An Empirical Study to Examine the Role of Manufacturing Informatics in Smart Manufacturing

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***Abstract*—** Smart Manufacturing(SM) being a technology plays a vital role in the enhancement of the performance of an industrial unit by incorporating different zones of engineering, both in terms of resources and informatics. Smart Manufacturing integrates manufacturing informatics (MIT) in real-time through an entire manufacturing process in medium and large companies. In the present era many reports are there that are dealing with the technical and operative characteristic of SM, but the role of manufacturing informatics as a vital element in the deployment of SM is not considered fully. Recognising the significance of role of MIT in SM, an empirical study has been carried out & presented in this paper with the purpose of achieving additional awareness.

Keywords- *Manufacturing Informatics, Smart Manufacturing, Flexible Manufacturing System; FMS, Information and Communication Technology; ICT, Enterprise Resource Planning; ERP, Cyber Physical Production System; CPPS.*

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I. Introduction

Manufacturing informatics (MIT) refers to the usage of novel and innovative Information & Communication Technology (ICT) tools and methodologies for tomorrow's manufacturing technologies, systems and processes. MIT is a manufacturing foundation, which primarily concerns efficient depiction, logical disposal and procedure of manufacturing information. Information is not only the leading feature but also the most vigorous actuation factor in digital manufacturing. One of the main technologies of digital manufacturing is enhancing the information processing ability of the manufacturing system [4][27][29][31].The usage of ICT to achieve reasonable benefit has become a vital tactical concern amongst companies in the rapid globalizing atmosphere as ICT plays a strategic role in the administration of organization[3]. The production tasks that can be controlled and monitored with ICT are increasing in number as well as complexity, allowing rapid production with improving precision [17][22]. A wide range of research is currently rising with the development of highly productive web and cloud technologies (service orientation, cloud manufacturing). This development accelerates the shift from industrial automation to integration of classical computer science or web technologies in near real-time control platforms of manufacturing.

Smart manufacturing is extremely knowledge demanding and information and communication technology plays a vital role in enhancing manufacturing-intelligence, association, rising effectiveness, and evolving new business models and technologies. SM is considerably intensified application of 'manufacturing intelligence' throughout the manufacturing and supply chain enterprise to both lead and respond to a dramatic and fundamental business transformation toward demand-dynamic economics, performance-based enterprises, demand-driven supply chain services and broad-based innovation and workforce. This amplification of 'manufacturing intelligence' 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. The manufacturing firms are intensively positioning a host of software/ hardware information/automation technologies in order tackle the varying societal atmosphere pulled by the growing customization of goods and services as required by consumers. "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].

A few of the initial Indian firms those adopted ERP practices are Sony India Private Limited, Godrej Soaps, ONGC, , Rallis India, Kirloskar, ESSAR, Glaxco, HLL and others There was a positive shift for improved productivity in most of these companies [5]. The ERP systems are designed to achieve integration and thereby streamline internal processes [21].To take significant advantage from ERP system, the organisations should assimilate their enterprise application solutions to their suppliers [12]. The accuracy of information becomes important if information is to replace inventory. This is achieved through the implementation of ERP system which helps in getting real-time information for better planning and control of manufacturing operations.

The term "cyber-physical production system" is often used to emphasize the strong interlink and interdependence of the digital (cyber) and physical components of modern production systems consisting of complex interactions of systems of systems. CPPS are networks of autonomous entities merging the physical and digital worlds. CPPS consist in the integration of physical systems, including sensors and actuators with digital ones, typically computer-based systems[13] . They are expected to significantly improve industrial performances expressed in terms of agility, efficiency and reconfigurability [19]. Prior to the recent development of CPPS, some research efforts have been done with the objective to propose decision-making process models or optimization models that were integrated into innovative architectures such as Holonic Manufacturing Systems (HMS) and Product Driven Systems (PDS) [7][18].CPPS could logically gain from the experience capitalized from these prior works. The sustainability aspect of the integration of CPPS in manufacturing is a great concern, from the energy delivery of factories through newly developed grids to the management of energy throughout the production shop floor [1][11].Furthermore, a wide range of research is currently rising with the development of highly productive web and cloud technologies (service orientation, cloud manufacturing) [2]. This development accelerates the shift from industrial automation to integration of classical computer science or web technologies in near real-time control platforms of manufacturing. CPPS implements mass manufacturing, but mass customization needs to be designed in advance, and it is often found that consumer is not clear what their requirements are [20] as said by world‘s innovative company Apple Inc. CEO 'people don‘t know what they want, until you show it to them' [10]. The sudden management of data will lead to evolution for the innovation by this constant communication and linkage that IoT enables and with this data aim to move from manually innovation like many successful company leaders (Steve Jobs, Henry Ford, etc…) to automation of this process.

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 I. SUMMARY OF LITERATURE REVIWED

Author(s) and year	Key Findings
Balsmeier and Nagar (2002)	According to this study the author found that few of the initial Indian firms those adopted ERP practices are Sony India Private Limited, Godrej Soaps, ONGC, , Rallis India, Kirloskar, ESSAR, Glaxco, HLL and others. There was a positive shift for improved productivity in most of these companies [5].
Kemppainen (2004)	The author suggested that the ERP systems designed to achieve integration and thereby streamline internal processes [21].
Davenport and Brooks (2004)	The author suggested that to take significant advantage from ERP system, the organisations should assimilate their enterprise application solutions to their suppliers [12].
Chen and Paulraj (2004)	The authors found that the accuracy of information becomes important if information is to replace inventory. This is achieved through the implementation of ERP system which helps in getting real-time information for better planning and control of manufacturing operations [8].
Lal (2005)	The findings of the study suggested that there are marginal increase in the employment productivity and effectiveness of firms that adopted information and communication technology.
Morel et al. (2005).	The authors 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].
Lee (2006	The author suggested that cyber-physical production systems are networks of autonomous entities merging the physical and digital worlds. It consist in the integration of physical systems, including sensors and actuators with digital ones, typically computer-based systems[13].
Shin (2006); Teoh et al.(2008)	The key finding of this study 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].
Frost and Sullivan (2008)	The authors found that because of the increasing cut-throat pressure several Indian firms are going to adopt ERP system which offers unrestricted entrance to information and permit them to contend efficiently [15].
Chen and Yin (2010)	In this study the authors explored that ERP support changes in user's logistics; the change of functional performance primarily occur in the initial year after implementation of ERP, and, the operating performance of ERP users is improved than non-users even before the implementation of ERP[9].
Mekid, Pruschek and Hernandez (2009); Isermann 2011)	The key findings of the study was 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)	The author 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)	The author proposed that the better use of ICT in manufacturing acquaintances the design phase of a component to the bigger assembly manufacturing system to

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Author(s) and year	Key Findings
	the use of finished goods [16].
Apulu and Latham (2011)	The authors found that ICT plays a strategic role in the management of organization to gain competitive advantage amongst organizations in the fast globalizing environment [3].
Jantunen et. Al (2011)	The author found that the phrase "cyber-physical production system" highlights the strong connect and inter-dependence of the cyber (digital) and physical mechanism of contemporary manufacturing set-up comprising of multifaceted communications of systems [14].
Trentesaux et. Al. (2014) & Thomas et. Al. (2014).	The authors suggested that cyber physical production system could logically gain from the experience capitalized from these prior works. Finally, the sustainability aspect of the integration of CPPS in manufacturing is a great concern, from the energy delivery of factories through newly developed grids to the management of energy throughout the production shop floor[1][11].
Colombo et al. (2014)	The author found that a wide range of research is currently rising with the development of highly productive web and cloud technologies (service orientation, cloud manufacturing). This development accelerates the shift from industrial automation to integration of classical computer science or web technologies in near real-time control platforms of manufacturing[2].
Herrera et. Al. (2014) and Barbosa et. Al. (2015)	The authors suggested that prior to the recent development of CPS, some research efforts have been done with the objective to propose decision-making process models or optimization models that were integrated into innovative architectures such as Holonic Manufacturing Systems (HMS) and Product Driven Systems (PDS)[7][18].
Lee et. Al. (2015).	The authors found that cyber physical production systems are expected to significantly improve industrial performances expressed in terms of agility, efficiency and reconfigurability[19].
Saldivar, et. Al., (2016)	The results of this study show that Industry 4.0 value chain aims to enable a novel stage of mass customization for improved firm performance. An analytics framework for incorporation with big data analysis, business informatics, cloud computing, CPS, and communication technologies in a digital manufacturing system was developed[25].
Wang, Wan, D. Li, Zhang (2016)	The authors suggested that, the smart factory of Industrie 4.0 can be setup with the help of Internet of Things, big-data, and cloud-computing together with artificial-intelligence. The smart machines and products can communicate and negotiate with each other to reconfigure themselves for flexible production of multiple types of products. The smart factory can be implemented in a progressive way, along with the unstopped technical advancements [24][31].

III. Development of Measurement Construct

The theory and categorization of manufacturing informatics and smart manufacturing 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.

A. Smart manufacturing(SM) synonyms Advanced Manufacturing Technology (AMT)

The quest for innovation and improved productivity has pushed a huge segment of entire manufacturing sector 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), Computer-Aided Design (CAD), Manufacturing Resource Planning (MRP II), Computer Numerical Control (CNC) machines, Automated Storage and Retrieval System (AS/RS), Direct Numerical Control (DNC) machines, Automated Material Handling Systems (AMHS), Robotics (RO), Automated Guided Vehicles (AGV), Material Requirement Planning (MRP), Statistical Process Control (SPC), Activity-Based Costing (ABC), Rapid Prototyping (RP) and Office Automation (OA).

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, JIT, etc. Some researchers provided the construct of interest to this research due to huge scope, exceed automated machine typology to wrap information technology, CAD/CAM, use of JIT/Kanban, administrative processes and configurational processes in their depiction of an sophisticated manufacturing organization. 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

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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.

B. *Various domains of Smart Manufacturing*

In depth investigation of the above theories divulge three obvious SM domains: a design domain that is concerned mainly with design technologies, a manufacturing domain that involves typically process-related technologies, and an infrastructural domain that includes production planning and control information. Key aspect of successful Smart manufacturing execution systems that researchers have abandoned to amalgamate under the rubric of SM, is the humanware.

IV. RESEACH METHODOLY

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 manufacturing informatics for smart manufacturing. The survey has been conducted to determine the present status manufacturing informatics and its role in smart manufacturing.

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 manufacturing informatics and smart manufacturing 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 1 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 0.8, which is considered adequate for exploratory research.

TABLE II. CRONBACH'S ALPHA FOR INDEPENDENT AND DEPENDENT VARIABLES

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
Independent Variable	**Description**	**Cronbach's Alpha**
ICT	Information and Communications Technology	0.956
ERP	Enterprise Resource Planning	0.908
MIT	Manufacturing Informatics	0.923
CPPS	Cyber-physical production system	0.943

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.

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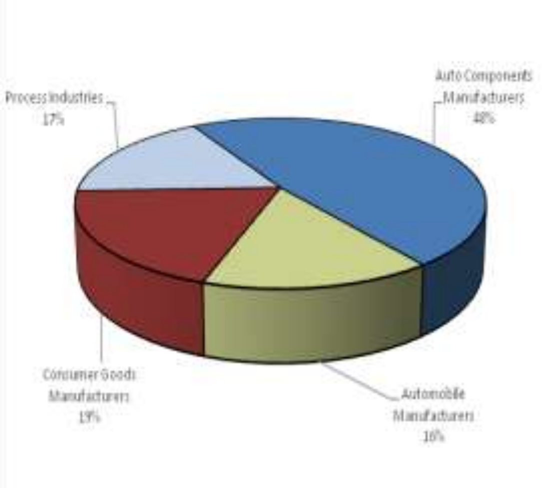

Fig. 1 Industry-wise breakup of respondents

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.

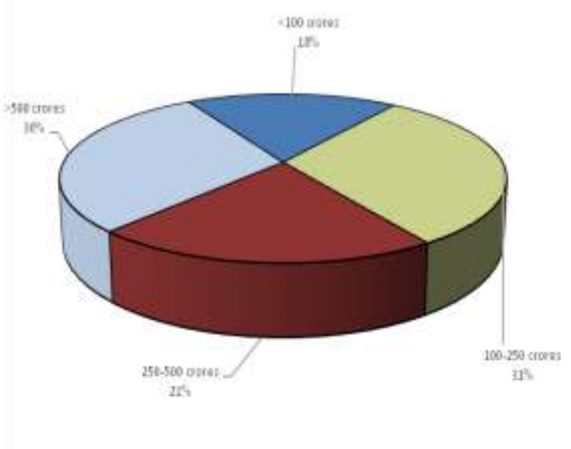

Fig.2 Turnover-wise breakup of respondents

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.

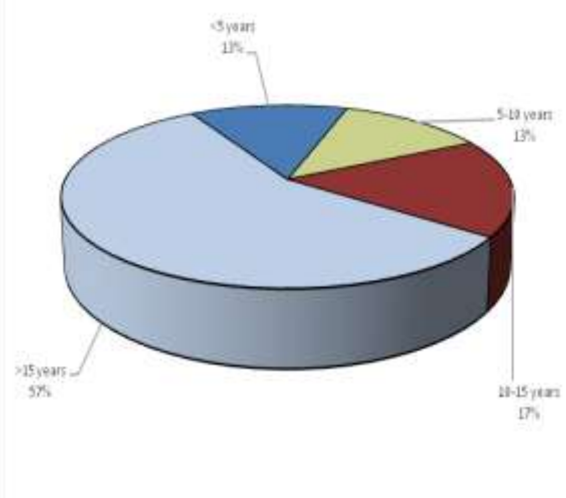

Fig.3 Age-wise breakup of responses

C. Status of manufacturing informatic and 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 adopt MI for SM, 16% adopt sometimes, 47% normally adopt where as remaining 30% always adopt.

V. DATA ANALYSIS

To empirically assess the role of manufacturing informatics in smart manufacturing 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

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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 III. CORRELATIONS BETWEEN INDEPENDENT AND DEPENDENT VARIABLES

	ICT	ERP	MIT	CPPS	SM
ICT	1	.699	.774	.660	.438
ERP	.699	1	.862	.750	.413
MIT	.774	.862	1	.777	.431
CPPS	.660	.750	.777	1	.358
SM	.438	.413	.431	.358	1

The canonical correlation measures the bi-variate correlation between linear composites of the independent (manufacturing informatics) and dependent variables (smart manufacturing). 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 ($r = 0.787$; $p < 0.001$) canonical correlation was found between the independent set of manufacturing informatics and the dependent set of smart manufacturing. 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 3 show the results of these stability runs corresponding to the elimination of ICT, ERP, MIT and CPPS respectively. The canonical loadings for the independent variate ranged from 0.852 to 0.935. SM, FMS, MI and SMES also loaded strongly (0.531, 0.834, 0.965 and 0.859 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 3.

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 ICT, ERP, MIT and CPPS have the major contribution to the dependent set, which is SM, FMS, MI and SMES combined, with cross-loadings of 0.671 and above.

The redundancy indices were 0.410 and 0.507 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 independent variate (0.818), not the canonical R2. The independent variate, however, has a markedly higher redundancy index (0.507).

TABLE IV. RESULTS OF CANONICAL CORRELATION ANALYSIS ALONGWITH STABILITY ANALYSIS

	Results with all variables		Results after the deletion of			
			ICT	ERP	MIT	CPPS
Canonical Correlation	0.787		0.761	0.783	0.782	0.784
Canonical Root	0.619		0.579	0.613	0.611	0.614
f statistic	0.000		0.000	0.000	0.000	0.000
Dependent variate	**Canonical Cross Loadings**	**Canonical Loadings**	**Canonical Loadings**			
SM	- 0.418	- 0.531	- 0.536	- 0.538	- 0.514	- 0.537
FMS	- 0.656	- 0.834	- 0.811	- 0.844	- 0.821	- 0.841

MI	- 0.760	- 0.965	- 0.957	- 0.968	- 0.963	- 0.965
SMES	- 0.676	- 0.859	- 0.893	- 0.837	- 0.875	- 0.851
Shared Variance	0.662		0.664	0.660	0.658	0.663
Redundancy Index	0.410		0.385	0.405	0.402	0.407
Independent Variate	**Canonical Cross Loadings**	**Canonical Loadings**	**Canonical Loadings**			
ICT	- 0.730	- 0.928	--	- 0.936	- 0.930	- 0.934
ERP	- 0.709	- 0.901	- 0.942	--	- 0.913	- 0.901
MIT	- 0.736	- 0.935	- 0.962	- 0.941	--	- 0.940
CPPS	- 0.671	- 0.852	- 0.886	- 0.851	- 0.862	--
Shared Variance	0.818		0.866	0.828	0.814	0.856
Redundancy Index	0.507		0.502	0.508	0.497	0.525

VI. Result and Discussons

This study presents the first empirical evidence for depicting the role of manufacturing informatics in smart manufacturing in large and medium scale organisations of North India. The role of manufacturing informatics has been explored and examined for achieving smart manufacturing of an organisation. It has been statistically found that the different constituents of manufacturing informatics have a positive impact on the achievement of smart manufacturing. The role of information and communication technology, enterprise resource planning and cyber physical production system in modifying products in real time, incorporating flexible manufacturing system, manufacturing intelligence and manufacturing execution system to manage the achievement and development of smart manufacturing. It has been observed that organisations have shifted their mind focus towards the optimum use of manufacturing informatics for achieving and developing the smart manufacturing. It has been found that a strong positive correlation (0.777) exists between manufacturing informatics and cyber physical production system of this study. A plant with smart manufacturing will operate more efficiently and smartly, if it has already developed an elevated level of smart manufacturing execution system.

VII. Conclusions

This research examined the role of manufacturing informatics in smart manufacturing. Empirical evidence was offered to maintain associations between manufacturing informatics and smart manufacturing. The results recommend that manufacturing informatics is quite important to manufacturing organisations going for smart manufacturing. The role of implementing the soft, intermediate and hard technologies was explored and found to be less significant when compared to the MIT and leads to the connotation that a strategic shift has been witnessed towards the virtual organisations. 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 manufacturing informatics & smart manufacturing and presented some reviewed literature that get advantage of these innovative technological environment. With the evolving of technology, the instant challenge is how to permit designers to organize this technology in the market. The research is required to carry on covering innovative facets those are being influenced by the advancement in both software and hardware technology.

VIII. Future Research

The future research of manufacturing informatics comprises the dependable attainment, depiction, transmission, storage and use of real-time industrial information and manufacturing proficiency. It also includes digital depiction of insignificant developed knowledge, such as fuzzy and sense knowledge etc. 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 MIT in medium & large scale enterprises as stated by a consortium of researchers in other developing countries.

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