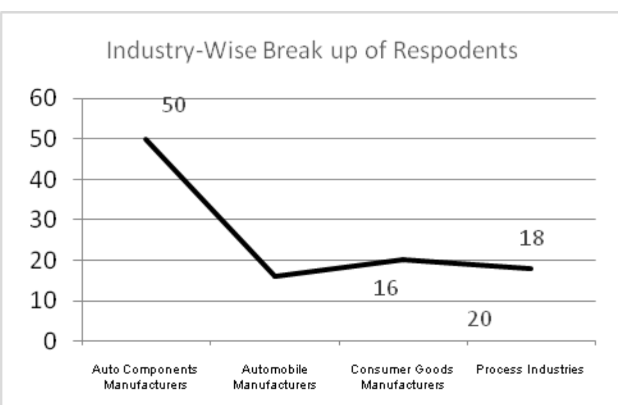

Fig.1 Industry-wise breakup of respondents

Figure 2 indicate that among the respondents, the 18% industries have authorized capital less than Rs. 100 crore, another 31% have between 100 to 250 crore, 21% have 250 to 500 crore and remaining 30% have authorized capital above Rs. 500 crore. It implied that 18% industries (with authorized capital less than 100 crore) are medium scale industries where as all other are large scale industries.

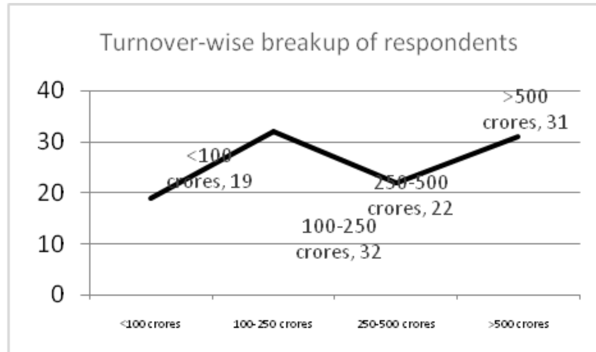

Fig.2 Turnover-wise breakup of respondents

Figure 3 show that out of 104responses, the 13% industries are less than 5 years old, another 13%are between 5 to 10 years old, 17%are between 10 to 15 years and remaining 57% are more than 15 years old.

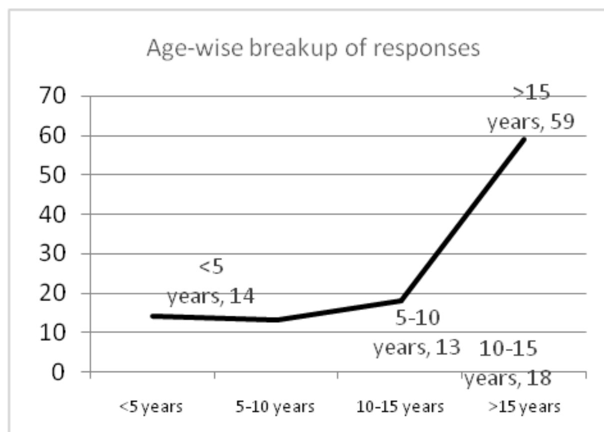

Fig.3 Age-wise breakup of responses

C. Status of smart manufacturing

Manufacturing has been evolving over the years as different needs and technologies arise. India, a large developing country with a population of more than 1.25 billion, has experienced fast and stable economic growth in the past decade. The customer of the twenty-first century, demands products and services those are fast, right, cheap and easy. The quest for lower operating costs and improved manufacturing efficiency and introduction of innovative concepts has forced a large number of manufacturing firms to embark on smart manufacturing (SM) projects of various types. SMs have been heralded as new way for manufacturing companies to gain a competitive advantage. The dramatic developments in SM at various organizational levels can be attributed to numerous benefits that improve the competitive position of the adopting companies. SM impact not just manufacturing, but also the whole business operations, giving new challenges to a firm's ability to manage both manufacturing and manufacturing informatics. This survey has highlighted very interesting results related to the current status of manufacturing informatics. In this section the data has been collected from the organizations to understand and explicate the process of MI adoption as a part of their business strategy. Out of the respondents companies, 7% companies rarely, 16% adopt sometimes, 47% normally whereas remaining 30% always adopt SM for improving productivity and accelerating innovation.

V. DATA ANALYSIS

To empirically assess the role of smart manufacturing in improving productivity and accelerating innovation, our key objective in data analysis is to study the association between independent and dependant variables. Since our concern centred on investigating the relationships between a set of multiple independent and multiple dependent variables with little past information of such relationships, canonical correlation analysis followed by regression analysis are deemed to be the suitable multivariate statistical methods to use (Hair et al., 1995). The pair-wise correlations between variables were examined to establish the mutual association and to avoid the problem of multi-collinearity. They were found to be discriminant-valid and are presented in Table III.

TABLE:3 CORRELATIONS BETWEEN INDEPENDENT AND DEPENDENT VARIABLES

	SM	FMS	MI	SMES	PDV	INN
SM	1	.534	.437	.574	.608	.520
FMS	.534	1	.706	.669	.762	.667
MI	.437	.706	1	.749	.781	.741
SMES	.574	.669	.749	1	.796	.660
PDV	.608	.762	.781	.796	1	.750
INN	.520	.667	.741	.660	.750	1

The canonical correlation measures the bi-variate correlation between linear composites of the independent (smart manufacturing) and dependent variables (productivity and innovation). The inbuilt flexibility of canonical correlation in accordance with types and number and of variables used, both independent and dependent, makes it a rational contender for numerous of the more difficult problems addressed with multivariate techniques. Canonical correlation analysis handles the association among composites of sets of multiple independent and dependent variables. As a result, it generates a number of independent canonical functions that maximize the correlation between the linear composites, also known as canonical variates, which are sets of independent and dependent variables. Every canonical function is in fact based on the correlation between two canonical variates, one variate for the independent variables and one for the dependent variables. One more unique trait of canonical correlation is that the variates are imitated to maximize their correlation. Furthermore, canonical correlation never ends with the imitation of a single relationship between the sets of variables. As an alternative, many canonical functions (pairs of canonical variates) may be imitated. The utmost number of canonical variates (functions) that can be extracted from the sets of variables matches the number of variables in the smallest data set, dependent or independent.

Table IV shows the analysis results of canonical correlation. A strong and statistically significant ($r = 0.897$; $p < 0.001$) canonical correlation was found between the independent set of smart manufacturing and the dependent set of productivity and innovation. The validity of the canonical loadings was assessed through stability runs by eliminating one variable at a time and re-executing the canonical correlation analysis due to the modest sample size. Of interest are the stability of the canonical loadings and the statistical significance of the univariate and step down F tests for the canonical correlation function. Canonical loadings measure the correlation between the individual dependent and independent variables and their individual canonical variates, and are analogous in interpretation to factor loadings. Columns 3, 4, 5 and 6 in Table IV show the results of these stability runs corresponding to the elimination of SM, FMS, MI and SMES respectively. The canonical loadings for the independent variate ranged from 0.615 to 0.812. PDV and INN also loaded strongly (0.979 and 0.869 respectively) on the dependent variate. Stability runs, eliminating independent variables in turn, were held. The stability of the canonical loadings in indicated by results in Columns 3, 4, 5, and 6 in Table IV.

The calculation of canonical cross-loadings has been recommended as a superior technique to deduce the results in canonical correlation analysis in comparison to canonical weights or canonical loadings (Hair et al., 1995). This method correlates every original observed independent canonical variate directly with the dependent variable, and vice versa. Cross-loadings offer a more direct measure of the independent-dependent variable associations by dropping an intermediate step involved in conventional loadings. The cross-loadings of independent variables from the analysis show that SM, FMS, MI and SMES have the major contribution to the dependent set, which is PDV and INN combined, with cross-loadings of 0.686 and above.

The redundancy indices were 0.689 and 0.569 for the dependent and independent canonical variates, respectively. The redundancy index shows the amount of variance in a canonical variate explained by the other canonical variate in the canonical function. As can be seen, the redundancy index for the dependent variate is considerable. The high redundancy of the independent variate results from the relatively high-shared variance in the dependent variate(0.857), not the canonical R2. The independent variate, however, has a markedly lower redundancy index (0.708).

TABLE:4 RESULTS OF CANONICAL CORRELATION ANALYSIS ALONGWITH STABILITY ANALYSIS

	Results with all variables		Results after the deletion of			
			SM	FMS	MI	SMES
Canonical Correlation	0.897		0.886	0.881	0.871	0.884
Canonical Root	0.804		0.784	0.776	0.758	0.781
f statistic	0.000		0.000	0.000	0.000	0.000
Dependent variate	Canonical Cross Loadings	Canonical Loadings	Canonical Loadings			
PDV	-0.878	-0.979	-0.980	-0.977	-0.989	-0.972
INN	-0.779	-0.869	-0.867	-0.873	-0.841	-0.884
Shared Variance	0.857		0.856	0.859	0.842	0.863
Redundancy Index	0.689		0.673	0.667	0.639	0.675
Independent Variate	Canonical Cross Loadings	Canonical Loadings	Canonical Loadings			
SM	-0.686	-0.615	--	-0.697	-0.707	-0.694
FMS	-0.865	-0.776	-0.875	--	-0.890	-0.876
MI	-0.905	-0.812	-0.916	-0.922	--	-0.920
SMES	-0.890	-0.799	-0.901	-0.905	-0.920	--
Shared Variance	0.708		0.806	0.719	0.713	0.699
Redundancy Index	0.569		0.633	0.558	0.541	0.546

VI. RESULTS AND DISCUSSIONS

This study presents the first empirical evidence for depicting the role of smart manufacturing for improving productivity and accelerating innovation in large and medium scale organisations of North India. The role of smart manufacturing has been explored and examined for achieving productivity and innovation in an organisation. It has been statistically found that the different constituents of smart manufacturing have a positive impact on the achievement of productivity and innovation. It is found that there is a vast role of flexible manufacturing system, manufacturing intelligence and smart manufacturing execution system in modifying products in real time, achieving productivity and innovation. It has been observed that organisations have shifted their mind focus towards the smart manufacturing for achieving productivity and innovation. It has been found that a strong positive correlation (0.796) exists between smart manufacturing execution system & productivity and (0.741) between manufacturing intelligence and innovation of this study. A plant with smart manufacturing execution system and manufacturing intelligence will operate more efficiently and smartly to improve productivity and accelerate innovation.

VII. CONCLUSIONS

This research examined the role of smart manufacturing for achieving productivity and innovation in an organization. Empirical evidence was offered to maintain associations between smart manufacturing, productivity and innovation. Innovation and productivity will be the key for pushing toward faster and more frequent product transitions while operating globally. The results recommend that smart manufacturing is quite important to manufacturing organisations for increasing productivity and accelerating innovation. The role of implementing the soft, intermediate and hard technologies was explored and found to be less significant when compared to the SM and leads to the connotation that a strategic shift has been witnessed towards the virtual organisations. Smart Manufacturing is most responsive in the context of performance and innovation oriented production.

It is identified that substantial innovations have been achieved in the previous years in information and communication technologies. These innovations are permitting the deployment of distributed and real-time embedded computing systems that can be converted into vital elements to the development of smart manufacturing. The paper explained the concept of smart manufacturing and presented some reviewed literature that get advantage of these innovative technological environment. This study can lead to new levels of business optimization as organizations become smarter about the performance metrics and the way they collect information to measure optimal productivity.

VIII. FUTURE RESEARCH

The Smart Manufacturing platform can be designed to address barriers to technology incorporation across all operations and human resources, break through the continued focus on optimizing individual unit processes that is reaching a point of diminishing returns from future investments in advanced manufacturing technology. The platform can be designed to extend modeling and simulation capabilities to those enterprises that do not have the capacity to deploy. These technologies will contribute to major improvements in product and process design and to more efficient and flexible shop floor operations, in future.

The limitations of this research may be carried out by future investigators. In this study, the size of the sample may be increased upto 150 companies. In addition, the author would like to restraint against the generality of the outcomes of this study outside framework of north India, even though the research provides partial support for the justification of accomplishment in implementing SM in medium & large scale enterprises as stated by a consortium of researchers in other developing countries.

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