# Additive and Digital Manufacturing: Implications for Organizational Strategy and Structure

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## Abstract

Additive Manufacturing (AM) or digital manufacturing is the new paradigm shift in the manufacturing domain which refers to technologies such as 3D printing, rapid prototyping, digital direct manufacturing, layered manufacturing, additive fabrication etc. The products are manufactured or printed using 3D printers directly from the CAD model without undergoing the conventional step of process planning that exists between the CAD and CAM systems. This technology is still to reach a stage where it could be commercially exploited by different manufacturing organizations to gain competitive benefits. Literature suggests that it has been already applied to some specific areas where it has levied promising results. To realize the long term benefits, it becomes imperative to align the organizational structure and strategy which should support the AM functions or could be successfully implemented. The paper focuses on some organizational implications which will pave the way to fully reap the benefits of AM and its successful implementation.

## Keywords
Additive manufacturing, organizational strategy, structure

## 1. Introduction

Additive manufacturing, 3D printing or rapid prototyping as it referred by many names is the set of advanced manufacturing technologies which are resulting into industrial sustainability. The consequences of adopting these manufacturing methods leads to localized production and highly customized products based on customer demand. These set of processes are often referred as disruptive technologies in literature. The disruptive technologies disrupt existing market and position themselves far ahead of existing market trends. They significantly affect all the three major domains i.e. product, process and supply chain. It results in redistribution of jobs and demand for low skilled workers are reduced due to automation. Supply chains are shortened and various functions in the value chain gets integrated. Organizations needs to align themselves to support this particular technology and reap its benefits. This paper discusses some prominent implications that additive manufacturing has on organizational strategy and structure.

## 2. Some Implications on Organizational Structure and Strategy

### 2.1 Manufacturing and marketing functions comes under one roof

For digital or additive manufacturing based organizations, the manufacturing and marketing division will be close to one another under one roof supporting mutual functions. In such a changed scenario, the concept of virtual teams comes into picture. Virtual teams will be larger in number. The different players of the supply chain viz. manufacturers, designers, engineers, marketing personnel and customers will be connected through virtual teams. The number of blue collar workers will be greatly reduced in such manufacturing organizations. Employees with higher educational qualifications i.e. white collar designates will simultaneously manage the production and maintenance work. Knowledge workers will operate at retail/manufacturing level and they will undergo training at the head office. Any problem or dispute arising out would be first dealt at retail/firm level and if not solved satisfactorily will be referred to the higher level i.e. head office. Designers will have much bigger veto power manufacturing personnel. The computer aided process planning (CAPP) steps for additive/digital manufacturing will be completely different from that of conventional manufacturing processes.

### 2.2 Additive manufacturing organizations adds to a new dimension in organizational strategy

Strategic literature has classified different manufacturing organizations based on their operational patterns and production strategy. A review on this literature helps us to understand the various production strategies operating in the environment as depicted in Table 1.

| Details | Typologies | Characteristics |
|---|---|---|
| Year: 1978<br>Proponents: Miles et al.<br>Basis: rate of change of products or markets | Defender | Stable form of organization is appropriate<br>Limited product range<br>Cover narrow segment of the total market<br>Compete on price or high quality<br>Efficient use of production and distribution of goods and services<br>Technological efficiency is highly emphasized<br>Little product or market development<br>Finance, production and engineering dominated marketing and R&D<br>Unable to respond to major shifts in market change |
| | Prospector | Continuously searching for market opportunity<br>Creator of change and uncertainty<br>Marketing and R&D dominates finance and production<br>Maintaining industry leadership in product innovation is more important than profit earning |
| | Analyzer | Combines the strongest of both the types<br>Avoids excessive risks, but excels in delivery of new products and services<br>Concentrates on limited ranges but outperforms in quality |
| Year: 1980<br>Proponents: Michael Porter<br>Basis: Competitive advantage (Smith, 1997) | Cost leadership | Lowest cost producer in the industry<br>Advantage may arise due to economies of scale or access to favorable raw material or superior technology |
| | Differentiation | Focuses on products highly valued by customers<br>Emphasis on quality and dependability of product, after sales service<br>Wide availability of product range<br>Product flexibility |
| | Focus | Dedicates to a segment poorly served by others<br>Comparative advantage is based on either cost leadership or differentiation |

| | | |
|---|---|---|
| Year:1982<br>Proponents: Miller and Friesen<br>Basis: extent of product innovation<br>(Smith, 1997) | Conservative | Engage in innovation with reluctance as a response to serious challenge |
| | Entrepreneurial | Aggressively pursue innovation<br>Control system is used only as a warning against excessive innovation |
| Year: 1982<br>Proponents: Gupta and Govindarajan<br>Basis: variations in strategic missions<br>(Smith, 1997) | Build | Improve market share<br>Improve competitive position even if it decreases short earnings and cash flows<br>Wants to gain competitive superiority |
| | Hold | Protects market share and competitive position<br>Obtains reasonable return on investment<br>High market share and high growth industry |
| | Harvest | Maximizes short term profit and cash flow<br>Market share is not important |
| | Divest | Business plans to cease operations |
| Year: 1994<br>Proponents: Miller and Roth<br>Basis: Product Innovation | Caretakers | Low emphasis on development and competitive capabilities<br>Price is dominant<br>Less importance to after sales service and high performance products |
| | Marketers | Key market oriented capabilities<br>Offer broad product lines, Responsive to changing volume requirements<br>Conformance quality, dependable deliveries, emphasis on product performance |
| | Innovators | Bring cutting edge technology to market, introduce new product quickly<br>Percentage expenditure on R&D is the highest |

**Table 1:** Literature on Organizational strategy Chatterjee (2014)

On examining the subsequent studies, it is found that broadly three types of strategic groups gained prominence. The strategic typology suggested by Miles et al. (1978), Porter (1980) and Miller and Roth (1994) namely defender or cost leadership, prospectors or differentiators and innovators is exhaustively used to classify the different manufacturing organizations based on their operating strategy. However, the concept of additive or digital manufacturing has a complete different perspective in terms of organizational and manufacturing strategy. The direct production of parts with the help of additive manufacturing directly from the CAD model offers benefits from conventional manufacturing. Additional advantages includes flexibility and customization (Weller et al., 2015; Fogliatto et al., 2012; Mellor et al. 2014 and Sandstrom, 2015). Holmstrom at al. (2010) pointed a number of features specific to additive manufacturing which allows the realization of production strategies of mass customization (Davis, 1987; Pine, 1993a, b; Duray, 2011) or customizability of products. These features included absence of tooling requirements, small and feasible production batches, implementation of quick design changes, optimized production in regard to functional purposes, economically feasible custom products and simplified supply chains (Deradjat and Minshall, 2017). Mass customization is a contradictory or in-between production strategy of realizing mass production of customized products. Tuck et al. (2008) gave product variety-volume matrix (Figure 1) in which the position of mass customization was clearly depicted. It acts as a bridging strategy between classic mass production and customized or one of its kind production. Hence, we argue that additive or digital manufacturing adds to on more dimension of organizational strategy which falls somewhat above differentiators/prospectors and below innovators (Figure 2).

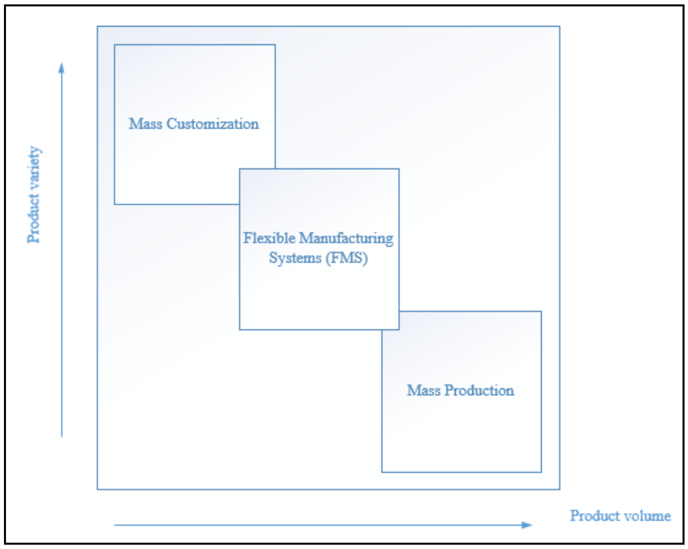


**Figure 1:** Product variety-volume matrix

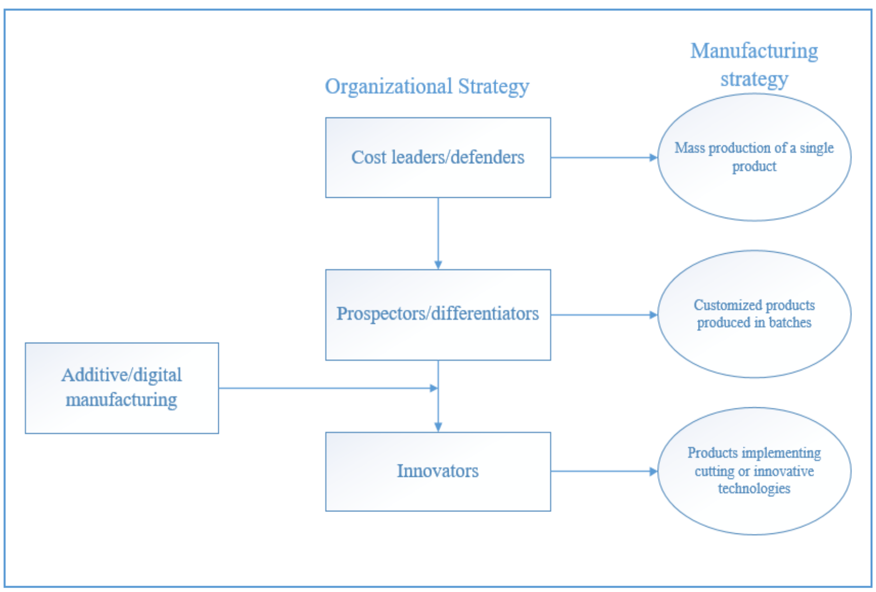


**Figure 2**: Position of Additive manufacturing within existing strategies

### 2.3 Additive manufacturing organizations represents ambidextrous nature

The distinctive characteristics associated with additive manufacturing suggests that manufacturing companies implementing additive/digital manufacturing has does not have fixed parameters for the dimensions of organizational structure, variables and operating manufacturing strategies. The dimensions of organizational structure as suggested by Pugh et al (1968) and subsequent researchers consists of Standardization, Specialization, Centralization, Formalization and Complexity of workflow. Organizations working with additive manufacturing must simultaneously have low and high values for these dimensions of structure depending upon the scenario or environment. Particularly, it can argued that the number of blue collar workers will be greatly reduced. Employees with higher educational qualifications will be engaged with production and maintenance activities. Organizations will be more flat or decentralized since staff at the lowest level is highly educated and at the same time the span of control will be much higher. This is definitely in contrary to the claims in literature that the use of IT leads to centralization and in many ways additive manufacturing utilizes IT resources. Another significant issue is that knowledge workers will operate at retail and manufacturing functions and they would be trained at head office. Any problem will be first referred to manufacturing/retailer level and if it not resolved satisfactorily, it will be referred to head office level. A lot of experimentation would be done before a final decision is arrive at. Formalization exists due to the adoption of IT and it may also be informal due to much higher levels of complexity. Decentralization exists due to distance between physical location of head office and retailer/manufacturing. Organizations will have high tolerance for failure else employees will not be informal. High formality would dysfunctional in the wake of high complexity. IT adoption will make the organizations more task oriented and at the same time low formalization or informal mode of operations will also lead organizations to people oriented.

On considering the operational/manufacturing strategies, these organizations will look purely for exploitation through architectural innovation. On the other hand, defenders or cost leaders type organizations look for exploitation of the existing infrastructure and resources and to a certain extent also go for incremental innovation. Innovator type organizations will simultaneously work for exploitation and at the same time pursue exploration through radical, architectural, modular or incremental as situation demands.

### 2.4 Relating Additive/digital manufacturing to Internet of things (IoT) technology

The modern manufacturing environments must be supported with advanced IT technologies to become competitive, flexible and able to rapidly accommodate the changes taking place in the market. Internet of things (IoT) is one such technology which has a variety of application areas in the manufacturing domain. IoT is a network of physical devices embedded with electronics, software, sensors and network connectivity which enable these objects to collect and exchange data. The management and control of manufacturing assets and its related supply chain network brings the IoT into industrial scenario. IoT systems enables smart manufacturing of new products, dynamic response to product demands and real time optimization of manufacturing production and supply chain networks by binding machinery, sensors and control systems. The design and implementation of suitable IoT architecture must support and reflect the strategic orientation of different manufacturing organizations. Vishvakarma et al. (2015) in their work studied the various specifications and features of different IoT architectures and made a pioneering attempt to relate these with the organizational and manufacturing strategies. In their work, the authors suggested that a 3-layered cloud centric IoT architecture is most suitable for defender/cost leader type of organizations. These organizations use IoT to maximize their resource utilization capabilities and to reduce the time and cost in supply chain. Their main focus is on cost minimization techniques, consistent quality, high performance products, on-time delivery, efficiency and automation.

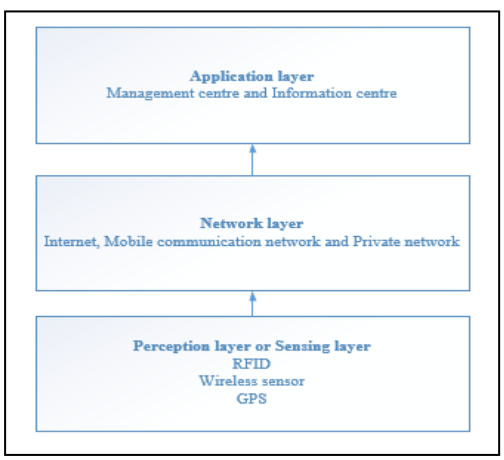


**Figure 3**: 3-Layer IoT architecture for defender and prospector type organizations

Further, they suggested that a 5-layered IoT architecture is suitable for innovator type of organizations depending on their specific strategic characteristics. Prospector or differentiator type of organizations simultaneously focus on cost cutting and capacity development. Hence, depending upon their specific orientation, the authors suggested that prospector type organizations are most likely to implement a 3-layered or a 5-layered IoT architecture.

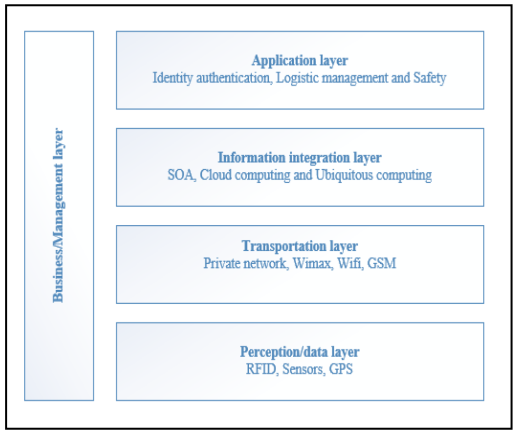


**Figure 4**: 5-Layer IoT architecture for innovator and prospector type organizations

Additive or digital manufacturing should be supported with multi-layered IoT technology for effective and better performance. Multi-layered architecture of IoT is also suitable for additive manufacturing taking into consideration the fact that different kind of materials that can be utilized for this kind of manufacturing having their different requirements.

## 3. Hypothesis Development

Based on our understanding of the existing literature and discussion of theoretical framework, we propose the following hypothesis.

**Hypothesis 1**: Organizations implementing additive manufactucturing technologies exhibit a new strategic orientation which is above prospectors/differentiators and below Innovators.

**Hypothesis 2:** Organizations implementing additive manufacturing represents ambidextrous organization and management.

Which follows:

**Hypothesis 2a**: Organizations implementing additive manufacturing can have simultaneously high and low values for the dimensions of organizational structure.

**Hypothesis 2b:** Organizations implementing additive manufacturing technologies can represent both task oriented and people oriented nature.

**Hypothesis 2c:** Organizations implementing additive manufacturing technologies will pursue a pure exploitation strategy.

**Hypothesis 3:** The additive or digital manufacturing technologies based organizations are more likely to implement 7, 9 or higher number of layers based IoT architecture to satisfy their manufacturing planning requirements.

## 4. Conclusion

Currently, additive manufacturing technologies have been applied only to a narrow and limited domain which includes production of models and prototypes during a product's development phase, parts for pilot series production in medical, automotive and aerospace industries, short series production where tooling costs for casting or injection molding would be too high to name a few. However, the potential advantages and flexibility offered by additive manufacturing can be commercially exploited. The organizational structure and strategy must support the technology to reap its full benefits.

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