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Developing Measures of Automation Implementation in Indian Industries

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Abstract

In the international business market, Automation has increased the competence of Indian Industry by making them fast, error free and providing them with greater customization option. This paper performs the review of automation and attempts to develop a framework for the implementation of automation by validating "IMPLAUT" (IMPLementing AUTomation) for Indian Industries. An exhaustive literature survey proceeded by simple meta-analysis have been carried out to find out various research gaps and further to address these gaps few objectives of this research study have been explored. For developing model for automation, the different variables are explored using 'Churchill's approach' as may be applicable to Indian industrial scenario. It is evident from the model of "IMPLAUT" that automation will lead to the rise of competence in Indian industry provided the various input and output model suggested by the generic model are to be kept in view. It has been observed that the application of "IMPLAUT" reduces the manufacturing and downtime therefore increasing the overall efficiency of the industry. So "IMPLAUT" can be further researched and must be considered as an emerging field for research in engineering discipline.

Keywords: Automation, IMPLAUT, classification schemes, Meta analysis, dimensions

1. Introduction

It is an established fact that automation has contributed to a large extent in Indian industry by simplifying and adding synergy top various functionaries. Automation is a step beyond mechanization and plays an increasingly important role in the world economy and in daily experience and has been responsible for the shift in the world economy from industrial jobs to service jobs in the 20th and 21st centuries.

The last decade is evident of the achievement in Indian industries by the use of automation techniques. Here we perform the review of automation and then develop a framework for the implementation of automation by validating "IMPLAUT" (IMPLementing AUTomation). On the basis of exhaustive literature survey followed by simple meta-analysis, various research gaps have been identified. To address the research gaps, objectives for this research study have been explored.

For developing model for automation, the different variables are explored as may be applicable to Indian industrial scenario. For this purpose, Churchill's approach is followed. It includes eight main steps. First, the domain of the Construct "IMPLAUT" is specified. Sample of governing variables are generated at the second stage. At third stage, initial data is collected by sending a questionnaire to experts and officials of sixty companies. By using mathematical and statistical analysis, the gathered data is refined at fourth stage. New data is collected for further refinement of information of "IMPLAUT" under fifth stage. The received information is evaluated for reliability assessment and validity assessment at the sixth step of this approach. Different norms are developed on the basis of refined information at the seventh stage. The model of "IMPLAUT" construct is developed in synchronization with other agents to add synergy to various functionaries in Indian industry at the eighth stage.

The findings and conclusion of the research study lies in the revelation of the applicability and scope of automation in Indian industry. From the model of "IMPLAUT" it is inferred that automation will lead to the rise of competence in Indian industry if it is applied keeping in view the various input and output model suggested by the generic model. It has also been observed that the application of "IMPLAUT" also helps to reduce the downtime. This leads to increase in overall efficiency of the industry. On the basis of research study conducted, it can be easily concluded that proper implementation of automation not only benefits the growth and profitability of the industry but also the end user customer by improving the quality of the end product.

2. Literature survey

Technology has brought about major changes in the techniques that have been applied for achieving automation. There is vast literature available that discuses the change in technologies for achieving automation form NC technology to artificial intelligence. J. Garrido Camposa and M. Hardwick (2009)[1] in their paper address manufacturing traceability requirements specification and the automation of manufacturing data collection. The proposed approach is to link traceability requirements to feature data to take advantage of features as the kernel technology for CAD/CAM integration. The paper proposes a solution based on NC functions that automates and integrates manufacturing traceability for STEP compliant CAD, CAM and CNC systems. The paper presents the new NC functions and a prototype implementation.

G. Reinhart et al (2008)[2] provide a promising approach to the automation of flow assembly lines. The developed system uses a standard industrial robot and synchronizes it to the product in all degrees of freedom. The synchronization is enabled by dividing the assembly process in different phases and controlling the robot in each phase with an adequate sensor system. Besides that compliance is integrated into the gripper system in order to reduce high contact forces and tolerate high frequent pose deviations.

R.W. Brennan et al (2008)[3] provided an overview of current techniques to allow the industrial systems to automatically adapt to change while maintaining predictable and stable system behavior. This is performed along the dimensions of simple, dynamic and intelligent reconfiguration and focuses on the physical device and software component levels of the shop floor and in particular, on automatic reconfiguration of programmable logic controller systems. The paper identifies the basic requirements for intelligent reconfiguration and the outstanding issues in this area.

Apart from developments in technology much research has been done on various other dimensions of automation such as economic aspects human involvements and influence of many process governing parameters. Margret Bauer, Ian K. Craig (2008)[4] in their paper review economic assessment methods that link the variation of key controlled process variables to economic performance quantities methods and incorporate them in a framework for the economic evaluation of APC projects. The results give information about the state-of-the-art assessment of economic benefits of advanced process control.

J. ElinBahner et al (2008)[5] in their paper investigates automation misuse based on complacency and automation bias in interacting with a decision aid in a process control system. The effect of a preventive training intervention which includes exposing participants to rare automation failures is examined. Complacency is reflected in an inappropriate checking and monitoring of automated functions

Mathias Jhonsson et al (2011)[7] in their paper presents a strategy for achieving volume flexibility in assembly lines, so that varying production demands can be met. The strategy involves providing assembly lines inherent cycle-time flexibility, through creating the possibility for operators to handle multiple work stations. A basic part-cost model serves as a basis for analyzing the cost effects of different staffing alternatives, its taking account of different performance parameters and numbers of operators. It is shown how the costs are affected by the production performance of the work force in question, temporary operators being expected to display a somewhat lower level of performance than permanent workers.

2.1 Evolution of automation concept and techniques

Although automation has impacted the industrial sector as a whole there are various dimensions that have surfaced which specifically illustrate the contributions of automation. These fields include technology, economics, organization and process oriented. Automation gives scope for development of new technologies in the industries today which are user friendly as well as more productive. The economic sector has been the most influenced field. Despite of various concerns about the initial cost of investment it can be safely said that automation has taken the world economy to a higher level. Labor force has been an important parameter in any organization. Man-machine relationship is quite complex and has posed trouble in successful implementation of automation. Not only this, automation has increased manifold the process parameters such as quality, volume of production and adaptability etc.

Table 2.1 shows the primary dimensions and related variables identified during the extensive literature survey that was carried out.

2.2 Classification Method

Based on the conducted literature survey and the explored dimensions of automation, two classification schemes have been introduced to systematically organize the research findings.

The first classification scheme as shown in Figure 2.1 focuses on the time span of developments in automation. The 37 variables that were used to develop the information framework were clustered into four different categories according to the purpose or field of implementation in relation to automation. These categories included technological parameters, economical parameters, organizational parameters and process oriented parameters.

The first category includes all the technical modifications that have taken place in the field of automation since its inception and the parameters that govern these changes. The technological changes vary from computer aided process controls to recent developments like artificial intelligence including tools such as neural networks and fuzzy logics. Further concepts of flexibility and adaptability are also deep seated in the technological aspects of automation. The second category includes the parameters that influence the cost and cost effectiveness of implementing automation. All factors related to costs have been included in this category. The third category deals with the human involvement and their relationship with the machines. All parameters that affect the man machine interface are discussed under this category. The fourth category deals with the process governing parameters in automation which includes functionality, safety, machine life, etc. Each category is further sub divided into perceptions of each variable associated with the respective category.

The whole scheme has been sorted into two broad time spans- early developments which include developments before the year 2005 and recent developments which include the years from 2005 to 2012. The changes developed in the two time spans show remarkable differences. For instance, early developments show a great deal of emphasis on the economic aspects of automation than in the latter years which focus mainly on the cognitive aspects of automation. Also, recently more emphasis is laid on improving man machine relationship.

The second classification scheme as shown in Figure 2.2 views automation from a commercial point of view. Here the variables along with their primary dimensions are categorized according to the functions performed by them in the industries they are applied in. A thorough examination of the Indian industries was done to enlist all the industries of India providing both products and services to the masses. A total of 27 fields were enlisted. These were categorized into three main categories- industrial sector, office automation and cognitive automation. The industrial sector involves manufacturing, textile and other industries which utilize automation mainly on the shop floor and provides products to the consumers. The automation mainly focuses on mechanization and cost effectiveness. The industries included in office automation include banks, media, retailing and telecommunication that provide services to the customer. Thus accuracy and speed are the governing factors which are reflected in the variables associated with this category. The cognitive automation includes sectors such as software, education and hospital where highest level of automation is required.

3. Simple Meta Analysis

Based on the type of data available Simple Meta analysis was performed. Although the nature of information provided by the results of a simple Meta analysis is descriptive it provides a thorough knowledge of the evolution of the concept of automation and its techniques. The analysis was based on the following:

- Distribution of articles by classification scheme
- Distribution of articles according to year of publication
- Distribution of articles Journal wise

3.1 Theorizing research issues and identifying research gaps

The most perceptible change in the field of automation came in the technological aspect. As decades went by, technology became more advanced and sophisticated. This had a clear impact on the methods used to implement automation. Automation became an effective tool to produce high quality products with increased efficiency, with introduction of robotics and artificial intelligence, the level of automation became higher and more complex. Decision support systems came into existence which boosted research in the field of cognitive automation.

Cost has always been an important factor while considering implementation of any technology. The initial apprehension to applying automation was due to its very high initial cost of investment. However, the general trend observed in the study is that cost was an important factor only in the early periods. Not much emphasis has been laid down on the cost effectiveness in recent researches. This may be due to the fact that technology is much cheaper now. Also, people are more concerned with the quality of the product even if it comes at a higher price.

One of the major breakthroughs in the fields of automation has been the involvement of humans and the study of man machine relationship. One question that has troubled every researcher is the level of human involvement in automation. People have proposed theories for complete automation (e.g. smart space automation) while some argue that a certain level of human involvement is necessary. Also, the researchers have taken up the issues of effect of human training and causes for operator errors. The workload and stress on the operators have also been discussed about. Human aspect of automation still remains a very popular topic for research in this field of study.

This extensive literature review exposed many research gaps in the studies conducted in the past. Some of the research gaps are:

- No mathematical model developed for the effects of automation on economic factors (1963)[7]
- No model development is done for the adoption of automation (1990)[8]
- Mathematical relations to optimize the overall productivity are not established (2001)[9]
- The safety aspect of automation is considered without considering the economic factors (1993)[10]
- Impact on environment not considered (2001)[9]
- No parameters developed for comparison of past and present trends (2001)[9]
- Health related issues not discussed, long term effects of office automation not discussed (1962)[11]

These gaps serve as the building blocks for new research in this field. The simple Meta analysis helped to identify and highlight these gaps. Also it provides a foundation for further research in this field. This analysis can be used as a reference to determine the areas that still need exploring and further study. To addresses the identified research gaps, following objective of the research study are proposed.

- To conceptualize the multi-variable construct 'IMPLAUT' such that it satisfy reliability and validity properties.
- To develop information framework on 'IMPLAUT'
- To evaluate/ analyze the variables identified for 'IMPLAUT' such that they satisfactorily fulfill reliability and validity proportion.
- To develop model on 'IMPLAUT'
- To evolve comprehensive set of conclusion for 'IMPLAUT'

4. Research Methodology

After the derivation of research objectives, Churchill's Approach (1979) of methodological research programming has been used for the development of the generic model for "IMPLAUT" construct.

4.1 Specifying Domain for Construct "IMPLAUT" (By Churchill's Approach)

On the basis of wisdom of literature, the domain of the construct "IMPLAUT" have been identified. In the conceptual domain, the scope of different variable in applicability of automation to different industry has been explored followed by its dimensionality. Various decision variable and dimensions that they incorporate have been found and arranged followed by reliability and validity assessment of each and every dimension. Finally, the extracted information is refined to get the results.

For specifying the domain of construct, research is emphasized on the extraction and delineation of the things included and excluded in the definition, therefore conceptual domain include, the scope identification followed by dimensionality verification in hierarchical level. This helped in the articulation of four dimensions in which decision variable for each dimension are found. To get the reliable data, reliability assessment of each and every dimension is done. This is followed by final refinement of data in order to get the exact and error free information.

4.2 Illustrating the Value of Variables

For developing better measure in automation items are generated which capture the domain as specified. The literature indicates how the variables have been defined previously and how many dimensions it has.

The explored variables are as following:

1. R & D
2. Computer Aided production control
3. Flexibility
4. Adaptability
5. Technological Trends
6. Complexity
7. Innovation
8. Product Variety
9. Size of Firm
10. Cost & Capital Effectiveness(Profitability)
11. Growth
12. Ability to meet Demand
13. Return of Investment
14. Human Training & Interface
15. Managerial Aspects
16. Decision Supports
17. Working Environment
18. Risk Analysis
19. Communication
20. Environmental Compatibility
21. Functionality
22. Product Life Cycle Management
23. Operator Error
24. Quality Standards
25. Feasibility
26. Machine Life
27. System reconfiguration capability
28. Safety
29. Software
30. Reliability
31. Sustainability
32. Robustness
33. Scope Of Customization
34. Volume of Product

4.3 Collection of Initial Data

Initial data was collected by consulting the experts and senior officials of Indian and foreign country involved in manufacturing or otherwise. Valuable information was collected from 60 companies. In measuring the scope of automation in different industries; it included discussions with (1) people involved in decision making process (2) technicians (3) maintenance personnel (4) quality control persons. Table 4.1 shows the number of Companies along with the respective Industrial codes.

4.4 Data Refinement of Dimensions

The calculations performed in refinement of dimensions depend on measurement model one embraces. The most logically defendable model is the domain sampling model which holds that the purpose of any particular measurement is to estimate the score that would be obtained if all the variables of the domain are used. The average correlation in the infinitely large matrix, r indicates the extent to which some common core is present in the item. The dispersion of correlation about the average indicates the extent to which item very in sharing the common core. The key assumption in domain sampling model is that all items, if they belong to the domain of the concept have an equal amount of common core. This statement implies that the average correlation in each column of hypothetical matrix is the same and in turn equal to the average correlation in the whole matrix. That is, all the variable in a measure that are drawn from the single construct responds to those variables should be highly inter-correlated. Low inter variable correlation, in contrast indicates that some variable are not extracted from the appropriate domain and producing error and unreliability. Table 4.2 shows Data Refinement chart by standard deviation and correlation coefficient.

In the next step, factor analysis of the core dimensions is performed. For each and every dimensions, design factor are derived i.e. how and up to what extent dimension is contributing to automation. Then communality of each dimension is measured. Also, variance which is a measure of the amount of variation of the values of that variable, taking account of all possible values and their probability or weightings (not just the extremes which give the range) is found, shown in table 4.3.

4.5 Collection of New Data

By mean of internet and personnel visit, new data were collected from 110 companies in the field and rated on five point likert scale. The questionnaire was made for this purpose in accordance to 5 point likert scale ratings.

4.6 Evaluation of Information

On the basis of 5 point likert scale rating, mean importance rating of variables is calculated and awarded the rank accordingly in table 4.4. These variables are classified as important variables, moderately important variables and less important variables in accordance to rank and mean importance rating as shown in table 4.5. Similarly, importance rating of three cardinal dimensions (primary) has been found and ranks are awarded accordingly in table 4.6.

4.7 Reliability Assessment of "Implaut" Construct

Coefficient alpha is a basic statistical coefficient for the determination of reliability of a construct based on internal consistency. Coefficient alpha does not adequately estimate, though error is caused by the factor external to the organization such as politico-legal factor. Therefore, for reliability assessment of IMPLAUT the coefficient alpha is found. For reliability result, $\alpha \geq 0.6$. Table 4.7 shows the coefficient of Alpha Values for Reliability Testing.

4.8 Findings of Information Evaluation and Reliability Assessment

25 decision variables represents Construct "IMPLAUT". 4 Adjuvant Dimension & 22 variables strongly capture the Construct "IMPLAUT" with $\alpha >= 0.60$

Certain variables & dimensions have more impact on Construct "IMPLAUT".

4.9 Information Evaluation, Data Refinement and Construct Validity

By principal component analysis, the cardinal dimensions have been termed as principal component. The evaluation is cross checked and is freed from any bias in order to make the generic model free from irregularity aroused due to wrong assumption, consultations etc.

For the reliability of the construct, $\alpha \geq 0.60$. For validity, construct should possess following four conditions:

- Content validity
- Unidimensionality
- Convergent validity
- Predictive validity

Table 4.8 and 4.9 shows the above validity assessments.

4.10 Development of Generic Model

On the basis of the derived norms from reliability and validity assessments the generic model is developed and shown in table 4.10, four type of variable are considered in the development model-technical, economical, organizational and process oriented.

5. Conclusions, Discussion & Scope for Further Study

On the basis of meta-analysis conducted it can be concluded that the number of published articles before 1990 is very meager. So it is worth assuming that the year 1990 is the starting point of evolution of automation technology in industry.

The present study has determined the amount of research done in the past years on automation techniques and has identified the areas of research that are yet to be explored. Study observed that most of the research work in the field of automation was done after the year 2004. This may be attributed to the fact that by then, both the need and the means were sufficient enough to boost the research in this field. As is seen from the table, immediate spurt in the number of articles published in recent years shows that automation is a widely sort after field of research. Also, discussing the dimensions of automation that were identified in the literature review, it is clear that the technological dimensions are predominant over the other primary dimensions. This is due to the fact that technological advancements have been the driving force behind the evolution of automation techniques.

There were many unexplored areas that surfaced during the study as well as during Meta-analysis. These are opportunities for the future researchers to work upon. Finally, the review cannot be claimed exhaustive but is sufficient to provide a clear understanding of the automation concept and techniques. This analysis can be used as a reference to determine the unexplored areas and for further study.

A generic model for implementation of automation by the name “IMPLAUT” Construct is proposed in which on the basis of literature survey and meta-analysis performed, various variables were suggested. We are hopeful that the proposed model of “IMPLAUT” will help Indian industry in gaining competitive advantage by improving its competence.

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Table 2.1: Primary dimensions and variables of automation

S No.	Primary Dimensions	Variables
1.	Technological	1. R & D 2. Computer aided process control 3. Flexibility 4. Adaptability 5. Complexity 6. Innovation 7. Technological trends
2.	Economical	1. Size of firm 2. Cost and capital effectiveness 3. Growth of industry 4. Return on investment
3.	Organizational	1. Human training 2. Managerial aspects 3. Decision support 4. Working environment 5. Risk analysis
4.	Process Oriented	1. Functionality 2. Operator error 3. Quality standards 4. Machine life 5. Safety 6. Software 7. Reliability

Table 4.1 Industrial Codes and No. of Companies

Standard Industrial Codes	No of companies
Electric works	12
Dairy Products	8
Cut Stone and Stone Products	10
Metal Working Machinery & Allied Products	18
Defense Industry	4
Steel Works	2
Miscellaneous Cement & Textiles Products	2
Food Specialties	2
Industrial Allied Products	2

Table 4.2 Data Refinement chart by standard deviation and correlation coefficient
(Correlation coefficient of r>0.7 signifies strong correlation and r<0.3 signifies weak
*=p<0.10, **=p<0.05, ***=p<0.001)

Dimensions	Mean	S D	1	2	3	4
Technical	2.21	0.76	1.0			
Economical	1.98	0.68	0.41***	1.0		
Organizational	2.78	0.82	0.49***	0.31**	1.0	
Process Governing	2.41	0.87	0.63***	0.44***	0.49***	1

Table 4.3 Communality and Variance

FACTORS	VARIABLES	COMMUNALITY	VARIANCE
Technical aspects	R & D	0.65	18.4
	Computer Aided production Control	0.58	
	Adaptability	0.61	
	Product Variety	0.53	
Economical aspects	Size of Firm	0.62	15.2
	Cost & Capital Effectiveness(Profitability)	0.66	
	Growth	0.67	
	Return of Investment	0.60	
Organizational aspects	Human Training & Interface	0.61	16.4
	Decision Supports	0.63	
	Working Environment	0.62	
	Risk Analysis	0.64	
	Environmental Compatibility	0.57	
Process Governing aspects	Product Life Cycle Management	0.57	16.1
	Operator Error	0.56	
	Quality Standards	0.59	
	Feasibility	0.61	
	Machine Life	0.62	
	System reconfiguration capability	0.53	
	Safety	0.63	
	Reliability	0.68	
	Sustainability	0.69	
	Robustness	0.64	
	Scope Of Customization	0.74	
	Volume of Product	0.60	

Table 4.4 Avg. Importance Rating For Decision Variables, n=110, α=0.60

VARIABLES		MEAN IMPORTANCE RATING	VARIANCE	RANK
1.	R & D	1.31	0.71	6
2.	Computer Aided production Control	2.54	0.98	20
3.	Adaptability	1.89	0.77	14
4.	Product Variety	3.21	0.99	24
5.	Size of Firm	1.87	0.67	12
6.	Cost & Capital Effectiveness(Profitability)	1.25	0.87	5
7.	Growth	1.20	0.68	4
8.	Return of Investment	2.12	0.84	18
9.	Human Training & Interface	1.95	0.81	16
10.	Decision Supports	1.55	0.69	9
11.	Working Environment	1.81	0.94	11
12.	Risk Analysis	1.45	0.75	8
13.	Environmental Compatibility	2.77	1.08	21
14.	Product Life Cycle Management	2.88	1.1	22
15.	Operator Error	3.09	0.82	23
16.	Quality Standards	2.21	0.91	19
17.	Feasibility	1.91	0.63	15
18.	Machine Life	1.88	0.89	13
19.	System reconfiguration capability	3.32	0.62	25

20.	Safety	1.80	0.74	10
21.	Reliability	1.12	0.64	3
22.	Sustainability	1.08	0.61	2
23.	Robustness	1.33	0.65	7
24.	Scope Of Customization	1.06	0.68	1
25.	Volume of Product	1.98	0.80	17

Table 4.5 Classification of Decision Variables
(Numerical value representing its respective rank)

Important variables (Specific decision variables)	**Moderately important variables (Specific decision variables listed in table)**	**Less important variables (Specific decision variable listed in table)**
1,2,3,4,5,6,7,8,9,10,11,12, 13,14,15,16,17	18,19,20,21,22	23,24,25

Table 4.6 Avg. Importance rating of Cardinal Dimension

CARDINAL DIMENSIONS	**MEAN IMPORTANCE RATING**	**STANDARDIZED DEVIATION**	**IMPORTANCE RANK ORDER**	**STANDARDIZED COEFFICIENT ALPHA**
Technical	2.36	0.81	2	0.83
Economical	2.21	0.73	1	0.86
Organizational	2.47	0.80	3	0.78
Process	2.52	0.83	4	0.76

Table 4.7 Coefficient of Alpha Values for Reliability Testing

DIMENSIONS	**NO. OF VARIABLES**	**COFF. OF ALPHA**
Technical	4	0.71
Economical	4	0.76
Organizational	5	0.63
Process	12	0.69

Table 4.8Unidimensional and Convergent Validity Assessment
(A scale having BBI≥0.90 represents strong convergent validity)

DIMENSIONS	**VARIABLES**	**DEGREE OF FREEDOM**	**CHI-SQUARE**	**BENTLER & BONET COFF. INDEX**
Technical	4	3	3.89	0.97
Economical	4	3	4.33	0.91
Organizational	5	3	7.77	0.95
Process	12	3	9.43	0.92

Table 4.9 Predictive Validity Assessment

Construct "IMPLAUT" Input Dimensions	CONSTRUCT OUTPUT DIMENSIONS			
	Gamma	Probability T-Value	Gamma	Growth T-Value
Technical	0.421	1.76	0.244	1.9
Economical	0.134	0.133	0.354	2.3
Organizational	0.122	2.34	0.112	1.3
Process	0.244	1.98	0.225	1.75

Table 4.10 Generic model

Economical	**Technical**	**Organizational**	**Process Governing**
• Size of Firm • Cost & Capital Effectiveness (Profitability)	• R & D • Adaptability • Computer Aided production Control	• Risk Analysis • Decision Supports • Working Environment • Human Training & Interface • Environmental compatibility	• Scope of customization • Sustainability • Reliability • Robustness • Safety • Machine Life • Feasibility • Quality Standards • Product Life Cycle Management • Operator Error • System reconfiguration capability
• Growth Return of Investment	• Product Variety		• Volume of Product

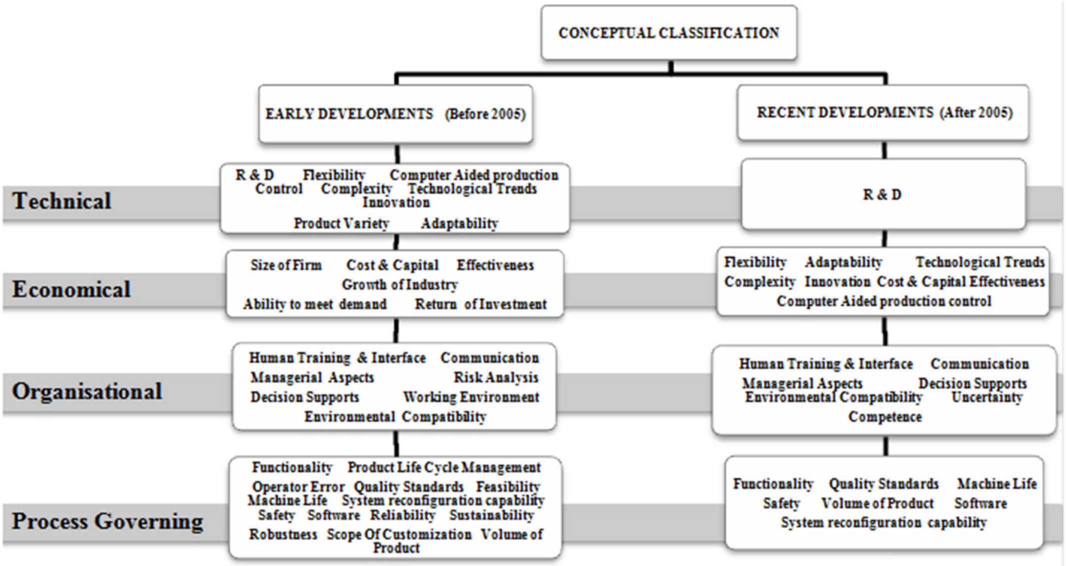

Figure 2.1: Conceptual Classification

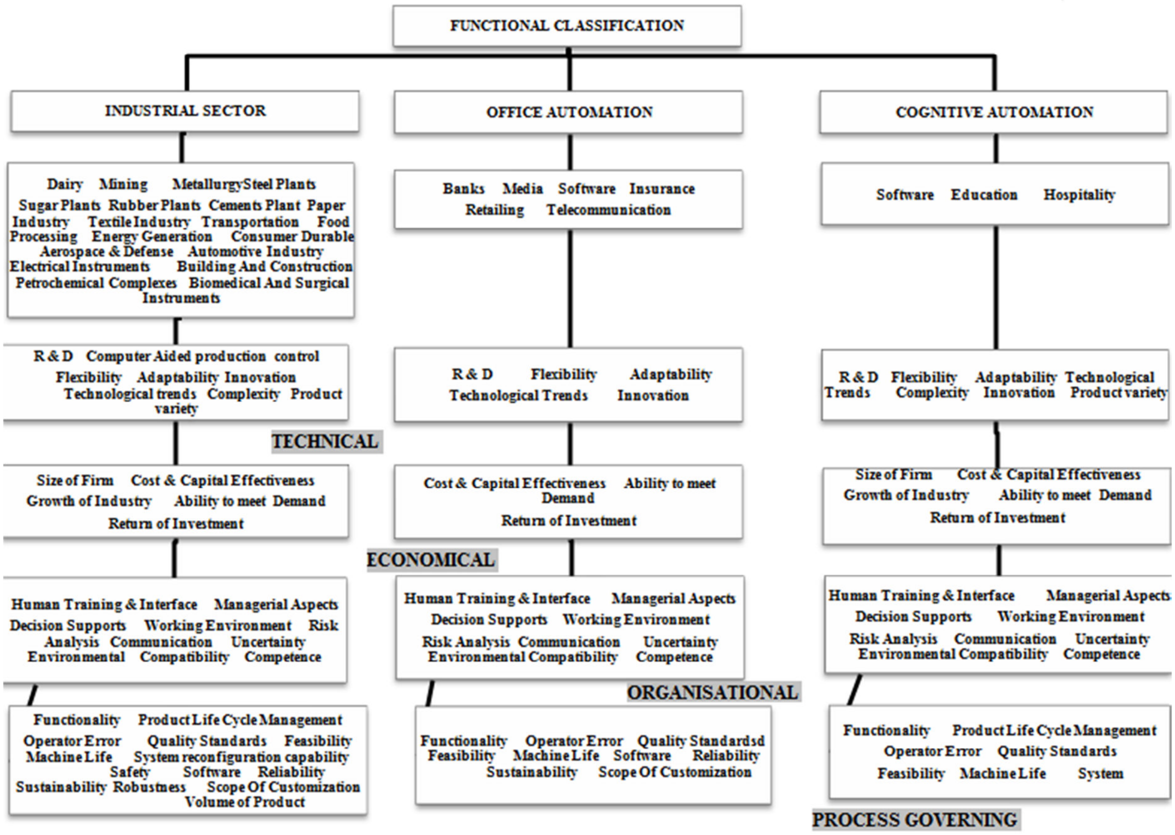

Figure 2.2: Functional Classification