Manufacturing Strategy in the Era of Industry 4.0

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Abstract. The evolution of Industry 4.0 has influenced the manufacturing sector with the latest technology for improving the manufacturing process. This study is carried out to understand and upgrade information with regards to small and medium enterprises (SMEs). In the context of the above study, the manufacturing strategies of small and medium enterprises (SMEs) are evaluated for the adoption of Industry 4.0. The main purpose of this study is to identify the opinions of the small and medium enterprises (SMEs) in Belagavi District of Karnataka state on the manufacturing strategy for the adoption of Industry 4.0 technology for improving manufacturing. This research used a structured questionnaire with a sampling method of random sampling with a nominal and Likert Scale of 67 small and medium enterprises (SMEs) in the manufacturing of auto-component products. The data was analyzed through advanced statistical tool Structural Equation Modeling for understanding the results. A major contribution from this study has highlighted the challenges influencing the manufacturing strategy of small and medium enterprises (SMEs) for the adoption of Industry 4.0 and has suggested measures to overcome these challenges through actual application of Industry 4.0 manufacturing strategy

Keywords: Industry 4.0, Strategic Management, Manufacturing Strategy, Automobile Sector, Structural Equation Modeling.

1. Introduction
Seventeenth-century witnessed the first industrial revolution, during this revolution steam engines, water power, and mechanization were witnessed in the various manufacturing sector. While the second industrial revolution witnessed assembly line-based manufacturing. The third industrial revolution was influenced by computers and automation in the manufacturing process. The fourth industrial revolution also called Industry 4.0 which was introduced in the year 2011 at Hannover Fair, Germany. This technology is based on Cyber-Physical Systems which would support the production process of the firms[1]. However, to transform a small and medium scale organization into digitalization, change in manufacturing strategy is essential for the firms. Further, the influence of the business environment influences changes in the acceptance of new technologies, this affects short-term and long-term growth and performance of the firms. Hence, firms need to develop technology-driven manufacturing strategies...
for acceptance of new manufacturing technology such as Industry 4.0 [19]. Hence, the manufacturing strategies that are required in Industry 4.0 needs a detailed and inclusive manufacturing roadmap [20]. However, small and medium enterprises (SMEs) have to evaluate their readiness with regards to factors associated with the acceptance of industry 4.0[2]. From the manufacturing strategic perspective, a comprehensive roadmap is required to implement Industry 4.0 in small and medium enterprises (SMEs) [19].The present research aims to offer a framework to understand the readiness of small and medium enterprises (SMEs) for acceptance of Industry 4.0 and its influence on the manufacturing strategy of these firms. This study is unique as it explores potential technical and economic benefits that small and medium enterprises (SMEs) derive through acceptance of Industry 4.0.

This study provides an insight into the challenges that small and medium enterprises (SMEs) experience while transitioning into Industry 4.0. The study also investigates factors that are associated with regards to manufacturing strategies such as investment in machinery, supply chain management, the skill of the workforce, and the role of management in the implementation of the technology in the SMEs. Hence, this study intends to answer the following research questions.

RQ1: What are the challenges for manufacturing strategy for implementation of Industry 4.0 in small and medium enterprises (SMEs)
RQ2: What should be the future course action for successful implementation of Industry 4.0 in small and medium enterprises (SMEs)

The research questions are investigated through the application of well-defined structural equation modeling (SEM) method. This method of investigation through SEM provides a relationship with regards to factors associated with manufacturing strategy and readiness of small and medium enterprises (SMEs) for acceptance of Industry 4.0. In general, we developed and analyzed the factors influencing manufacturing strategy for acceptance of Industry 4.0 and the readiness of small and medium enterprises (SMEs) towards Industry 4.0. The remainder of the paper is organized as follows. In the next sections of this paper, we have tried to explain manufacturing strategy, challenges for acceptance of Industry 4.0 from the perspective of SMEs and research design, and methodology with regards to manufacturing strategy through Industry 4.0. An effort has been made in this study to analyze the reliability of the factors selected for the study. This study also provides the profile of the respondents and results are presented through structural equation modeling. In the last section of this paper, the main issues and challenges of acceptance of this technology are presented with a conclusion and further development of manufacturing strategy in the light of Industry 4.0.

2. Study on Manufacturing Strategy and industry 4.0

Manufacturing strategy: “Manufacturing strategy is a competitive tool for enhancing manufacturing productivity”. Skinner (1969) defined manufacturing strategy as “exploiting certain properties of the manufacturing function as a competitive weapon” [10]. Likewise, Hayes & Wheelwright (1985) define “manufacturing strategy as a consistent pattern of decision making in the manufacturing function which is linked to the business strategy” [8]. The above definitions mention that manufacturing strategy plays a very important role in the business and provides a competitive advantage to the manufacturing process of the firms. Competitive advantage to firms is derived through the adoption of the latest technology-driven tools of manufacturing. Today’s, firms are adopting Industry 4.0 tools to become competitive in all respect. Industry 4.0 can be defined as a technology that is based on design principles and techniques. These design values or principles enables manufactures to forecast the right procedures and solutions and the application of technology provides effectiveness in the process of manufacturing [10]. Therefore, the above discussion indicates that manufacturing strategy would be effective through Industry 4.0. Hence, firm’s competitive advantage would be effective through the application of tools of Industry 4.0.
2.1 Challenges of adoption of Industry 4.0 in Small and Medium Scale Industries in India

Industry 4.0 leads to significant changes in the manufacturing process of firms. This would entirely change and transform the traditional manufacturing process and operation of the firms\(^7\). Industry 4.0 adoption in small and medium enterprises (SMEs) firms are influenced by factors like manufacturing strategy, employee skill-sets, cost of implementation in small and medium enterprises (SMEs), level of digitization in the firm, level of digitization of supply chain of the firm, and commitment of top management towards Industry 4.0. These above factors were well documented in the literature of the large and medium scale firms\(^8\). However, from the perspective of small and medium-scale firms of the Indian industry needs more detailed study to understand the influence of these factors in the adoption of Industry 4.0. Hence, this study has considered these factors and has attempted to investigate the interrelationship between manufacturing strategy and factors influencing small and medium scale firms in developing a manufacturing strategy for implementing Industry 4.0. Table.1 presents the review of the literature on challenges influencing small and medium scale firms in the implementation of industry 4.0. Table.1 presents challenges of adoption of Industry 4.0 in small and medium enterprises (SMEs).

| Sr.No. | Author and Year | Details | Outcomes |
|-------|----------------|---------|----------|
| 1     | Müller, Julian; Maier, Lukas; Veile, Johannes; Voigt, Kai-Ingo, 2017 | The research focused on collaborating measure between the large, small and medium firms for implementation of Industry 4.0. | Most of the Small and medium scale firms are in the early phase of implementation, hence the collaboration with large firms needs more understanding of Industry 4.0. |
| 2     | Egon Müller and Hendrik Hopf, 2017 | The development of competencies would add value in implementing Industry 4.0 in SMEs. | There is a resource constraint with regards to finance, workforce for application of Industry 4.0 in SMEs. |
| 3     | Mohammed Bakkari and Abdellah Khatory, 2017 | Market forces need to be considered while implementation of Industry 4.0 in the SME sector. | Opportunity to identify markets for products produced by SME need to be identified and develop strategic manufacturing roadmap for production to sales of the product produced using Industry 4.0 |
| 4     | David Grube, Ali A. Malik & Arne Bilberg, 2017 | SME sector long duration of implementation due to constraints related to finance and manpower in SMEs. | There is partial research to address the challenges of the implementation of Industry 4.0 in the SMEs sector. |
| 5     | Sameer Mittal, Muztoba Ahmad Khan, David Romero, Thorsten Wuest, 2018 | There are very few SMEs who have reached the maturity of implementation of Industry 4.0 | The majority of the research outcomes were focused on large manufacturing units, there is little research with regards to SMEs implementation of Industry4.0. |
Industry 4.0 is strategic for manufacturing companies and therefore firms have to take careful steps for implementation of Industry 4.0 in manufacturing. A strategic roadmap may be influenced by various factors that might be significantly different from large manufacturing firms in comparison to small firms.

SMEs are fully equipped with regards to the implementation of Industry 4.0 as it influences the production, planning, and control of these firms. The role of strategic manufacturing might support the development of production, planning, and control measures for successful implementation of Industry 4.0.

The present digital transformation measures undertaken by SMEs are enough due to the lack of clarity with regards to the production process with Industry 4.0. Manufacturing strategy provides a key for the identification of key digital manufacturing transformation and provides support to implement the same in SMEs.

Implementation of Industry 4.0 needs a higher level of digitalization in the manufacturing process of SMEs. Role of manufacturing strategy provides an opportunity to design and develop methods of digitalization of manufacturing process for effective implementation of Industry 4.0.

Employee skill-sets are an significant feature of the implementation of Industry 4.0 in SMEs. Strategic manufacturing allows designing, implementation of the strategy to involve in developing skill-sets of employees and prepare them for implementation of Industry 4.0 in SMEs.

3. Methods
Research design is the blueprint for collection, measurement, and analysis of data. Exploratory research design has been used to get more insights on the role of Industry 4.0 in manufacturing strategy of SMEs. The data was collected through the structured questionnaires and the data was collected from small and medium enterprises (SMEs), operating in the foundry industry at Belagavi, Karnataka, India. The structured questionnaire was tested for reliability analysis and results of reliability analysis showed that all six factors that is manufacturing strategy, employee skill-sets, cost of implementation, digitization of small and medium scale firms, digitization of supply chain in small and medium enterprises (SMEs) and top management commitment towards Industry 4.0 showed the reliability of more than 0.89. Reliability results are the summated scores on the scale as predictor components in the study factors. Since summated scales are assembled for interrelated variables level of importance. The test results are considered when they give stable and reliable responses over the test outcomes. The test outcomes are calculated through the method of Cronbach's alpha; this is calculated through a formula as under;
The formula for calculation of Cronbach’s alpha for reliability analysis

\[ \alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N - 1) \cdot C} \]

Where: \( N \) = the number of items. \( \bar{c} \) = average covariance between item-pairs. \( \bar{v} \) = average variance.

Variables derived from test instruments are stated to be reliable only when they offer stable and reliable responses over a repetitive administration of the test. The details with regards to reliability analysis are presented in Table 2. The reliability results of more than 0.80 and above are acceptable for future analysis of the study \cite{9}. The sample for the study was collected from 67 foundry units operation in small and medium scale sector at Belagavi, Karnataka. The profile of foundry units is presented in Table 3. The data collected is analyzed through structural equation modelling, which is based on regression analysis. The statistical intervention applied for the study includes structural equation modeling (SEM). This method is a multivariate analysis that is applied to understand the relationships between the variables. In this method factor analysis and multiple regression method is applied to evaluate the relationship between measured variables and latent variables. This method is applied as it provides estimates of manufacturing strategy for Industry 4.0, were in manufacturing strategy technique are interrelated to dependent factor that is manufacturing strategy. The variables under consideration for structural equation modeling (SEM) are based on the fit indices in path coefficient that includes p-value and standard error and model through the root mean square error of approximation and chi-square. The Chi-Square provides results with regards to any discrepancy between variables in the model, any results with less than P-value of 0.05 are accepted indicating that variables in the study are consistent and any value higher than the P-value of 0.05 is rejected indicating that the variables in the study are not consistent. Further, Root Mean Square Error of Approximation (RMSEA) fitness of the study model, value of 0 shows that the model of fit, while more than 0 shows the lack of fitness of the model. The results from RMSEA and SRMR show that the study results are consistent with the study model. Standardized Root Mean Square Residual (SRMR) results of less than 0.09 shows a good model fit. In the structural equation modeling, a comparative fit index is presented covariance matrix the results range from 0.0 to 1.0, higher the value of the comparative fit index better is the model fit. The goodness of fit index indicates sample size fit for the study, results in the range of 0-1.0 is a better fit for the study. Tucker Lewis Index indicates sample size, results from this test need to more than 0.90, which is considered fit for the study results \cite{31,32}.

| Sr.No | Reliability Analysis | Variables of the Study | Reliability Scores |
|-------|----------------------|------------------------|-------------------|
| 1     | Manufacturing strategy |                        | 0.88              |
| 2     | Employee skill-sets  |                        | 0.91              |
| 3     | Cost of Implementation of Industry 4.0 | | 0.95 |
| 4     | Digitization of small and medium enterprises (SMEs) | | 0.92 |
| 5     | Digitization of supply chain in small and medium enterprises (SMEs) | | 0.83 |
| 6     | Top management commitment towards Industry 4.0 | | 0.93 |

Table 2. Reliability Analysis of Study Variables
Table 3. Profile of the Study Respondents based on Number of Employees

| Sr.No | Profile of the Respondents          | N   | Percentage |
|-------|-------------------------------------|-----|------------|
| 1     | 100 to 150 employees                | 15  | 22.38%     |
| 2     | 70 to 100 employees                 | 28  | 41.73%     |
| 3     | 50 to 70 employees                  | 7   | 10.44%     |
| 4     | Less than 50                        | 17  | 25.37%     |
|       | Total                               | 67  | 100%       |

4. Results
The analysis of the study is presented in section four of the study. Table 4 presents a descriptive analysis of the study, while figure 1 shows the structural equation relationship between the independent and dependent variables of the study. Table 5 shows structural equation fit analysis results and Table 6 show relationship results with regards to the independent and dependent variables of the study.

Table 4. Descriptive Analysis

| Factors                              | N    | Mean   | Std. Deviation |
|--------------------------------------|------|--------|----------------|
| Manufacturing Strategy               | 67   | 2.52   | 1.283          |
| Employee Skill-Sets                  | 67   | 3.13   | 1.266          |
| Cost Structure                       | 67   | 3.76   | 1.195          |
| Digitization of SME’S                | 67   | 2.73   | 1.286          |
| Digitization of Supply Chain of SME’s| 67   | 3.10   | 1.339          |
| Top Management Commitment towards Industry 4.0 | 67   | 2.58   | 1.437          |

Figure 1. Model Fit Analysis Results
Table 5. Results of Structural Equation Modeling (SEM)

| Model Fit Analysis | Obtained Values |
|--------------------|-----------------|
| CMIN               | 1182            |
| Df                 | 341             |
| Significance       | .000            |
| CMIN DF            | 1.469           |
| GFI                | 0.95            |
| NFI                | 0.92            |
| RFI                | 0.96            |
| TLI                | 0.97            |
| CFI                | 0.95            |
| RMSEA              | 0.052           |

The study results show that mean value of (2.52) for manufacturing strategy, employee skill sets is having a mean value of (3.13), cost of implementation has a mean value of (3.76), level of digitization of small and medium scale has a mean value of (2.73), digitization of supply chain management has a mean value of (3.10) and top management commitment has a mean value of (2.58). The structural equation modeling analysis presented in Table 4 shows that CMIN is obtained at (1182), while Degree of freedom is at (341). GFI is (0.95 > 0.90) than, NFI is at (0.92 > 0.90), RFI is at (0.96 > 0.90), TLI is at (0.97 > 0.90), CFI is at (0.95 > 0.90) and RMSEA is (0.052 < 0.05) all the variables are in the acceptable range; hence the model fit is found in the study results.

Table 6. Results of Regression Analysis

| Independent | Dependent | Estimate | S. E | C. R. | P | Label |
|-------------|-----------|----------|------|-------|---|-------|
| Cost Structure | Manufacturing Strategy | .417 | .110 | 3.78 | 000 | Supported |
| Digitization of SME’S | Manufacturing Strategy | .334 | .107 | 3.12 | .007 | Not Supported |
| Digitization of Supply Chain of SME’s | Manufacturing Strategy | .556 | .103 | 5.41 | .008 | Not Supported |
| Top Management Commitment towards Industry 4.0 | Manufacturing Strategy | .730 | .092 | 7.95 | .000 | Supported |

Results from regression analysis shows that small and medium enterprise (SMEs) have taken effort to develop skill-sets of employees for Industry 4.0, the P value of (000) shows that employee skill-sets development has been included in the manufacturing strategy. While regression results with regards to cost and investment by SMEs has been supported with P value is (0.007) which is more than (0.005) that is confidence level. Further, results with regards to digitization in SMEs have also shown negative
results with P-value of (0.008) which is higher than (0.005) of confidence level. There is an acceptance with regards to supply chain management, as most of the study SMEs are the vendor for large automobile manufacturing firms, hence, they have taken effort for partial digitalization of supply chain management, therefore, p-value shows (0.000) which is lower than confidence level of (0.005). Preparedness of top management of SMEs towards Industry 4.0 has shown an P-value of (0.142) which is higher than (0.005), this indicates that top management of these firms need more time to accept and implement the concept of Industry 4.0 in SMEs. The overall analysis of results shows that relationship between dependent variable that is manufacturing strategy and independent regression analysis shows that manufacturing strategy is supported with employee skill-sets, while cost structure, digitization of small and medium scale industries and top management commitment towards industry 4.0 in SMEs is not support. However, level of digitization of supply chain management is supported in the study results.

5. Discussion
The discussion in the study is focused on the research questions developed for the study, which are developed based on challenges of small and medium scale sector for acceptance of Industry 4.0. In this section, the first research question is about the challenges for manufacturing strategy for implementation of Industry 4.0 in small and medium scale firms.

RQ1: What are the challenges for manufacturing strategy for implementation of Industry 4.0 in SMEs

The smart factory is the main theme of Industry 4.0, these smart factories operate manufacturing on Cyber-Physical Systems[10]. Hence, the traditional methodology of manufacturing would change the SMEs operation and manufacturing. This would influence directly on the workforce with regards to skill-sets [11]. These skill-sets include critical thinking and advanced technological skills such as Big data, robotics, machine learning, cyber security[12]. Therefore, the traditional nature of employee engagement and responsibility assessment would change in the organization's security [12]. The study results show that with regards to SMEs employees skill-sets are in the development stage for the implementation of Industry 4.0. Therefore, manufacturing strategy implementation would be supported in this sector. Further, challenge with regards to cost-benefit analysis is an important aspect in the implementation of these technological solutions in the SMEs[13]. Industry 4.0 is expected to large with regards to personnel and hardware. However, the expected benefit of this investment would be in reduced variable costs and enhanced quality and productivity [14]. The study results with regards to cost on implementation showed that negative relationship with regards to manufacturing strategy and cost of implementation of Industry 4.0 in SMEs. The result with regards to digitization in SMEs needs to be evaluated for application of Industry 4.0[15]. In the present situation of study, the level of digitization has not penetrated much in the SMEs. Hence, manufacturing strategy implement for digitization in SMEs would require more time for implementation of industry 4.0. Supply chain operations in Industry 4.0 would be based on Cyber-Physical Systems. This would influence supply chain operations[16]. The traditional supply chain management would change significantly [15]. However, with digitalization in SMEs, there is partial and, in few cases, full digitization of operations in supply chain management. Therefore, the study outcomes have shown that SMEs would be able to implement digitization in supply chain management. However, for complete implementation of the digitization of supply chain management new procedures are needed to manage supply chain management. The role of top management is critical for the success of Industry 4.0[17]. Since the implementation of Industry 4.0 requires extensive firm’s consequences and heavy investment support from top management of SMEs [18], the study results have indicated that top management evaluates manufacturing strategy with regards to cost-benefit analysis and investment in industry 4.0 technologies.

RQ2: What should be future course actions for successful implementation of Industry 4.0 in SMEs

This paper identified five independent factors and one dependent factor in the use of Industry 4.0 tools and technologies in manufacturing. The study focused on understanding variables concerning
manufacturing strategy and its influence on Industry 4.0 in SMEs. The most important factor that influenced the SMEs for implementation of Industry 4.0 is the cost structure, even though long term benefits are witnessed with high-quality products and enhanced productivity, but the investment is much higher for small and medium. This factor of cost has influenced the top management commitment towards Industry 4.0 and thereby influencing the reduction in the digitization of the firms and operations in the firms. Apart, from manufacturing strategy, digitization of the firms brings a higher level of success of Industry 4.0, also employee adaptability to enhance skill-sets to match the needs of Industry 4.0. Therefore, firms need to design strategy based on the predicted changes in the firms in the implementation of Industry 4.0 in the firms.

6. Conclusion
Academic interest in Industry 4.0 has gained a lot of interest among the academicians. The findings from this study would support the future direction of research. Influence of manufacturing strategy to manufacturing units needs deeper studies to understand the influence on Industry 4.0, such studies would support in understanding the success factors of Industry 4.0 on different sectors of the manufacturing industry. Further, the influence of Industry 4.0 would also influence the relationship between business environment and organization and have a direct impact on the value chains, hence future studies need directions on the influence of Industry 4.0 on the value chain of the firms, especially with regards to small and medium-scale firms. The present study was confined and limited with regards to SMEs at Belagavi, Karnataka operating in automobile component sector, further studies in other sectors of SMEs and understand implications on manufacturing strategy in implementing Industry 4.0 would provide broad perspective on challenges of implementation of Industry 4.0 in SMEs.

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