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Towards a Service-Based Manufacturing Model: Opportunities and Challenges for On-demand Manufacturing Platforms

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ABSTRACT

Since the start of the first industrial revolution, manufacturing has been the strength of pushing industrial and societal transformation forward. Today, we are in the midst of a new industrial revolution, as a new generation of sophisticated technologies is transforming manufacturing into a largely connected, intelligent, and ultimately, more productive industry. Modern manufacturers are no longer just makers; they are the thread that connects the whole lifecycle of a product. Service plays an increasingly significant role in modern manufacturing. Many companies, which give producer services and manufacturing services to one another, shape a service-based manufacturing network. The aim of this study is to identify the opportunities, challenges and the impact of on-demand manufacturing platform. A questionnaire was designed to get first-hand information from around forty customers, suppliers and industry experts of the machine tools industry. The questionnaire contained section-wise questions on opportunities, challenges and impact of on-demand manufacturing platform. The results showed that there is a clear positive vibe about the concept of on-demand manufacturing platform. Both the opportunities and challenges faced by on-demand manufacturing strongly vouch for the adoption of a service-based manufacturing model by the on-demand manufacturing platforms.

Originality/value – The paper uses a questionnaire tool for on-demand manufacturing platform in a unique way. The results generate new interesting knowledge about the opportunities, challenges, and impact of on-demand manufacturing platforms.

Keywords – On-Demand Manufacturing, Digital Manufacturing, Cloud Manufacturing, Factory-on-demand, Service 4.0, Opportunities, Challenges, Impact

Paper type - Research paper.

1. INTRODUCTION

"We want to build intelligence that augments human abilities and experiences"- Satya Nadella, CEO, Microsoft.

A review of the 2019 Manufacturing Trends report released by Microsoft (2019) shows some interesting highlights as under –

- Advances in network, big data, and the extension of the Internet of Things (IoT) have opened the entryway for a new type of intelligent manufacturing innovation.
- There are anticipated to be 36.13 billion associated IoT gadgets by 2021. Sales of collective robots are anticipated to increase by 159% between 2018 and 2020.
- As more producers look to make their inheritance frameworks progressively shrewd, the market size for sensors and controllers has developed considerably and is anticipated to expand to $6.1 billion by 2020, up from $5.1 billion in 2016.
- The increased availability has driven down cost for IoT sensors. Between 2004 and 2018, the cost of a sensor dropped about 200% to $0.44. This has made assembling progressively moderate and open for manufacturers.
- The Industrial IoT (IIoT) is ready to significantly impact fabricating and the global economy, expected to create $15 trillion of global GDP by 2030.
- Global IoT spend is expected to reach $772 billion in 2018 and cross $1 trillion in 2020. Manufacturers are slated to spend $189 billion on IoT in 2018, the largest amount from any industry, with the primary focus on production asset management and manufacturing operations.

- Cobots—community robots—are turning into a more significant piece of the workforce. By 2025, Bar-dirts Equity Research projects that the cobot market size will reach $12.23 billion, in excess of a 8x increment from 2018 ($1.35 billion).
- Expected to grow to nearly $57 billion in 2018, on-demand services represent perhaps the biggest of these categories.
- By 2021, 1/5th of G2000 manufacturers will rely on technologies like Blockchain, IoT and machine learning to automate major processes.
- 3.9 million people worked in the gig economy in 2017; by 2021, that number is anticipated to grow to 9.2 million.
- The sharing economy is anticipated to develop to 86.5 million U.S. clients by 2021, up from 44.8 million in 2016.
- Sensors have become more affordable and are anticipated to cost $0.38 by 2020, down from $1.30 in 2004.
- With these changes, the market size for sensors and controllers has developed considerably and had increased to $5.6 billion in 2018.
- Intuit assessed that 3.9 million individuals routinely worked in the gig economy in 2017, and by 2021, they are projected to expand to 9.2 million.
- By 2021, 20% of G2000 makers will have moved to an intelligent assembling model.
- Businesses will create $2.9 trillion in business value from AI by 2021. Twenty-three percent of organizations are presently utilizing blockchain innovation.
- By 2025, spending on automated frameworks will reach $67 billion.
- 3.5 million jobs in manufacturingwill open up in the following decade in the U.S., and 2 million of them will go unfilled.
- There could be a requirement for 736,000 data scientists by 2024, yet estimates just forecast 438,000 data scientists in the workforce.
- As manufacturers move operations to the cloud, organizations that have invested heavily in on-premises platforms must grapple with the challenge of utilizing these systems.
- Two-thirds of U.S. manufacturers reported deploying 3D printers in some capacity.
- As cloud computing becomes more common, Anything as a Service (XaaS) business models are also becoming more popular.
- The most known XaaS model is Software as a Service (SaaS), which provides individual software applications and services through the cloud. However, of late, Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) models have also gained attention as a way for technology companies to expand their footprint.
- The forging of big data with new technology has made processing huge data sets easier than ever, and from mining big data to predictive analytics, leaders in manufacturing are increasingly relying on these new, intelligent tools to help them succeed.
- AI provides manufacturing leaders with an incredible degree of insight into the market and operations, allowing them to assess consumer data to review economic indicators to predict market trends, to forecast purchase and usage behavior, and to evaluate operations metrics to help cut costs and streamline processes.
- As technological advances in cloud-computing, connectivity and remote sensors improve, it is becoming easier and faster for manufacturers to integrate new systems with their legacy systems and integrate the management of industrial technology.
- Advanced analytics capabilities and modern AI can be used to improve performance and productivity across any organization, analyzing trends and behavior in real time.

(Source: The Manufacturing Trends 2019 report by Microsoft Dynamics 365.)
All these insights point out towards the dynamic change that is slated to happen in the field of manufacturing.

"On-Demand Manufacturing" (ODM) is a new business model that provides rapid prototyping and end-production for any quantity, budget or timeline. It is achieved by using a cloud-based software platform for instant quote generation, automated verification of manufacturability, single-click ordering, tracking of production and delivery and overall project management from any browser, anytime. Manufacturers can list their company on the ODM platform and enhance their market reach and capacity utilization of their machines. It works like "Uber of Machines". Manufacturing on-demand means retailers never have to warehouse stock. One can avoid getting trapped with excess inventory at the end of the season by manufacturing only the products that customers order. One is also not required to deal with minimum order requirements. This eliminates the need to markdown products to sell off old stock, reduces over-production of finished products, and cuts back on wasted materials. The right on-demand manufacturing system also allows retailers to raise their speed to market. It is likely that orders can be shipped within one to ten days after a customer places an order. The on-demand manufacturing model eliminates the risk of overproducing and underselling — making it likely for small business, Kickstarters , entrepreneurs, and makers to create and test new products with very minimal upfront financial risk and commitment. On-demand manufacturing, sometimes called cloud manufacturing, is a latest business model that makes it possible for vendors to offer support for the production of

electronic devices all the way from the PCB assembly of a single prototype through last product delivery to the customer. This is achieved using a cloud-based software platform that makes it easy for developers to get immediate quotes, manage projects, and track inventory from any browser, anytime.

Michael Mandel (2019) had evaluated that the big tech platforms get all the attention these days. However, the biggest tech news of 2019 may turn out to be the rise of the manufacturing platforms- Companies that rephrase the rules of production and product development and in the process generate new opportunities for localmanufacturing. In number of ways manufacturing platforms are the logical outcome of existing trends from outsourcing and production without owning a factory. Manufacturers have been increasingly bifurcating product design and marketing from the actual production process for years.These manufacturability algorithms are possibly equivalent in strategic importance to Google's search algorithm. One, they can be improved through machine learning, based on the platform's experience across large number of producers. Second, they can improve the efficiency of the process of product design, as designers can now get immediate feedback on cost and feasibility even before making prototypes. Third, and may be the most important, an entrepreneur opening up a new factory in Illinois, for instance, can now potentially tap into global demand via the manufacturing platforms, as long as they meet the requirements of the algorithm. These are developments that were not possible before.

Alexis MeraDamen (2018) had explained that on-demand manufacturing is advantageous for small businesses because of its low minimum order requirements. Ian Wright (2018) had discussed that while Kawola acknowledged Proto Labs as a pioneer in on-demand manufacturing, he believes the key to the company's achievement can be found on the Web rather than the shop floor.

Consideration of these definitions and views of authors on the on–demand manufacturing platform leads us to some basic questions like - What is on-demand manufacturing? What are the opportunities for on-demand manufacturing platform? What are the challenges for on- demand manufacturing platform? What is the impact of on-demand manufacturing platform? These are some of the questions that would be studied by surveying and statistically analyzing a sample of around 40 customers, suppliers and industry experts of the machine tools industry. These initial questions have been conceptualized into a framework of the study that has been outlined as under:

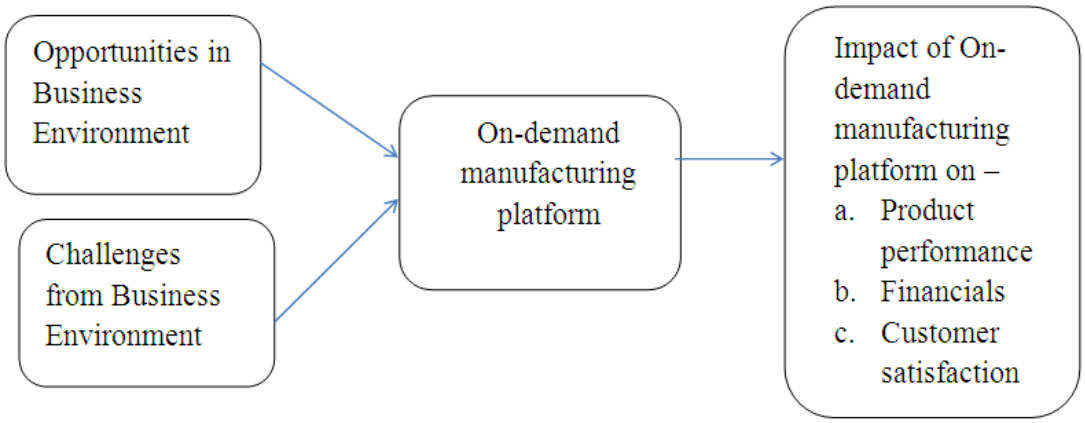

Figure 1: Proposed Conceptual Framework of the Study

In line with the aforesaid discussion, we formulate the following main hypothesis for the study:
The business environment offers excellent opportunities for ODM and it will significantly impact product performance, financials and customer satisfaction. However, some challenges will have to be tackled.

Two terms have been frequently used in this work – opportunities and challenges. These are briefly discussed to put things in proper perspective.

Opportunities are areas in which the organization may go beyond normal expectations of earning return on investments. Opportunities may begin from analyzing your strengths and recognizing approaches to more readily utilize them. Or those may come from distinguishing a competitor's weakness and discovering approaches to capitalize on those. Opportunities may incorporate latest items or administrations, new markets or an alternate sort of client than you as of now have.

Opportunities refer to the favorable external factors that could give an organization a competitive benefit. For example, if a country cuts tariffs, a car manufacturer can export its cars into a new market, increasing market share and sales.

In the context of on-demand manufacturing the following opportunities could be identified –

- Wider market reach for suppliers resulting in new customer acquisitions/orders
- Lower inventory requirement for customers due to no minimum order quantity requirement
- On-time delivery to customers can be secured by offloading production to other suppliers on the platform during machine breakdowns or similar production bottlenecks
- Quicker turnaround and shorter lead times for customers due to instant quote generation and manufacturability verification on the platform
- Direct order fulfilment and shipping to customers leads to lower shipping costs and lower inventory requirement for customers as products are made, picked, packed and shipped from the same facility
- Rapid prototyping of products and market testing allows customers to find their product-market fit before spending more money on their idea.
- Better production planning for suppliers due to increased visibility of automated orders, inventory and delivery schedules
- Access to better design competence on the on-demand manufacturing platform
- Better utilisation of unused production capacity for suppliers
- More competitive pricing to customers due to higher economies of scale

Challenges are threats external to the industry that could threaten the past growth of a business. A challenge may be government enactment that could influence your business, a merger between two giant contenders or an industry pattern toward more up to date innovation that you don't as of now offer. Organization pioneers should survey the challenges and build up an arrangement to battle or overcome those that are a high hazard.

Challenges refer to factors that have the potential to spoil an organization. For example, a drought is a threat to a wheat-producing company, as it may reduce or destroy the crop yield. Other common threats include things like rising costs for materials, tight labor supply, increasing competition and so on.

In the context of on-demand manufacturing the following challenges were identified –

- Certifying an on-demand manufacturer as a new vendor may be costly as large manufacturers with an order size of 100,000 to 150,000 already have a list of approved vendors and hence reluctant to add new vendors.
- Automating the manufacturability verification of product design may be difficult
- Customers may be reluctant to share the confidential CAD drawings.
- Quicker availability of raw materials for production may be challenging
- Offline communication, coordination and calculation may be required as the instant quoting system may not be 100% accurate.
- Lack of advanced technology or application knowledge on the part of manufacturers may hamper the quality and delivery of custom parts.
- Frequent back-and-forth communication due to incompatibility of the tool that customer uses for design and the factory that makes the part from that design
- Selection criteria of manufacturing partners, audit of manufacturing facilities and quality inspection of on-going production may pose significant challenges for the platform.
- Choosing the right manufacturing process or tools in an automated system may pose a challenge.
- Quality, delivery and payment assurance may pose a challenge for the platform.

The paper will seek an answer to the research question and the main hypothesis in the following sequence. First, a literature review about ODM will be carried and presented. Based on the theoretical framework a set of hypotheses will be formulated, and a comprehensive measurement tool to test them will be created. The hypotheses will be tested by surveying and statistically analyzing a sample of around 40 customers, suppliers and industry experts of the machine tools industry. The results of the main study will be then discussed thoroughly. The conclusions will lead to a number of practical recommendations and suggestions for further research.

2. LITERATURE REVIEW

Authors have highlighted the fact that with a humble beginning, the ODM companies have achieved significant growth over the past few years. A recent article in the Sourcing Journal (2017) had stated: "The win with on-demand is two-fold: the customer gets exactly what they want, and the brand only has to make exactly what they want. That means little waste, no accounts receivable risk and no excess inventory." MacroFab (2019), discussed that over the last few years, there has been a shift in the way latest products are brought to market. Cloud-based technology has opened the door for new ideas to come to the end result without the involvement of major corporations. This new approach to innovation has fuelled the need for a better production option for small and start-ups businesses: On-demand Manufacturing. Techopedia (n/d), explained that in many ways, manufacturing on-demand has been made possible through advances in technology such as laser cutting and 3-D printing. With highly customizable and technical

equipment, and a highly adjustable workforce and assembly line, a third-party company can propose different types of manufacturing on demand. Nanalyze Weekly (2019) has stated that on-demand manufacturing is all about making a business model work for (B2B) business-to-business applications. Since throughput is the key, these business models require that one has more machines than would ever possibly required at any given time. This then translates to extremely short lead times when an order is received. "Data Analytics and Automation and have enabled a new breed of start-ups to adopt agile made-to-order production cycles. Mass market players will begin to follow suit, aiming to respond more rapidly to trends and consumer demand", Business of Fashion (2019) has predicted. The success of on-demand manufacturing also depends a lot on open communications across supply chains. Fortunately, combining data and predictive analytics and Internet of Things, have improved this, says Laura Cox (2019).

Great opportunities for the concept have been pointed out by authors. Ian Wright (2018), in the study, discussed that a whole new industry has been built today around quick turnaround on-demand manufacturing services, including companies such as Plethora, Proto Labs, Xometry, Star Rapid, and 3ERP. Much of the growth in this industry can be credited to the falling costs of 3D printing and the development of additive manufacturing as a production process. Alexis MeraDamen (2018) had stated that there are a number of benefits to the on-demand manufacturing approach that makes it a much sustainable manufacturing option for retailers, including eliminating waste, no markdowns, seamless proto sampling, better cash flow, better sourcing and material management, no minimum order quantity (or MOQ), quick turnaround, market testing: reacting to your customers, easier inventory management and easy order fulfillment and shipping. MacroFab (2019) has stated that there are a number of benefits to the on-demand approach for both PCB prototypes and fully assembled electronic devices such as friction-free prototyping, scale with one manufacturer, quick order fulfillment and shipping, instant quotes and easy cost modeling, better sourcing and parts inventory management, improved product inventory management etc.

At the same time, researchers have highlighted specific challenges to be faced by on-demand manufacturing. Alexis MeraDamen (2018), has stated that "The goods will be manufactured in batches based on factors such as the customer shipping address, the patent reads, by aggregating orders from different geographic locations and coordinating apparel assembly processes on a huge scale, the embodiments provide new ways to increase efficiency in apparel manufacturing." While this patent is designed for clothing, the inventors consider this system could work for other categories and materials, including plastic, paper, rubber and leather. However, coordination would be a challenge. Globalluxsoft (2018) had stated that there are the top-5 challenges faced by startuppers and entrepreneurs working in the industry – the cost of equipment and materials, insufficient in-house expertise, lack of standards and regulations / Quality, Uneven development of the market and the need for more automation. Industrial Goods & Services (n/d), in their report findings, have highlighted several challenges to achieve global excellence in manufacturing like short supply of skilled manpower, inefficient supply chains, labor-intensive manufacturing practices particularly in nations like India, and suppliers failing to provide high-quality products.

Specific impacts of on-demand manufacturing have been pointed out by researchers. CB Insights (2019) has stated that manufacturing is becoming increasingly more efficient, modular, customized, and automated. However, factories remain in flux. Manufacturers are well-known to be slow adopters of technology, and many may resist making new investments. However, as digitization becomes the latest standard in the industry, competitive pressure will escalate the inventive to progress. The most powerful levers manufacturers will come in the form of AI, robotics and basic IoT digitization. Richer data and smart robotics will maximize a factory's output, while minimizing defects and cost. Martin Bogess (2019) had discussed the top ten 2019 manufacturing industry 4.0 tech trends according to Hitachi Solutions, which assists manufacturers including Seventh Generation, Ping and Maxell to leverage the latest technology in order to grow, are - IoT is the big thing, predictive maintenance is keeping production on track, shifting focus from B2B to B2B2C, ERP systems are continuing to streamline processes, VR and AR are continuing to forge winning partnerships between man and machine, greater visibility into Big Data is helping manufacturers achieve more, continued re-shoring is leading to an increase in made in the U.S.A products, finding tech-savvy employees will be challenging, leveraging supply chain for competitive advantage etc.

Industry Week Special Research Report (2016) has stated that there is a widespread belief that U.S. manufacturing is disappearing and that the US doesn't make things anymore. Such impressions are patently false. Real manufacturing output hit record highs in recent quarters, and is 75 percent higher than it was 25 years ago, according to the U.S. Bureau of Labor Statistics. It is right that manufacturing employment has declined significantly (by 28 percent) during the same period, as companies restructured and made the investments essential to boost productivity and become more globally competitive. While the abolition of jobs has been painful for displaced workers and their families, U.S. manufacturers as a full are bullish about their future economic prospects. The future economy will be characterized by even more extensive trade and movement of goods, data analysis and faster information transfer, and new technology that helps manufacturers maximize profitability and customer value. Industrial Goods & Services (n/d) has explained that except for a few pockets of excellence, manufacturing in India is yet to become worldwide competitive. India's manufacturers have been recovering slowly and steadily over the past few years, but more is needed to expand the few pockets of excellence. The principles of lean manufacturing will enable businesses to achieve operational excellence and competitive edge at a global level.

Collective consideration of the conceptual review, review of opportunities and challenges and those of impact of on-demand manufacturing leads us to a clear proposition that it is high time to move towards a service-based manufacturing model. Based on the literature reviewed and the model presented earlier, the following set of hypotheses is formulated for this study –

H1 – There are significant opportunities presented by the on-demand manufacturing platform
H2 - There are significant challenges faced by the on-demand manufacturing platform
H3– On-demand manufacturing platforms will have a significant impact on –
H3-1 - Product/ service performance
H3-2 - Financial performance of a business
H3-3 - Customer Satisfaction

3. RESEARCH METHODOLOGY

Going by the popular rule of thumb regarding that the minimum sample size should be 30, the questionnaire was sent to 50customers, suppliers and industry experts of the machine tools industry. 42 out of the 50 responded. The questionnaire was organized into three main sections – opportunities, challenges and impact, apart from the profile information. Constructs were designed based on the review of the literature. 10 constructs each were taken for opportunities and challenges. Impact constructs were divided over three variables – product/ service performance (7 constructs), financial performance of business (7 constructs) and customer satisfaction (3 constructs). Thus the total constructs were 37. Responses were obtained on a 5-point Likert scale of agree/disagree. Reliability test was carried with the help of a standard spreadsheet (Del Siegle), and the results were as under:

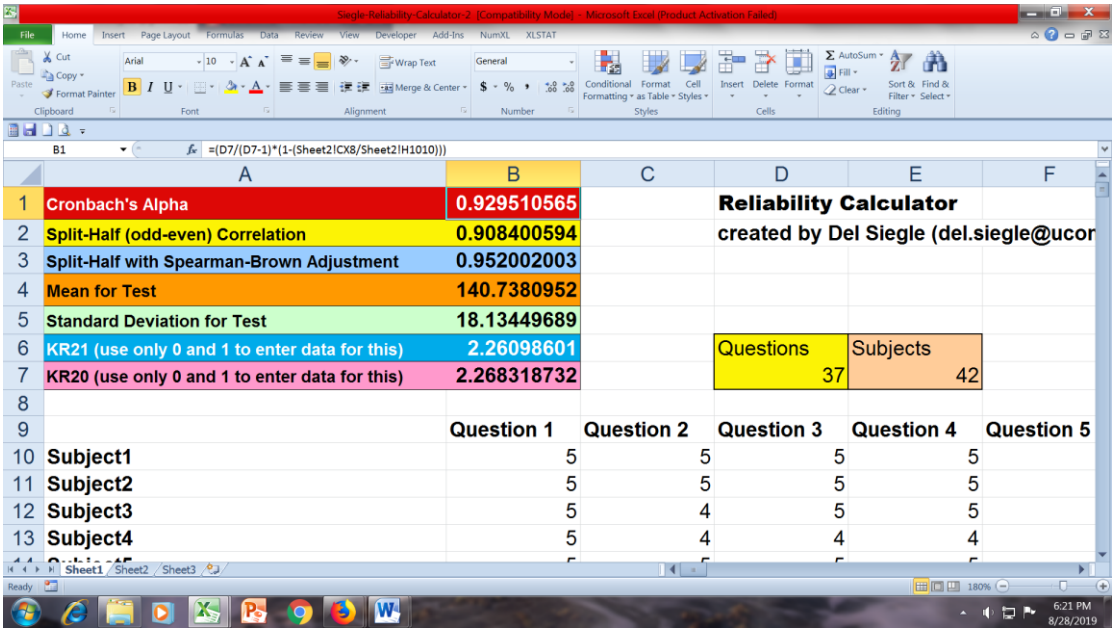

Figure 2: Reliability tests of the survey instrument

As the Cronbach's Alpha value of 0.93 was well-over the standard of 0.70, the questionnaire was considered as reliable.

Methodology planned for testing the hypotheses

The responses to the 37 questions were quantified with values of -2,-1,0,1& 2 for responses Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree respectively. An average score was calculated for each of the 42 respondents on the basis of these values. For example, the Opportunities average was the average of the 10 responses under the opportunities section. Then the average of the 42 averages was calculated for both the opportunities and challenges variables. This super-average was then compared with the null hypothesized mean of 0 (neutral) for the population. A t-test @ 95% confidence level was applied to calculate the t-statistic and p-value, and it was ascertained whether the difference between the sample mean and hypothesized population mean was significant or not. The 1st two hypotheses were thus tested for acceptance or rejection of the null. In the case of impact variable, three separate super-averages were calculated for Impact-Product/Service Performance, Impact-Financials and Impact-Customer Satisfaction. These 3 super averages were then separately compared with the null hypothesized mean of 0 (neutral) for the population. A t-test @ 95% confidence level was applied to calculate the t-statistic and p-value, and it was

ascertained whether the difference between the sample mean and hypothesized population mean was significant or not. The 3rd hypothesis was thus tested for acceptance or rejection of the null.

4. Results and Discussion

Results from Descriptive Analysis

All the 42 respondents were male. 79% of the 42 respondents were from the age-group 35-54 years. 67% of the respondents were graduates, while 33% were post-graduates. A vast majority of 90% of the respondents belonged to the work experience group of 2-5 years. A majority of 40% of the respondents were service engineers. Others were either owner/CEO (24%) or managers (33%). The agreement/disagreement percentages for the top 5 challenges were as under –

Table 1 Top 5 present challenges for manufacturers

Sr. No.	Challenge	SD	D	N	A	SA	Weighted Score	Rank
1	Under-utilization of capacity	2%	7%	21%	38%	31%	0.880952	1
2	Outdated Technology	12%	10%	17%	29%	33%	0.619048	4
3	Non-availability of skilled labor	14%	10%	10%	38%	29%	0.571429	5
4	Unstable market	10%	14%	14%	21%	40%	0.690476	3
5	Sourcing challenges	2%	7%	38%	19%	33%	0.738095	2

SD = Strongly Disagree, D – Disagree, N = Neutral, A – Agree, SA – Strongly Agree

Under-utilization of capacity, sourcing, unstable markets, outdated technology and non-availability of skilled labor were rated as the top 5 challenges in the order of highest difficulty to lowest.
On asking as to what would be done to tackle these challenges, the responses were as under:

Table 2: Top solutions preferred for addressing challenges

Sr. No.	Preferred solution	No. of resp.	Rank
1	Automation	8	4
2	Additional spend on sales and marketing	9	3
3	Service-based approach	15	1
4	Developing better insights into the market	10	2

The preferred solutions were in the order of service-based approach, proper planning, developing better insights of the market, additional spend on sales and marketing and automation.

An inquiry into the level of automation revealed that while 15 were employing an intermediate level of technology, 14 were employing the basic level and remaining 13 were operating at an advanced level.

Results from Inferential Analysis

The first set of the hypotheses was set as:

Ho1 - There are no significant opportunities presented by the on-demand manufacturing platform

Ha1 - There are significant opportunities presented by the on-demand manufacturing platform

The 10 opportunity areas and the average agreement score for each were found to be as under:

Table 3: The 10 opportunity areas and the average agreement score

Sr. No.	Opportunity	Average Agreement (on a scale of maximum value 2 indicating score of Strongly Agree)
1	Wider market reach for suppliers resulting in new customer acquisitions/orders	1.19
2	Lower inventory requirement for customers due to no minimum order quantity requirement	0.62
3	On-time delivery to customers can be secured by offloading production to other suppliers on the platform during machine breakdowns or similar production bottlenecks	0.88
4	Quicker turnaround and shorter lead times for customers due to instant quote generation and manufacturability verification on the platform	0.90
5	Direct order fulfillment and shipping to customers leads to lower shipping costs and lower inventory requirement for customers as products are made, picked, packed and shipped from the same facility	0.57
6	Rapid prototyping of products and market testing allows customers to find their product-market fit before spending more money on their idea.	1.07
7	Better production planning for suppliers due to increased visibility of automated orders, inventory and delivery schedules	1.00
8	Access to better design competence on the on-demand manufacturing platform	0.64
9	Better utilization of unused production capacity for suppliers	1.14
10	More competitive pricing to customers due to higher economies of scale	0.86
	Average	0.88

These areas were analyzed on the basis of their average agreement score, and the results of the t-test were as under:

Table 4: Testing of 1st hypothesis

Particulars	Value
Average agreement score	0.8880952
Standard Deviation	0.757468
Ho (Null)	0
H1 (Sample)	0.89
N (Sample size)	42
t-value	7.60
p-value	<0.0001

The null hypothesis that there are no significant opportunities presented by the on-demand manufacturing platform was rejected.

The second set of the hypotheses was set as:

Ho2 - There are no significant challenges faced by the on-demand manufacturing platform
Ha2 - There are significant challenges faced by the on-demand manufacturing platform
The 10 challenge areas and the average agreement score for each were found to be as under:

Table 5: The 10 challenge areas and the average agreement score

Sr. No.	Challenge	Average Agreement (on a scale of maximum value 2 indicating score of Strongly Agree)
1	Certifying an on-demand manufacturer as a new vendor may be costly as large manufacturers with an order size of 100,000 to 150,000 already have a list of approved vendors & hence reluctant to add new vendors.	0.83
2	Automating the manufacturability verification of product design may be difficult	0.83
3	Customers may be reluctant to share the confidential CAD drawings.	0.95
4	Quicker availability of raw materials for production may be challenging	0.43
5	Offline communication, coordination and calculation may be required as the instant quoting system may not be 100% accurate.	1.05
6	Lack of advanced technology or application knowledge on the part of manufacturers may hamper the quality and delivery of custom parts.	0.98
7	Frequent back-and-forth communication due to incompatibility of the tool that customer uses for design and the factory that makes the part from that design	0.86
8	Selection criteria of manufacturing partners, audit of manufacturing facilities and quality inspection of on-going production may pose significant challenges for the platform.	0.64
9	Choosing the right manufacturing process or tools in an automated system may pose a challenge.	0.57
10	Quality, delivery and payment assurance may pose a challenge for the platform.	0.76
	Average	0.796

These areas were analyzed on the basis of their average agreement score and the results of the t-test were as under:

Table 6: Testing of 2nd hypothesis

Particulars	Value
Average agreement score	0.7904762
Standard Deviation	0.725766
Ho (Null)	0
H1 (Sample)	0.79
N (Sample size)	42
t-value	7.06
p-value	<0.0001

The null hypothesis that there are no significant challenges faced by the on-demand manufacturing platform was rejected.

The third set of the hypotheses was set as:
Ho3 - On-demand manufacturing platforms will not have a significant impact on:
H3-1 - Product/ service performance
H3-2 - Financial performance of business
H3-3 - Customer Satisfaction
Ha3 - On-demand manufacturing platforms will have a significant impact on:
H3-1 - Product/ service performance
H3-2 - Financial performance of a business
H3-3 - Customer Satisfaction

Responses to 7 impact areas for H3-1, 7 impact areas for H3-2 and 3 impact areas for H3-3 were as under:

Table 7: Performance impact areas and the average agreement score

Sr. No.	Impact area – Product/service performance	Average Agreement (on a scale of maximum value 2 indicating score of Strongly Agree)
1	Increases productivity of product/ service in terms of machine output, speed, uptime and change time	0.64
2	Enhances serviceability of product/ in terms of service response, service competence and availability of spare parts	0.74
3	Enhances quality of product/service in terms of low tolerances, part rejections and post-the processing of parts	0.31
4	Increases the flexibility of product/service in terms of versatile uses in different environments, removal of time & space constraints and easy storage	0.69
5	Reduces the cost of ownership of product/service in terms of price, acquisition, delivery & running costs, resale value and cost of disposal	0.71
6	Enhances customer convenience in terms of accessibility, acquisition, delivery and ease of use of my product/service	0.83
7	Improves sustainability factors of product/service such as low energy consumption, low pollution, recyclability and low waste during product/service use	0.50
	Average	0.63

Table 8: Financials impact areas and the average agreement score

Sr. No.	Impact area – Improved Financials	Average Agreement (on a scale of maximum value 2 indicating score of Strongly Agree)
1	Increases revenue/ growth	1.36
2	Reduces procurement costs/ finance costs	0.74
3	Improves margins	0.38
4	Improves profitability	0.71
5	Increases market share	1.07
6	Improves assets utilization ratio	1.43
7	Improves cash flow	0.86
	Average	0.94

Table 9: Customer Satisfaction impact areas and the average agreement score

Sr. No.	Impact area – Customer Satisfaction	Average Agreement (on a scale of maximum value 2 indicating score of Strongly Agree)
1	Improves product/ service reviews	0.83
2	Increases customer loyalty (more repeat customers/ more reference customers)	0.71
3	Reduces customer complaints	0.43
	Average	0.66

These were analyzed and the results were as under:

Table 10: Testing of 3rd hypothesis

Particulars	Value-H3-1	Value-H3-2	Value-H3-3
Average agreement score	0.6326531	0.9353741	0.6587302
Standard Deviation	0.545713	0.602139	0.708019
Ho (Null)	0	0	0
H1 (Sample)	0.63	0.94	0.66
N (Sample size)	42	42	42
t-value	7.51	10.07	6.03
p-value	<0.0001	<0.0001	<0.0001

The null hypothesis that there on-demand manufacturing platforms will not have a significant impact on product/ service performance, financial performance of business and customer satisfaction was rejected.

DISCUSSION

Under-utilization of capacity was rated as one of the top 5 challenges on hand by the respondents. It reflects the competition and also hints towards saturation of the markets. Other challenges in the top 5 were in the form of sourcing, unstable markets, outdated technology and non-availability of skilled labor. Maximum respondents were of the opinion that a service-based approach to on-demand manufacturing is the most preferred solution. Other solutions preferred included proper planning, developing better insights into the market, additional spend on sales and marketing and automation. As far as levels of automation are concerned, there is a fair bit of equality in the use of basic, intermediate and advanced levels of technologies.

The 10 opportunities were on an average rated with an average score of 0.88 on the maximum scale of rank value 2. 0.88 average rank score is close to 1, which indicates an agreement to the opportunities identified. While there were opportunity areas like wider market reach for suppliers resulting in new customer acquisitions/orders with the highest score of 1.19 there were areas like direct order fulfillment and shipping to customers leads to lower shipping costs and lower inventory requirement for customers as products are made, picked, packed and shipped from the same facility that scored the minimum rank score of 0.57.

The 10 challenges were on an average rated with an average score of 0.79 on the maximum scale of rank value 2. 0.79 average rank score is close to 1, which indicates an agreement to the challenges identified. While there were challenge areas like offline communication, coordination and calculation may be required as the instant quoting system may not be 100% accurate with a highest score of 1.05 there were areas like Quicker availability of raw materials for production may be challenging that scored the minimum rank score of 0.43.

The three impact areas, namely, impact on product/service performance, impact on financials and impact on customer score got average agreement rank scores of 0.63, 0.94 and 0.66 respectively. These average rank scores are close to 1, which indicates an agreement to the impact of on-demand manufacturing on the three areas.

CONCLUSION

It is quite clear that opportunities for on-demand manufacturing galore. Significant among those are wider market reach for suppliers resulting in new customer acquisitions/orders, lower inventory requirement for customers due to no minimum order quantity requirement and on-time delivery to customers can be secured by offloading production to other suppliers on the platform during machine breakdowns or similar production bottlenecks. Moreover quicker turnaround and shorter lead times for customers due to instant quote generation and manufacturability verification on the platform is another opportunity. Direct order fulfillment and shipping to customers leads to lower shipping costs and lower inventory requirement for customers as products are made, picked, packed and shipped from the same facility. Rapid prototyping of products and market testing allows customers to find their product-market fit before spending more money on their idea. Better production planning is possible due to increased visibility of automated orders, inventory and delivery schedules. Access to better design competence on the on-demand manufacturing platform is improved. Better utilization of unused production capacity for suppliers, more competitive pricing to customers due to higher economies of scale were the opportunities quite overwhelmingly agreed for on-demand manufacturing. At the same time, one needs to address the challenges as well. Certifying an on-demand manufacturer as a new vendor may be costly as large manufacturers with order size of 100,000 to 150,000 already have a list of approved vendors and hence reluctant to add new vendors.

Automating the manufacturability verification of product design may be difficult and customers may be reluctant to share the confidential CAD drawings. Quicker availability of raw materials for production may be challenging. Offline communication, coordination and calculation may be required as the instant quoting system may not be 100% accurate. Lack of advance technology or application knowledge on the part of manufacturers may hamper the quality and delivery of custom parts. Frequent back-and-forth communication due to incompatibility of the tool that the customer uses for design and the factory that makes the part from that design can be challenging. Selection criteria of manufacturing partners can be difficult to fix. Audit of manufacturing facilities and quality inspection of on-going production may pose significant challenges for the platform. Choosing the right manufacturing process or tools in an automated system similarly can be a daunting task. Quality, delivery and payment assurance may pose a challenge for the platform. These were some of the challenges that were agreed upon for on-demand manufacturing platforms. The impact of on-demand manufacturing on product/service performance, financials and customer satisfaction was well agreed to. It is expected that on-demand manufacturing will have a positive influence on these areas. To capitalize on the opportunities and to address the challenges, service-based manufacturing approach to on-demand manufacturing platforms was found as the most preferred solution, and hence the same is strongly recommended for adoption.

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