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Manufacturing strategy dimensions as I4.0 performance antecedents in developing economies

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Abstract. The challenge with technology implementation in today's world is the industrial workforce's acceptance, awareness, and cost implications. This also requires old systems to be obsolete and complete staff training on the new system change. This research aimed to understand the readiness, acceptance, and implementation of the concept of I4.0 and performance in the Indian industrial sector for achieving a business edge. In addition, the paper strives to analyze the impact of dimensions of manufacturing strategy (i.e., cost, delivery, flexibility, and quality) on I4.0 performance. The conceptual framework was developed under the lenses of dynamic capability theory [1–3].

The survey method was used to collect the perception data from middle to above middle executives. To test the hypotheses, CB-SEM measurement and path models were developed using the IBM- AMOS 25. A random sampling using an in-person survey and an online sample collection method was used to obtain the sample data. A total of 232 valid sample data were eventually analyzed out of the total collected 273 datasets to check the reliability of our hypothesis. The results showed that quality and the delivery performance had a strong positive relationship with industry 4.0 supplier performance (i4.0SP) while cost and flexibility performance failed to improve i4.0SP significantly. Academically this research contributes to the literature of industry 4.0 and dynamic capability theory. The findings of this research give clear directions to the manufacturing organizations of the developing nations to focus their efforts towards inbound logistics to improve the i4.0SP.

Keywords: Industry 4.0 supplier performance, cost, quality, flexibility, delivery, manufacturing strategies

1 INTRODUCTION

Developments in advanced technology have led the manufacturing strategies to be data-driven and based on the internet. The “fourth Industrial Revolution”, commonly known as Industry 4.0, aims to shape industrial efficiency and productivity [4]. Manufacturing strategy reflects the development of competency by the firm to gain a competitive advantage and enables it to achieve the desired manufacturing structure,

infrastructure, and a set of specific capabilities. Manufacturing strategy is evaluated through multi-competitive performance criteria. The most important criterion is cost, delivery, flexibility, and quality performance [3, 5]. Supplier performance can be measured using three basic parameters, i.e., price, quality, and production cost. The cost includes Total Cost of Operations (TCO), which constitutes baseline cost, delivery, storage, security, internal movement, machine processing, disposal, and final delivery. The concept of the Internet of Things (IoT), Cloud computing, Cyber-Physical systems (CPS) is few such facilitators[6]. The overarching theme of this study is to evaluate the role, acceptance, implementation with respect to manufacturing strategies and industry 4.0 supplier performance (i4.0SP). One of the prime objectives of industry 4.0 is to achieve a significant level of operational effectiveness and automatization in the manufacturing industry while working with multiple suppliers at a given point in time. Operations process effectiveness, supplier and customer relationships lead to competitive advantage for the organizations. Industry 4.0 has contributed to full digital integration end-to-end [7]. With these arguments, we pose our first research question as follows. *Which performance dimensions of the organizations drive the performance in developing nations?*

In both developing nations, firms today pose great challenges from production, customization, shortened lifecycle, and competitors' entry into their zone. In the context of MSME [8–10], the supply chain and environment are reported as important enablers to sustainability in Industry 4.0. The cumulative analysis of the various studies shows limited work on the implementation of industry 4.0 in the Indian domain. The key factors identified [11] towards the smooth acceptance of industry 4.0 were top management support and government policies. Most of the studies have taken an Industry-specific view versus a company sector analysis. It is important to identify the focused performance dimension as a strategy of the firms in developing nations in order to drive the i4.0SP. With these contexts and background, we propose our second research question as follows. *What focused supplier strategies can be developed by the manufacturing organizations of the developing nations to reap i4.0SP?*

A sampling in the manufacturing companies in developing nations, taking the view of vendor managers, suppliers, and customers, provides a new perspective of the emerging technology and its needs. We aim to analyze the manufacturing strategies and i4.0SP in the Indian Automobile sector in the current study. The automobile sector in India covers the major share in the manufacturing industries in India [11, 12].

2 LITERATURE REVIEW

2.1 Cost performance (CP) and i4.0SP (ISP)

The effect of Industry 4.0 improving cost performance is overtly focused on (1) mechanization, water power, steam system; (2) mass production, assembly line and electricity line; (3) computers and automation; (4) Cyber-Physical Systems (CPS) respectively. The cost performance has also been witnessed in the case of cloud

computing [13] and various other technologies [6]. Cloud computing and cognitive computing within the umbrella of the Internet of things. An environment where machinery and equipment are aligned and work together to improve processes, in turn saving the cost of production and manufacturing. Thus, multilayered IoT systems help industries in reaching a balanced state of flexibility and efficiency to optimally reduce cost and increase the possibility of customization. In the above company's example, the energy consumption was optimized by the application to be reduced by 10%. Improved efficiency at lower cost with higher revenue and increased innovation are the byproducts of Industry 4.0.

H1. *The cost performance positively influences i4.0SP*

2.2 Delivery performance (DP) and i4.0SP

The lead time of major raw materials to be turned to finished goods can be greatly improved by adopting the Industry 4.0 phenomenon. Industry 4.0 is about connectivity; it is an opportunity to radically change how the industry responds to the needs of society. Internet of Things (IoT), Radiofrequency identification (RFID) or wireless reader communication are ways to differentiate, assess, and track the objects and orders during the manufacturing process. It also is a seamless way of chronologically tagging the part (s) in a product cycle. RFID readers allow users to distinguish, monitor and track objects automatically with RFID tagging [2, 14, 15]. Hence, a smart, interconnected pervasive environment is the foundation of Industry 4.0 while managing the delivery performance by enhancing speed, reliability and improved production cycle. Major industries using this phenomenon are warehouse, healthcare, textile, consumer goods etc. [16]. The delivery flexibility and speed directly influence the profitability and market share of the manufacturing firms [17]. With these arguments, we present our next hypothesis:

H2. *The delivery performance positively influences i4.0SP*

2.3 Flexibility performance (FLP) and i4.0SP

There are two types of flexibility: machine flexibility and routing flexibility. The fourth industrial revolution brings along intelligence in the system to enhance and improve the physical product's data. The mere possibility of reacting to change in manufacturing processes and adapting to any new developmental process within as less time is what we call flexibility in the system. Industry 4.0 flexibility performance can be measured through the readiness of the system to predict, process and prevent order management and failure in the process.

The focus on supply chain orientation, supply chain integration grounded in industry 4.0 shows a positive influence on the supply chain performance [18]. Business process management (BPM) a framework of Industry 4.0 provides flexibility. BPM analysis measures, models, automates, optimizes, and improves manufacturing processes. Machine-to-machine two-part communication is one of the applications. The opportunity to make production 30% faster and 25% cheaper is the goal of the systems approach.

H3. *The flexibility performance positively influences i4.0SP*

2.4 Quality performance (QP) and i4.0SP

Quality and process are the drivers of improvement of Industry 4.0 [19]. Integration of new technologies plays a crucial role in enhancing the performance of Industry 4.0 [20]. [21] argued that better industrial performance can be achieved through the adoption of Industry 4.0. Quality is the key parameter for manufacturing process-related requirements [22]. [23–25] elaborated that quality leads to product performance which further avoids production deficiencies and finally results in customer satisfaction. The study by [26–28] found that quality provides holistic product and service characteristics that include engineering, manufacturing, marketing, and maintenance to meet customer expectations. [29] epitomized the eight different dimensions of quality: Aesthetics; Perceived quality; Performance, Conformance; Features; Serviceability; Reliability, Durability. With these arguments, we present our next hypothesis:

H4. *The quality performance positively influences i4.0SP*

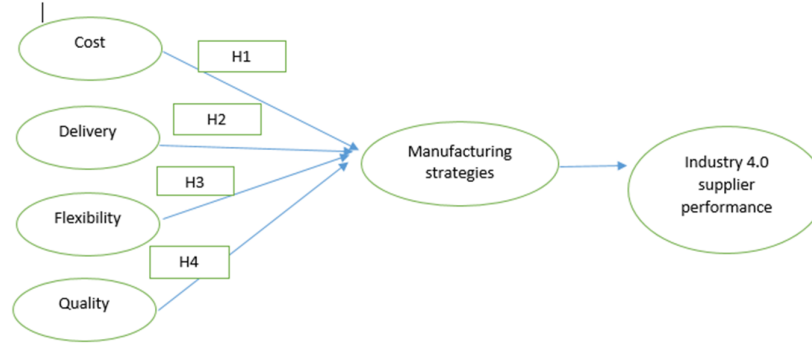


Figure 1. Proposed theoretical model

3 METHODOLOGY

This current study based on the proposed theoretical model (figure 2) intends to examine the i4.0SP and its drivers in terms of different operations performance competitive dimensions. The perception data were collected from the middle to top executives in a developing nation from predominantly textile, automobile, machinery, and consumer goods firm (s). The study has been operationalized in India, which is one of the fastest developing economies of the world in recent times.

3.1. Research instruments/questionnaire

The scale and questionnaire are attached in the appendix. For measuring cost performance, the scale items are adopted from the study by [30, 31]. [32, 33] measurement scales adopted for delivery performance. For flexibility performance, we adopted scale items from the study by [34–36]. [33, 37, 38] are used to adopt scale for quality performance. Finally, for measuring i4.0SP, the scale items were adopted from

the study by [39, 40]. The i4.0SP and manufacturing strategies items were measured using perception scales with 1 and 7 as the ranges of responses.

3.2. Sample size and data collection

The target respondents were the Managers (Assistant Manager, Deputy Manager, senior managers), store in charge, operations head within the seller management, supply chain, commercials, backend operations, or sales representatives majorly. A total of 5 constructs with 28 manifests required us to collect 5x (i.e. 140 samples) the number of sample data as per [41]. Consequently, we collected 273 datasets which were higher than the required range. A final number of complete and filtered responses are 232, which was imported in SPSS. After the removal of outliers, the data set reduced to 225 responses.

4 ANALYSIS AND FINDINGS

The measures were tested for its reliability and validity. The convergent and discriminant validity were ensured.

4.1 Scale Reliability, Measurement Model and Validity test

The alpha values for the constructs were above the required thresholds.

Constructs were also found valid (Table 1) as average variance extracted (AVE) and composite reliability (CR) values were greater than 0.5 and 0.7 respectively i.e., convergent validity [42] and the AVE values were greater than maximum shared squared variance (MSV) of each construct i.e., discriminant validity [43]. Fit indices of the model for the estimation of the validity were $\chi^2/df = 1.562$; SRMR=0.029; GFI=0.86; CFI= 0.974; TLI = 0.97; RMSEA= 0.049; PCLOSE= 0.545. These indices suggested that the model is a good fit [44].

Table 2. Validity measures

Details	Alpha	CR	AVE	MSV	MaxR(H)	QP	CP	DP	FLP	ISP
QP	0.943	0.943	0.769	0.686	0.949	0.877				
CP	0.889	0.886	0.665	0.587	0.967	0.766	0.815			
DP	0.950	0.950	0.792	0.587	0.980	0.766	0.739	0.890		
FLP	0.950	0.950	0.791	0.686	0.986	0.828	0.742	0.702	0.890	
ISP	0.958	0.957	0.737	0.593	0.989	0.770	0.721	0.718	0.713	0.859

4.2 Structure Equation model: (Hypothesis testing)

The conceptual model was subjected to structural equation modeling using the Most likelihood estimation (MLE) method [45] using the AMOS tool. Figure 2 represents the structural equation model, and the hypothesis outcome is summarized in Table 2.

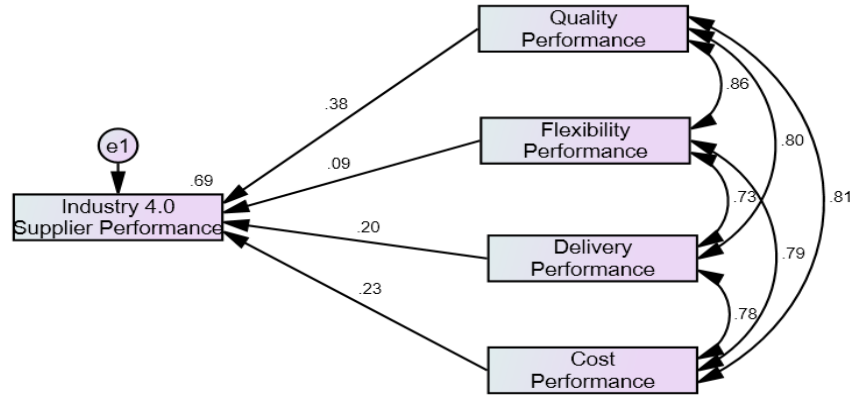


Figure 2. Structure equation model

Table 2. Hypothesis results

Hypothesis	Beta	S.E.	C.R.	p val	Outcome
H1. Cost performance positively influences i4.0SP	0.228	0.074	3.265	0.001	Accepted
H2. Delivery performance positively influences i4.0SP	0.201	0.063	3.064	0.002	Accepted
H3. Flexibility performance positively influences i4.0SP	0.089	0.075	1.183	0.237	Rejected
H4. Quality performance positively influences i4.0SP	0.379	0.085	4.466	***	Accepted

5 RESULTS

The study focused on evaluating the effect of dimension of manufacturing strategy (i.e. flexibility, cost, delivery and quality) on i4.0SP. We have observed the model to be significant at 5% confidence interval level. The observations from the structural equation modeling are as follows:

The hypothesis H1 gets accepted basis analysis (Beta = 0.228, $p = 0.001$). This shows that there was a positive effect of cost on i4.0SP. The hypothesis H2 states true basis analysis (Beta = 0.201, $p = 0.002$). The third hypothesis states the i4.0SP improves when flexibility performance goes up gets rejected based on analysis values (Beta = 0.089, $t = 1.092$, $p = 0.237$). The fourth hypothesis states that the i4.0SP Improves when quality performance goes up. gets accepted basis received values (Beta = 0.379, $p = 0.000$). Table 2 shows all the results.

The delivery and quality were the two major performance dimensions observed significant and important for manufacturing organizations in developing nations besides the cost performance. Further to this, the quality is observed as the focused strategy for the manufacturing organizations in developing nations followed by the delivery dimension. Cost efficiency has always been vital to the price sensitive consumer markets. Most of the flexibility aspects are part of operational goals in the firm, and they demand trust-building, relationship withholding with long-term vendors who are supplying raw materials, so a systematic change will need all the personnel issues that might arise from such revolution.

This theoretical research contribution adds to the dynamic capability view [46], where the focus on quality and delivery becomes the dynamic capabilities of the manufacturing organizations for an improved sense and response. The findings of this research have explicit business relevance. The practicing managers gain insights that the quality delivery consciousness is now significantly improving among the consumers of the developing nations. The digitalization, social media, and technology have made consumers more aware. A focus on quality and delivery from suppliers may intern results in improved customer performance and dynamic delivery capability[17, 46].

No research is free of limitations. The findings of this research are also limited to the country where the research was operationalized. In order to develop robust findings, the study needs replication in various other developing nations. The focus of the study was mainly the manufacturing sector; therefore, the findings may further be only applied to a limited arena. The study can be extended to the services sector, especially because the services sector is growing exponentially in developing nations.

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