An Exploratory study on a Consumer Centric approach to 3D Printing for SMEs

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**Declaration**

I declare that this dissertation that I have submitted to Dublin Business School for the award of Master of Business Administration (General) is the result of my own investigations, study and research, except where otherwise stated, where it is clearly acknowledged by references. Furthermore, this work has not been submitted for any other degree.

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Date: 25th August, 2020
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<td>Additive Manufacturing</td>
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<td>CAGR</td>
<td>Compounded Annual Growth Rate</td>
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<td>Perceived Ease of Use</td>
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<td>PSS</td>
<td>Product Service System</td>
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<td>PU</td>
<td>Perceived Usefulness</td>
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<td>TR</td>
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Abstract

This study primarily explores the consumer perception and readiness to embrace the 3D Printing technology. To measure consumer’s technology readiness and perception the empirical studies on Technology Readiness and Technology Acceptance Model were applied in succession. The study is cross sectional and inductive in its research design, and pursues a grounded theory strategy. An online mixed-method survey was shared with the research participants and gathered data from 204 general consumers segment. The data findings reported that majority of the participants are aware of and show intentions to embrace 3D Printing but have rather less 3D Printing perception and readiness. Secondarily, the study discusses the implications of consumer behaviour to portray business insights to aid SMEs pursue 3D Printing technology. Finally, this study concludes that there is tremendous potential to deliver value to consumer segment in 3D Printing if the gap between consumer readiness and perception can be mitigated.
Introduction

The 3D Printing industry, also called Additive Manufacturing - the superset of 3D Printing, has shown promise to deliver the new age of manufacturing and production technology. 3D Printing has the potential to revolutionize the production process, product lifecycle planning, and rethink the consumer capabilities (Gal, 2019; Marak, Tiwari and Tiwari, 2019). To explain briefly, 3D Printing is a process to manufacture products using a CAD design file. There are various types of 3D Printers available like Fused Deposition Modelling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM), Digital Light Process and Multi/Poly Jet fusion but all have a peculiar process of developing product layer by layer through individual material adding process. This development of products through material addition at every layer like stacking a silhouette of 2D on top of each other. This technology opens avenues to design intricate and complex geometries, reduce wastage and embrace sustainable manufacturing in decentralised locations (Pasricha and Greeninger, 2018). Thus, enabling businesses to rapid prototype, efficiently customize and reduce lead time in the supply chain.

Further, the field of 3D Printing Industry is growing at a tremendous pace, a compounded annual growth rate (CAGR) of 30% - 35%; faster, more versatile printers having extensive multi-material printing support; and attracting new project/venture listing (over 107 early stage) investments valued at $1.3billion in 2019 alone to highlight a few (Annunziata, 2019; Markets and Markets, 2019; McCue, 2019; Mordor Intelligence, 2019). With such high growth for the past decade, the adoption of 3D Printing is on the verge of ‘crossing the chasm’ from early adopters to early majority, as it presents new technology to manufacturing complex
high performance designs. But significant amount of adoption is in B2B segment with consumer engagement being hampered due to high cost, technical difficulties and business models tailored for the B2B segments (Raghavan, 2016; Öberg, 2019, pp. 8–9). The big companies look to develop scalable businesses through iterative innovation and repeat business potential customers segments. It seems this has left the consumer segment in 3D Printing with relative drawback and has widened the gap between the SMEs and large businesses to pursue 3D Printing.

With consumers not actively involved in 3D Printing business model and hampered SMEs to embrace 3D Printing, its core development would lose potential value addition propositions from consumer centric viewpoints. Subsequently, it would concentrate technology development with large enterprises, leading to monopolization and forming stringent legal barriers around the technology (Gal, 2019). Additionally, 3D Printing has potential disruptive effects by reshaping the global manufacturing supply chain and significantly altering the relationships between market players (Laplume, Petersen and Pearce, 2016; Gal, 2019; Van Heck, 2019). According to Öberg (2019), this disruptions create a power imbalance on the supply, research and development side which leaves many existing or upcoming SMEs in vain. These changing dynamics could adversely affect economic sectors through job loss and distressed SMEs (Steenhuis and Pretorius, 2016). With the growing advancement and usefulness of 3D Printing during the Covid-19 distress, it is speculated more companies will plan to adopt 3D Printing (Bell, 2020; Binkhuysen and Schipper, 2020; Business Wire, 2020). The scenarios of post-Covid19 era and growing use of 3D Printing will disrupt the previous existing market dynamics. In events of disruptions, SMEs face a higher uncertainty to survive, primarily due to lack of robust corporate infrastructure, long-term strategy, and
liabilities of size and resources (Tieber, 2019). A study across the past century found out the mortality rate of small organisation was significantly higher across all the dimensions such as public, private and non-profit sector when markets are disrupted (Glor, 2015). Thus, the dominant B2B segment alienates the 3D Printing technology from general consumers and hinders the value generation and value addition channels for SMEs.

Subsequently, to present value addition channels 3D Printing is perfectly poised to aid SMEs. Studies identify that 3D Printing holds potential for mass production and customisation, and creates a strong position syncing with the eCommerce marketplace (Cantú and Jonsson, 2012; Chen, Cui and Lee, 2019). Further, the decentralised business model brings customer in a closer loop of products and services to serve heterogenous markets (Cantú and Jonsson, 2012; Salmi and Ituarte, 2017; Jordan, 2019). The key trends influencing 3D Printings growth from consumer perspective are 1. Individualisation, 2. Democratisation, 3. Sustainability (Steenhuis and Pretorius, 2016; D’Aveni, 2018a; EY Global, 2019a, 2019b; Marak, Tiwari and Tiwari, 2019; Stewart, 2019). Studying the consumer segment opens a new dimension for the 3D Printing technology utilisation. Equally important, it presents SMEs a chance to deliver value to consumer needs in 3D Printing technology sector, generate employment and broaden the reach of technology innovation and adoption.

For consumers to embrace 3D Printing potential it is necessary to design technology solutions that can be used by them. Online service quality dimensions like ease of use and consumer confidence play a vital role in growing business (Zhilin Yang, Minjoon Jun and Peterson, 2004). More importantly, the consumers should feel the need to explore the technology and invest time to use it. For example the explorative study in 3D Printing in the
field of fashion to produce zero-waste apparels highlighted that designers/consumers needed divergent thinking and faced difficulties to move from Computer aided design to final manufacturing succinctly (Pasricha and Greeninger, 2018). Similarly, Ariadi (2016), conducted a study in technical domain for 3D Printing design to suggest a Computer-aided consumer design system that focuses on user-friendly CAD designing for consumers. Having highlighted the need for user-friendly solutions it is important to measure the consumer perception to gauge engagement and identify options for business to develop.

Both the above examples showcased consumer difficulties in engaging and utilizing 3D Printing technology and highlighted the importance of studies to understand consumer behaviour for embracing new technology like 3D Printing. It is exclaimed that the consumer behaviour is changing rapidly with the growing digital usage, the consumer have shown a demand pull inclination to consume goods and services. According to the EY study, the consumers are increasing demanding good that are local, authentic, traceable, transparent and ethical (LATTE) thus, shifting control more towards the consumers. (Thewihse et al., 2016) This implies the greater need to understand the user perception, develop satisfying user experience and finally identify goals to help business deliver value to the consumers.

Having shown the importance of 3D Printing from a consumer centric view point and how it can potentially impact negatively on the SME segments, the author has identified the need to understand consumer readiness and perception to embrace 3D Printing technology as it has been not been evaluated. The examination of consumer centric behaviour has been deemed as the research gap this study contributes knowledge. Mapping and exploring the consumer behaviour parameters provide clinical insights, which present an indication of the
level of awareness and potential engagement to the 3D Printing technology by the general consumers. Finally, understanding consumers aids to develop business implication for improving technology acceptance and embracement. These business explorations can highlight Business Model Innovation, digitalisation and consumer segment to target for SMEs.
Literature Review

The 3D Printing industry in the revised Covid-19 scenario has potentially more demand and exponential growth, has showing Compounded Annual Growth Rate (CAGR) of 30%-35% over the next 3-5 years period (Business Wire, 2020; Pearce and Pearce, 2020; Sallomi, 2020). The growing market adoption of 3D Printing is primarily due to high customisability, ability to manufacture complex designs locally and development of circular economy (EY Global, 2019b; Garmulewicz et al., 2018; Pasricha and Greeninger, 2018; Stewart, 2019). The Covid-19 scenario has highlighted the 3D Printing capabilities by locally manufacturing products and components required by hospitals, spare parts and consumer goods using open source designs and collaboration (Bell, 2020; Binkhuysen and Schipper, 2020; O’Sullivan, 2020). Overall, the implementation of 3D Printing into mainstream production would dynamically change the global supply chain creating new business models and product innovation in a diverse set of fields (D’Aveni, 2018a, 2018b). Thus, it is important to study the parameters that lead to growth of 3D Printing.

Exploring the growing adoption rate of 3D Printing, it is observed the dominant utilisations is in B2B (business to business) segment (Tieber, 2019, p. 2). Companies have found prominently use of 3D Printing for prototyping and product development solutions. Businesses leverage the freedom to customise design and produce high performance products through trained employees. But manufacturing business face a dilemma between product innovation and supply innovation to progress towards deploying effective 3D Printing (EY Global, 2019b; Deloitte, 2019). Hence, there are many directions a business can pursue towards embracing 3D Printing technology.
Subsequently, to elaborate on the changing dynamics in market, the growing use of technologies like 3D Printing, to empower the customers can lead customers to be an active participants of the production system. In the adverse situation of Covid-19, governments made modifications to legal liabilities and reducing barriers to production, empowering innovators, creative groups and small businesses to 3D Print patented designs and scale up dynamically medical production (Susan E. Hendrickson et al., 2020). This allowed engineers, entrepreneurs, designers and manufacturers to respond to the huge demand of medical and necessary goods. Thus, strongly hinting the reliance on 3DP to serve end-consumer demands.

In stages to empower consumers, technology firm’s business model be developed around customer centric attributes. The earlier set boundaries of suppliers, producers, markets and innovation agents have constricted and begun to overlap (Steenhuis and Pretorius, 2016; Botha, 2019). The new business models present the customers with significant power to customize and cater to their needs.

**Business Models as described earlier**

**How it is changing**

![Image of consumer centric business model](Botha, 2019, p. 9)

**Figure 1: Consumer Centric Business Model**

Although customers have more power in making a decision but parameters like confidence in utilising and perception towards accepting the technology are important
metrics to gauge purchasing and embracing of the technology. The study by Pasricha and Greeninger (2018) highlights the difficulties consumer face during 3D Printing for fashion based innovation. Specifically pointing out the need for divergent thinking and struggles in technical aspects to create CAD model and sending it for manufacturing. Similarly, Ariadi (2016) presents a non-designer views towards Modelling software and explores the consumer experience in terms of direct and in-direct manipulation of CAD control points. It is important that the customer experience is improved and knowledge is developed for product innovation. Developing avenues for customer knowledge management i.e., set of dynamic skills and organisational practises that are connected to creation, conserving and transferring knowledge in creating customer value (Alegre, Sengupta, & Lapiedra and Cepeda-Carrion et al., cited in Alani et al., 2019). As highlighted, with the need to connect with customers at crucial touch points, it is important to understand the customers for a good customer experience. Thus, understanding consumer is a critical part for developing user-friendly technology solutions.

For consumers to be a central part, it is important to develop solutions that are user-friendly and have a seamless user experience with the technology. According to Al-Marooof et al. (2020), User Experience (UX) has strong impact on intentions to use and accept technology, as it is connected with user cognition, action and product. While speculating the studies relating to exposure of design and difficulties faced by general consumer, the author realised there is a gap in academic literature exploring consumer behaviour in relation to 3D Printing technology. Although 3DP technology is upcoming in many segments only a few studies are performed in consumer centric direction, with majority studies being in manufacturing, technical and business innovation domain. To measure Consumer Behaviour this study
evaluates the consumer perception and readiness in respect to 3D Printing technology. In the next section, consumer behaviour theories are discussed in apt with new technology.

**Theme 1: Understanding the Consumers**

There are many empirical studies in the field of Marketing that studies customer behaviour and psychology towards products and services. Understanding what the customers values and which stage of buying the customer is helps businesses develop strategies to develop the products/services. The customer perception and customer readiness act as indicators towards adoption of technology (Kotler *et al.*, 2019, pp. 502–504). Adoption refers to use / buy / embracement of technology for the first time or exploring products/services for future use (Chien-Hsin Lin *et al.*, 2005, p. 1; Adnan *et al.*, 2019, p. 2). The perception of same product or experience varies greatly across every individual and changes with time. In marketing, perception is important as it influences consumer behaviour and vice versa (Kotler *et al.*, 2019, pp. 207–209). For example, Nunes and Arruda Filho (2018) highlighted in Google glasses study, the positive perception towards technology greatly boosts the scope to growth, vice-versa negative perception hinders market adoption blatantly. In a technological reference, consumer perception pulls innovation, generates intrinsic value and creates social recognition. The customer perception complements customer readiness to develop deeper business insights. The primary aim of this study is to model and measure consumer perception and readiness for 3DP technology. And to achieve this primary aim, the objective is to survey general consumers for their perception and readiness to embrace 3D Printing technology based on an empirical model.
The empirical studies approached to study the customer perception and readiness are - the 5 stages of buying decision process, the theory of consumption value, Unified theory of Acceptance and Use of technology, Technology Acceptance Model and Technology Readiness Index. There are many more theories to study Consumer behaviour but the shortlisted choice set is based on academic literature and applications in technology domain. There are many theories that selectively look at technology embracement like TOE have not been pursued as they view the concept of technology from an organisation standpoint (Liu and Wang, 2010). This study focuses on the customers as an individual, thus consumer, and hence consumer centric theories are selected. Further all the selected theories have good number of application in technology studies.

To begin discussion, the Theory of Consumption Value is based on 5 consumption values, viz. functional value, social value, emotional value, epistemic value and conditional value, which influence consumer choice behaviour (Sheth, Newman and Gross, 1991). In varying circumstances different consumption values, alone or in sets, have influence on consumers behaviors. Though desirable, often it is not practical to maximize all the 5 consumption values that influence consumer choices (Sheth, Newman and Gross, 1991, p. 163). Focus or bias on some values due to external short-term causes can hamper validity in the cross-sectional study. Subsequently, the author highlights difficulties and misalignment in Theory of Consumption values and studying technological acceptance for consumers. A study to evaluate consumer readiness using the consumption values by Poushneh and Vasquez-Parraga (2019), aids to evaluate loyalty, customer values and switch cost in technology sector as compared to adoption of a new technology. Another study by Lee and Han (2017) explored consumption values over 6 dimensions of consumption value over TAM to explore Mobile
service consumption for a pre-existing features using focused group interviews. The researchers identified difficulties to map and measure values in purely technological domain as the consumption value theory has vast applications. Also, both these study parameters are developed based on well-established industries. Unlike 3D Printing which is in its early stages in consumer segment.

Another study, (Lin, Huang and Wang, 2010), applies theory of consumption values to verify and eliminate gap between consumer behavior and green products marketing. This study identifies the FMCG attributes to map the consumption values paradigm for clearer understanding for policy makers. Finally, Nunes and Arruda Filho (2018) study points out the need to match social value in terms of security and functional value to clearly highlight the differentiating factors for a reliable and market consumption of the product within the use of consumption values. It is evident that Theory of consumption values is empirical and can be applied in vast areas but developing relevant technological mapping requires insights in the existing consumer understanding of 3D Printing technology through relevant studies or focus groups. This research doesn’t have access to either of those alternatives and hence, Theory of Consumption Value is rejected. Thus, the researcher previewed another model – the UTAUT model for the study.

Although progressively, Unified Theory of Acceptance and Use of Technology (UTAUT) was developed by incorporating 4 core constructs viz., performance expectancy, effort expectancy, social influence and facilitating conditions, and 4 moderating constructs viz., gender, age, experience and voluntariness of use to measure behaviour intentions. The UTAUT is developed through review and integration of 8 dominant theories to outperform
the individual integrated models to understand consumer usage intentions (AbuShanab and Pearson, 2007; Williams, Rana and Dwivedi, 2015; Donmez-Turan, 2019). But according to Williams, Rana and Dwivedi (2015), the UTAUT is still in early stages of development with no prominent areas of maturity. On the contrary, the TAM theory has been cited across many different technology domains and is widely used by researchers to study consumer behaviour and intentions. With restricted applications from academicians, UTAUT presents difficulties to determine valid and reliable hypothetical models, data collections and methodological approaches as compared to Technology Acceptance Model (TAM).

**Technology Acceptance Model**

The Technology Acceptance Model (TAM) was developed by Davis (1989) as an extension to Theory of Reasoned Action (TRA) to predict consumers embracing of new technologies. According to Davis (1989), perceived usefulness and ease of use are direct determinants of technology usage. Although studies, e.g., (Lee and Han, 2017), portray TAM as a model to explore organisational technology acceptance. But TAM grounds its research on individual’s relationship with technology. TAM focuses on individual consumers perception towards the technology and their interests and attitude towards utilising it. In the theory, Davis (1989) defines attitude to use the technology as “the degree of evaluative effect that an individual associates using the target system”. TAM has been explored by researchers, (Shankar and Kumari, 2019; Suleman, Zuniarti and Sabil, 2019; Vuković, Pivac and Kundid, 2019; Al-Maroor et al., 2020), in their quest to study technology acceptance across Internet baking, mobile commerce and electric vehicles adoption. TAM has many citations and it has matured into academic model to study technology acceptance and adoption.
Across the studies of TAM, the crucial parameters that occurs recurring are Perceived Usefulness, Perceived Ease of Use, Perceived Security and Trust. Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) are generic constructs of TAM. They form the foundation blocks for TAM to evaluate various new technologies. If consumers perceive that the new technology can help reduce time, effort and cost then a positively perception is developed towards the technology. According to Schniederjans and Yalcin (2018), PU and compatibility are among the crucial thematic factors and play a significant role in potential uses of 3D Printing especially among the potential future users and non-users. PU is defined as the belief that new technology can provide benefits compared to existing technology (Davis, 1989). PU is the crucial antecedent to adoption of technology across different technology and e-services context.

Subsequently, PEOU has a significant impact on trust and adoption intention (Sefora et al., 2019; Shankar and Kumari, 2019). PEOU directly contributes to build the PU construct. Perceived Security (PS), also noted as perceived risk, and trust play a pivotal role in successful adoption of new technology services. Trust is an emotional state that has understanding and sentimental value (Sefora et al., 2019; Shankar and Kumari, 2019). The study by (Suleman, Zuniarti and Sabil, 2019), to embrace online shopping of products found that PU and trust are influencing factors in customer purchase decisions. Overall the trust factor in consumer understanding develops the intention to purchase/embrace new technology. (Mencarelli and Arnaud, 2012) The study by Chang and Chen (2016) in 3D bio-printing, showcased the relationship between people perception, usefulness and confidence potentially enhances the acceptance and promotion of technology. Studies using TAM have added constructs to develop relations as intervene variable and dependent variable to better understand the
customers intention to purchase products and goods. This addition practise has enabled researchers to tailor certain parameters based on the technology they intend to evaluate in consumers understanding, giving the researchers an important advantage in a truly consumer centric study.

**Technological Readiness Index**

Subsequently, Technology Readiness (TR) was a concept popularised by Parasuraman (2000) to present a construct to measure people’s technology readiness and discuss its conceptualisation. TR is an index which new technologies can measure to identify the consumers stance towards embracing it.

The TR helps understand consumers propensity to embrace and use technologies (Blut and Wang, 2020). According to Parasuraman (2000), TR is a multi-dimensional construct with initial conceptualisation over 4 dimensions – innovations and optimism (motivators), and discomfort and insecurity (inhibitors). A high value of Innovation and Optimism parameters contribute positively towards the Technology Readiness Index. Subsequently, a high value on Discomfort and Insecurity contribute negatively towards the Technology Readiness Index. On the overall both set of motivators and inhibitors work in conjunction to determine the TR of the consumer. Although, debate over the number of constructs and dimensional usage exists in academic literature, TR is considered stable, individual-level, trait-like characteristics model to study technology acceptance (Pires, da Costa Filho and da Cunha, 2011; Blut and Wang, 2020). TR presents an insight into consumers frame of reference towards new technology and difficulty levels they face embracing it.
**Integrating TR and TAM**

While TR and TAM are interrelated constructs there is a major difference between the two – TR is individual specific consumer belief driven while TAM is specific towards technological system (Roy and Moorthi, 2017). This combination is also cited as TRAM (Lin, Shih and Sher, 2007; Chen and Lin, 2018). Many authors have integrated TR and TAM together in their literature to develop a clear hypothesis to understand consumers intention to embrace new technology like e-commerce, smartphone usage and internet related services (Chien-Hsin Lin *et al.*, 2005; Lin, Shih and Sher, 2007; Pires, da Costa Filho and da Cunha, 2011; Chen and Lin, 2018). It is observed, TR helps to gauge the individual technology readiness of the consumers based on consumer experience and ability, and integrates it intrinsically with technology acceptance model.

The TR acts as an antecedent to TAM understanding to develop relations across the perception of technology. TR and TAM together develop critical insights for marketing and consumer-centric development of the technology (Chien-Hsin Lin *et al.*, 2005, p. 5; Pires, da Costa Filho and da Cunha, 2011). Using TR and TAM, the aim is to study and understand consumer behaviour for 3D Printing technology. This study will develop a hypothesis based on TR and TAM integration, to evaluate the correlations across variables. The quest of this study is to shed light on consumer readiness and perception of 3D Printing to gain higher customer participation.

In conclusion, the customer participation attribute present high value in business models. Also, across all metrics it is evident that customer with insufficient readiness and poor perception of the technology will face difficulties embracing new technology (Alani *et al.*, 2018).
And this causes the technology to have slow market adoption, poor technology development and reduced marginal growth. This study will present an 3D Printing exposure towards the empirical literature of TR and TAM, through the medium of understanding general consumers. Finally, theme 1 sets to gather data and develop crucial business insights to aid SMEs pursue 3D Printing.

**Theme 2: The SME Business Implication**

Understanding customers is key as it is a stepping stone towards customer knowledge management and customer behaviour. According to Alani et al. (2019), customer knowledge plays a mediating role in strategic orientation and development, and product innovation across all small, medium and large enterprises. The understanding of consumer behaviour and knowledge helps to gauge adoption of existing and new technology. As formerly discussed, 3D Printing holds potential to grow and become the driver of change yet, there are many technical and operation difficulties to leverage the full potential that are optimistically chalked out (Oropallo and Piegl, 2016). 3D Printing isn’t going to encompass all of manufacturing methods rather complement existing methods to product evolution/create new opportunities (Stewart, 2019). 3D Printing has scope for value addition, and alongside emphasizes innovating strategies and business models to serve the customer demand. Additionally, during Covid19 the quick response prowess 3D Printing has showcased, aids to develop a local networks for 3D Printed products/services, form digital Supply chains and provide a new business dimensions for SMEs to pursue.

Firstly, SMEs play a vital role of boosting economies as they employ huge labour force and contribute greatly to business landscape. For example, on average SMEs form more than
90% of the business across all countries in the world and employ more than 70% of labour force worldwide (International Labour Organisation, 2019; World Bank, 2019). But SMEs face not as much a disruption from 3D Printing alone but more from misalignment/lack of technology and innovation networks (Jones and Tilley, 2003, pp. 140–141). Digital transformation is necessary step towards 3D Printing and use of other advance technologies. With the Covid19 scenario the digital transformation is surmount. But SMEs tend to lack financial inputs, limited management expertise, restricted scope and market exposure, and lack of infrastructure (Beggs, 2010; International Labour Organisation, 2019). Thus, with the set of hindrance and growing importance of digital embracement, it is important that SMEs focus their attention of some points like business innovation, customer behaviour and new technology opportunities.

**Business Model Innovation and Technology**

Businesses function by developing certain set of practices, operationalizes aspects of the market it caters to and monetizes certain product/service to generate revenue (Osterwalder and Pigneur, 2010). The doctoral thesis by Janrattana (2017), explores SME business models in depth from the view of value chain, leveraging networks, and ideas development, to sum that business model (BM) helps SMEs broaden their value proposition by operating as organisers of resources. But as technology changes or upgrades, the dynamics of the business change. Market Competitors, either insurgents or enterprises from other segments, take advantage of such dynamics and render existing businesses outcast. SMEs usually succumb under the disruptive force (Muller, Hutchins and Cardoso Pinto, 2012; Marom, Lussier and Sonfield, 2019). Businesses demand innovation to address the disruption. But, SMEs have low innovation output per risks they incur (Büttner and Göritz, 2008; Cantú
and Jonsson, 2012). The study Marom, Lussier and Sonfield (2019) investigated the relationship between firm size and entrepreneurial strategy in terms of innovation and survival risks, reported, SMEs need to take more risk to survive. Similarly, lower use of technology and misaligned consumer mapping could prove fatal for SMEs (Shah et al., 2017; Müller, 2019). Summing up, SMEs need to manage innovation and risks in order to overcome the disruptive forces.

On the bright side, innovation, Chesbrough (2007) highlights, isn’t always an arduous, capital intensive or purely technological process, it can be iterative and limited to areas of business development. According to Chesbrough (2007), business primarily have 2 functions: value creation and value capture, and identifies 6 pillars to innovate to generate new value in an industry. The pillars being – value proposition, target market, value chain, revenue mechanism, value ecosystem and competitive strategy. These pillars lay the foundation to BM innovation. For SMEs, it isn’t necessary that all the pillars are targeted for innovation but acknowledging the segments aids to decide innovation direction. For this study, the author focuses on markets and value addition to steer SMEs. The study took the opportunity to understanding the consumer for the 3D Printing technology and abridging risk by discussing business model innovation segments.

Business Model (BM) Innovation can stem from the dynamism of variables like market conditions, business trends, macro-economic factors that affect the business. For SMEs the BM innovation stemming from an idea extends value proposition within technology domains (Janrattana, 2017). More importantly, each technology has different diffusion rate to innovation and the logistic curve (S-shape) based on demand and supply side factors to
highlight the various social segments like innovators, early adopters, early majority, late majority and laggards within the diffusion outlook (Tidd and Bessant, 2013). To contextualize reality, complex benefits demand higher accuracy of communications between the social segments thus hampering adoption rate. Also early users are atypical consumers as they are superior technical skills thus manage using the technological product/process more effectively (Tidd and Bessant, 2013). Thus, presenting a potential argument that SMEs are not superior skilled with technology but can target certain ideas to pursue the domain.

To survive, SMEs can form a strong network to derive value. According to Antonelli et al. (2015), SMEs tend to be more profitable when they function in forms like clusters, competitive poles, industrial districts or scientific parks. In addition, when a network, categorized as the supply chain, the Hub and Spoke, and the job shop, are established, measurable features evolve like labor division flexibility and productivity, level of specialization, and cooperation vs competencies incentives have a positive influence the business metrics of the individual SMEs (Antonelli et al., 2015; Villa and Taurino, 2018). A graphical study of business networks highlight various types of profitable networking structures presents to benefit the community (Antonelli et al., 2015; Villa and Taurino, 2018). The SMEs take advantage of the local networks to overcome their shortcomings like restricted innovation potentials through collaboration and the example of 3D Printing in a dual channel strategy, online and in-store, utilizing the local logistic network for business supports the claim (Halmes and Pierreu, 2014; Bhatia, 2019; Chen, Cui and Lee, 2019). SMEs through innovation can expand their technological reach to avail the benefits of effective and efficient operations (Van Heck, 2019). According to Janrattana (2017, p. 195), collaboration and partnership presents an option to expand resources and technological progress. Building on
that, approaching 3D Printing industry in Innovation as a Service business model presents new segments for value proposition (Bhatia, 2019). With the shifting technology trends, consumers became crucial element of production, causing the earlier hard boundaries of producers and suppliers blurry. The force like customer knowledge, ease of production and personalisation govern the market adoption (Botha, 2019). This highlights the need to look at the business dynamism that affect 3D Printing adoption.

**3D Printing Business Dynamism**

In this section, the author will discuss the role of mass customisation and production, consumer perception of circular economy, customer knowledge management and servitization within 3D Printing and their effect on businesses. According to the study by Cantú and Jonsson (2012) 3D Printing is capable of mass customisation and mass production. The successful implementation of 3D Printing in Orthodontics segments proves the mass customisation possibility (Jordan, 2019). Further, according to Jordan (2019), not only the are dental products made from strong reliable materials but they are manufactured exactly to the shape desired by the Dentist. The mass customisation across many materials opens avenues of supplementary manufacturing technology and innovation models to satisfy customer’s personalised demands. Additionally, the models of product-service system can enhance value addition and generate new dimensions for monetizing services.

The mass customisation and production is the milestone that shows the technological dynamism across the manufacturing Industry. According to Calori (as cited in Cantú and Jonsson, 2012) Industry is defined as actors that influence operations: for instance technology, raw materials, the product, customers and competition. It is important to define
these actors as they play a vital role in enhancing product value. According to Osterwalder and Pigneur (2010, chap. 1), industrial actors influence the various aspects of the business model generation. The business model is affected by market dynamism, macro-economic forces, industrial dynamism and key trends (Osterwalder and Pigneur, 2010, chap. Strategy). For example, the reconfigured Sales channels for manufacturing productions using online and offline channels (Chen, Cui and Lee, 2019, pp. 27–28; Jordan, 2019). Another changing trend is servitization of manufacturing industry.

The Product-Service System (PSS) model is designed to target customer demands and generate value through system of products, services, stakeholder networks and infrastructure (Miller et al. 2002, Baines et al. 2009, cited in Green, Davies and Ng, 2017, p. 1; Yong Se Kim, 2020). Servitization, it means including service oriented functions for products, helps develop a network of businesses through technology improvement, easy spare components replacements and better customer experience with products to highlight a few (Yong Se Kim, 2020). Across the different systems, a product-service relationship can be devised to achieve business innovation and satisfy customers demands for a longer term in product usage (Yong Se Kim, 2020). It is a customer-centric concept practised by businesses to deliver precise values as customer demands like easy ON or OFF subscription based video streaming by Netflix or a personalized DIY furniture service designed by small companies to showcase a few examples. These examples enable customers to pick the level of interaction in product usage and gain maximum value from the experience.

Further, 3D Printed products manufactured have high recyclability and the material used to remanufacture other products. It also implement sustainable zero waste models
business models to minimize damage in environment (Garmulewicz et al., 2018; Pasricha and Greeninger, 2018). This presents the opportunity to manufacture and recycle products locally and could, if the opportunity is grabbed, boost the SME businesses. Benefiting from circular economy, closed loop reuse concepts and inverse logistic management system can help SMEs form the part of ‘digital’ supply chain (Jones and Tilley, 2003, pp. 203–204; Garay-Rondero et al., 2019). The growing perception of sustainable products highlights the need for Customer Knowledge Management (CKM). CKM implies tracking knowledge to adapt to customer expectations (Alani et al., 2019). Systems that are easy to use and have an excellent design are welcomed by users as they increases satisfaction levels and improve the probability of returning customers (Bayraktaroglu et al., 2019). This helps businesses steer over the dynamism of external variables.

**Transformation Journey**

The growth 3D Printing will impact supply chain, production processes and create new business segments More over most of the stages are digital and allow for easy edits and restaging. Instead of the previous supply-push business models the 3D Printing technology embraces demand-pull customize channel (Jordan, 2019). Further, decentralised manufacturing facilities will change how organisation function (Jordan, 2019). If firms compete in 3D Printing domain it will allow for greater growth in technology and more probability of higher diffusion. But first it is desired that owners/managers of SMEs are willing to take on the transformational journey.

To take the critical steps the SMEs owners/managers have to be open to innovation, organisation change and embrace ICT (Information and Communication Technology) (Beggs,
Further, Beggs (2010, pp. 84–90) identified that managerial characteristics influence ICT adoption variables like, perceived benefits, perceived control and technology readiness, that impact adoption of change and dynamics new concepts like the digital supply chain. Subsequently, to form a crucial part of the digital supply chain various value adding activities in 3D Printing can be target by SMEs. According to Christensen (2016), historically the attributes that tagged uncompetitive turn out positive impactors in emerging value network for disruptive technologies. Excluding the traditional primary supplier functions, technology induced activities like data management and analysis, knowledge based decision making, material testing and post-processing to name a few can be developed (Jones and Tilley, 2003; Rachinger et al., 2019). In addition, innovation as a service can help organisation leverage technology in supply chain fashion. SMEs can utilizes the value innovation and model in terms of value network e.g. provide innovation as a service/process to the consumers (Bhatia, 2019). Thus, across a broad domains there are many channels 3D Printing technology presents which SMEs can exploit.

With reduced processes for manufacturing as compared to the traditional manufacturing, 3D Printing should have picked up across customer segments significantly. But shortcoming as reliance over external designers, outsourcing for designs and process completion, and comfortable technology readiness in using e-commerce over the internet to embrace 3D Printing. According to Gal (2019), 3D Printing has the potential to become standard household practise and with the investment in technology, material science, printer development and stronger reliance on competitive policy they can achieve it.
Limited Reach of 3D Printing

At this stage it is important to note that 3D Printing isn’t encompassing all the manufacturing technologies in one technology but stands to extend the market reach and technical capacity to manufacture. Even so, 3D Printing has certain limitations that can hurdle its adoption. Cantú and Jonsson (2012) had anticipated that any special skills or trainings are required to operate 3D Printing as they will hinder fast adoption of technology not only by employers but more so by general consumers. The unskilled labour and consumers in using the technology hampers the ability of consumers to embrace 3D Printing. Thus technology development and e-commerce support are some points pointed out to grow 3D Printing usage (Cantú and Jonsson, 2012). Across the 3 main capabilities of Mass Customisation, the demand elicitation, logistics and process flexibility need more focus (Chen, Cui and Lee, 2019, p. 28). Further, developing robust regulation frameworks, incentivizing investment in 3D Printing and reducing barriers to 3D Printing lead to higher adoption (Gal, 2019). Addressing these points aids to perceive 3DP technology positively.

Whenever new technology shows signs of stability in early adoption stages, it gains traction from news, academic researchers and business units. But as seen from case of Google Glasses, it fails consumer adoption even after the hype (Nunes and Arruda Filho, 2018). According to Van Heck (2019), emerging technologies follows a hype cycle of 5 stages – technology trigger, peak of inflated expectation, disillusionment phase, slope of enlightenment and productivity plateau. Although each stage duration will vary, the stages summarize the extent of adoption. In the case of 3D Printing speculations are raised about the range of raw materials used to print goods (Gal, 2019). Such speculation highlight 3DP is far from stable adoption growth of technology.
Finally, 3D Printing is still in its early stages for consumer market but as listed above there are many tactics businesses can pursue. The crucial implications of the study are to present SMEs with a chance to join the 3D Printing revolution and importantly deliver value to the consumers looking to avail 3D Printing benefits. The theme 2 addresses the secondary objective to explore SMEs value addition to pursue innovation and value channels for 3DP.

Summary

The primary aim of this study was to measure the consumer behaviour that affects the 3D Printing technology based on the TR and TAM framework. The primary objectives is to measure the perception and readiness at 3D Printing. A hypothesis was developed to quantify correlations that govern the consumer behaviour. Subsequently, the secondary aim was to discuss literature to link consumer behaviour and SME business model through value innovation. The secondary objective of the study is discuss the value addition and business models innovation based on the responses to steer SMEs towards 3DP. Finally, both the aims synergise to explore the research question:

What are the prospect business innovations and value addition channels for SMEs in 3D Printing industry based on consumer perception and readiness?

In the next section, the author focuses on Methodology to unravel an approach to explore the research question.
Methodology

In this section, the methodology of the research is depicted. This study follows a cross sectional mixed-methods research design. The study primarily aims to evaluate and examine consumer behavior variables to understand the general consumer stance on 3D Printing. Hence, it is necessary to develop a methodological understand to collect and analyze data.

Participants

The target research population for this study are general consumers and hence a diverse set of participants is approached. The sample size of the questionnaire is expected to be between 150 to 200 participants. Similar, TAM study in the field of bio-3D Printing acceptance, (Chang and Chen, 2016, p. 1), internet banking acceptance, (Vuković, Pivac and Kundid, 2019, p. 1) and mobile governance acceptance, (Shankar and Kumari, 2019, p. 10), have approached a equivalent participant sample size. The researcher will present the questionnaire to individual pursuing a variety of career fields. This is done to avoid concentration of individuals from one domain creating a bias in the study. The mix of professionals are gathered based on researcher’s convenience and availability of individuals to take the survey. Further, author has requested some individuals to share the survey link on social media networks where the author isn’t a part. Thus, survey includes participants from social media network, friends and colleague, acquaintance and other social groups of close friends. This spread allows for the target population of 1st and 2nd degree of separation of general consumer in the researchers reach. The study admits participants from any geography, gender, age segment or profession as the author has limited control over these characteristics of the survey participants in the general consumer segment.
Research Design

The author has explored the literature to pick the most associated research methodological approach to apply for this study. The research paradigm that stimulates the research is Interpretivism, as the drive of the researcher is to create new, richer understanding and interpretation of the social constructs revolving around consumer in 3D Printing. According to Saunders, Lewis and Thornhill (2019, p. 149), the exploration and interpretation of social purposes relate closely with Interpretivism paradigm. The participants of the survey act on their perception and knowledge to present the reality in the social construct as is defined of Interpretivism (Ariadi, 2016). The purpose of the study is Exploratory towards the consumer behavior in 3D Printing and its implication for SMEs businesses. Since the field of 3D Printing has limited literatures pertaining to understanding consumer behaviors and implications towards SME businesses, this study is bound as exploratory. Once the initial data is collected the author will develop business implications for SMEs to pursue and aid in their quest to utilize 3D Printing.

Further, the study follows a flexible design strategy with focus on grounded theory. According to Chun Tie, Birks and Francis (2019), Grounded theory systematically discovers or constructs theory from data through comparative analysis. The grounded theory contributes to the study to develop exploratory trajectories. To examine the data collected, a hypothesis is developed to operationalize variables and sequentially analyze data for business insights. The choice of grounded theory strategy aids to develop comparative analysis for discovering literature and to discuss business theory keeping 3D Printing at the core of discussion. Following the grounded theory, this study proposes to discover richer theoretical insights of technology readiness and acceptance of 3D Printing for consumer segments.
Subsequently, the study follows a mono mixed-method design to gather qualitative and quantitative data to interpret the relationship emerging between variables. A mixed method allows a great diversity of views, helps generalize and develop clinical insights. Both qualitative and quantitative insights from the consumer perception and readiness data help to develop a theory that can help understand consumer behavior better and develop business insights for SMEs. An Inductive approach to theory development is identified as the theory follows the data based on reasoning (Saunders, Lewis and Thornhill, 2019, p. 155). The data will be gathered using the Research Instrument to explore the TR and TAM concepts to identify themes and develop insights for discussing the findings within the existing business literature for 3D Printing.

**Research Instrument**

The research Instrument for this study is a survey questionnaire with a mix of open and closed questions presented through an online medium to participants. There are 20 questions mapping across to various dimensions of the study. A mix of qualitative (2) and quantitative (18) questions are developed, refer appendix 3 for the questionnaire. One of the qualitative questions is open ended text type while the other is multiple checkbox selection. The qualitative question present in-depth insights into participants understanding and potential to use 3D Printing. Among the 18 quantitative question, 3 are demography based, 1 is 3D Printing readiness, 12 are theory parameters-based question and 2 are based on intention to use parameter of 3D Printing.

The parameters measured are mapped out from previous empirical research, but no single research maps out exactly the same parameters to be measured as 3D Printing is
relative new technology. Multiple literatures on Technology Readiness (TR) and Technology Acceptance Model (TAM) are studied and proceeded for building the hypothesis. To measure the parameters, a hypothesis model will be developed taking in account empirical literatures and relevant studies (Davis, 1989; Chien-Hsin Lin et al., 2005; Khalil et al., 2011; Chen and Lin, 2018; Bayraktaroglu et al., 2019; Blut and Wang, 2020). Many studies have extended TAM to tailor it to understand the consumers from their respective segment distinctly. Deriving motivation from these studies, the questionnaire developed will be mapped to parameters of empirical studies, TR and TAM to improve face validity and reliance of the questions posed. TR and TAM literature are used to operationalized variables in the similar setting by other researchers like (Sefora et al., 2019; Shankar and Kumari, 2019; Suleman, Zuniarti and Sabil, 2019). The 4 dimensions of Technology Readiness as per (Parasuraman, 2000) are

1. Optimism: A positive view of technology and a belief that it offers increased control, flexibility and efficiency in lives
2. Innovativeness: A tendency to be a technology pioneer and thought leader
3. Discomfort: A perceived lack of control over the technology and a feeling of being overwhelmed by it
4. Insecurity: Distrust of technology and scepticism about it to work

These categories are measured with 5 point Likert scale viz, Strongly disagree (1), disagree (2), neutral (3), agree (4), strongly agree (5) for the study (Vuković, Pivac and Kundid, 2019, p. 7). Although, literatures follow a scaling of 4 point Likert or 7 point Likert dominantly, but they have additional constructs and can confidently ask participants to either avoid the neutral field or devise greater in-depth for responses (Chien-Hsin Lin et al., 2005; Larasati, Widyawan and Santosa, 2017; Roy and Moorthi, 2017; Chen and Lin, 2018). Unlike, for 3D Printing readiness the author would allow participants to pick neutral as a choice to better understand
the relationship between technology readiness and 3D Printing readiness. 3D Printing readiness constructs extends the TR model to look selectively at 3D Printing and its related technology.

Table 1: Proxy Indicator for TR Construct

<table>
<thead>
<tr>
<th>Categories</th>
<th>Proxy Indicators</th>
<th>Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimism</td>
<td>1. Consumer opinion about technology in daily use</td>
<td>(Parasuraman, 2000; Lin, Shih and Sher, 2007;)</td>
</tr>
<tr>
<td></td>
<td>2. Consumers think of 3D Printing customisation parameter will impact their life</td>
<td>Vuković, Pivac and Kundid, 2019)</td>
</tr>
<tr>
<td>Innovativeness</td>
<td>1. Consumer’s ability to solve others technological issues</td>
<td>(Parasuraman, 2000; Lin, Shih and Sher, 2007;)</td>
</tr>
<tr>
<td></td>
<td>2. Consumers pioneering to use technology, measuring their thought leadership</td>
<td>Vuković, Pivac and Kundid, 2019)</td>
</tr>
<tr>
<td>Discomfort</td>
<td>1. Consumers ability to leave the comfort zone when asking for help</td>
<td>(Parasuraman, 2000; Lin, Shih and Sher, 2007;)</td>
</tr>
<tr>
<td></td>
<td>2. Consumers confidence in failing to deliver on technology</td>
<td>Vuković, Pivac and Kundid, 2019)</td>
</tr>
<tr>
<td>Insecurity</td>
<td>1. Consumers trust to shop online from small shops</td>
<td>(Parasuraman, 2000; Lin, Shih and Sher, 2007;)</td>
</tr>
<tr>
<td></td>
<td>2. Fear of online information sharing</td>
<td>Vuković, Pivac and Kundid, 2019)</td>
</tr>
</tbody>
</table>

To advance, the questions pertaining to TAM measure the perception towards 3D Printing and have options with 7 point Likert scales as was developed by Davis (1989) in the
original study. Since the exploration of the TAM application in 3D Printing is in the early stages of academic studies, the author kept to the original scales for reliability and validity. The scales have been exercised in literatures like Davis (1989), Cheng, Lam and Yeung (2006), and Suleman, Zuniarti and Sabil (2019) for their academic reliability and validity.

Table 2: Proxy Indicator TAM Construct

<table>
<thead>
<tr>
<th>Categories</th>
<th>Proxy Indicators</th>
<th>Research Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Ease of</td>
<td>1. Consumer believes the technology is easy to use</td>
<td>(Davis, 1989; Chang and Chen, 2016; Shankar and Kumari, 2019; Vuković, Pivac and Kundid, 2019)</td>
</tr>
<tr>
<td>Use</td>
<td>2. Implementation during Covid19 showcased the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>perception that 3D Printing is easy to use</td>
<td></td>
</tr>
<tr>
<td>Perceived</td>
<td>1. Consumer believes the technology is going to benefit</td>
<td>(Davis, 1989; Chang and Chen, 2016; Shankar and Kumari, 2019; Vuković, Pivac and Kundid, 2019)</td>
</tr>
<tr>
<td>Usefulness</td>
<td>2. Consumer believes that the technology can be used for</td>
<td></td>
</tr>
<tr>
<td></td>
<td>general consumption</td>
<td></td>
</tr>
</tbody>
</table>

While measuring these variables, the participants ethical rights and comfort is kept in mind. A standard procedure to onboard the participants is conducted.
Procedure

The questionnaire is presented in an online medium for the participants convenience to fill in their responses. Due to Covid19 lockdown, all requests to help spread the questions in secondary circles were conducted over the phone. For the participants there was no compulsion to respond to the survey. Before the questionnaire began, a small brief of the topic was presented for their understanding. They were presented an email link to ask any questions on the research. Finally, after the questionnaire a warm note of gratitude was extended to the participants.

Ethical Considerations

The survey questionnaire is presented through an online medium and ethical consideration were presented at the start of survey. The information and consent sheet were attached at the first 2 page of the web survey for participants consent, refer appendix 1 and 2. By electronic communication the implicit coercion is minimised. No personal identifiable information was asked in the questionnaire. IP address and any other personal tracking software were turned off to keep the participants anonymous. The data is stored in securely and was used only for academic purpose.
Hypothesis Development

Figure 2: Hypothesis Development using TR and TAM construct

The Hypothesis has been designed by integrating TR and TAM framework to understand new technologies as is constructed in academic literatures and studies by other researchers (Chien-Hsin Lin et al., 2005, p. 2; Lin, Shih and Sher, 2007; Pires, da Costa Filho and da Cunha, 2011; Chen and Lin, 2018). According to Chien-Hsin Lin et al. (2005), Lin, Shih and Sher (2007) and Raf Buyle et al. (2018) the TR and TAM integrated hypothesis model improves explaining capacity of consumer behaviour for marketing acumen by developing relationships across variables. The following hypothesis are designed:

- **H01**: Technology readiness enhances consumers 3D Printing readiness
- **HA1**: Technology readiness has no impact or deteriorates consumers 3D Printing readiness

The first hypothesis tries to identify the link between general TR and 3DP readiness. The researcher plans to identify links between 3D Printing technology and consumer technology
for understanding consumer behaviour. Further, Innovation, Optimism, Discomfort and Insecurity form the contributing variables to gauge technology readiness (Parasuraman, 2000). As discussed in detail in the literature review section, Innovation and Optimism are motivators while Discomfort and Insecurity are inhibitors to technology readiness. Technology readiness is statistically calculated as per the studies conducted by Burba et al. (2012). Subsequently, the study explores a relationship between the consumers perception of 3D Printing and technology readiness. The observation an individual with a strong technology awareness and experience could have better understanding of 3D Printing technology, forms the crux of this measurement. Similar to (Lin, Shih and Sher, 2007; Chen and Lin, 2018; Raf Buyle et al., 2018) studies the author explores the potential correlation between TR and PEOU (H3), and TR and PU (H2). H2 and H3 form the link between TR and TAM constructs in a sequential format.

- **H02**: Consumer technology readiness positively correlates Perceived Usefulness (PU) of 3D Printing
- **HA2**: Consumer technology readiness negatively correlates Perceived Usefulness (PU) of 3D Printing
- **H03**: Consumer technology readiness positively correlates Perceived Ease of Use (PEOU) of 3D Printing
- **HA3**: Consumer technology readiness negatively correlates Perceived Ease of Use (PEOU) of 3D Printing

Additionally, the technology readiness and Intention to use link plays a vital role in business studies to gauge consumer adoption of technology and measure the level of
innovation acceptance through tested theories on innovation management and customer value. A consumer with higher technology readiness value has more intention to use new technology (H4) (Chen and Lin, 2018; Al-Maroof et al., 2020). Intention to use further link to purchase in marketing, but that construct is not measured in this study due to limited sample.

- **H04**: The intention to use 3D Printing is positively influenced by Technology Readiness
- **HA4**: The intention to use 3D Printing is negatively influenced by Technology Readiness

Further, the TAM construct Perceived Usefulness and Perceived Ease of Use have positive correlation based lifestyle technology adoption studies (Chen and Lin, 2018) and adoption of e-service (Chien-Hsin Lin et al., 2005). Thus, the H5 link explores the PU and PEOU correlation. Finally, the PU and PEOU correlation with Intention to use technology (H6) and (H7) is explored pertaining to adoption of internet banking (Vuković, Pivac and Kundid, 2019), e-commerce and m-commerce (Primasari, Sudjono and Abriani, 2019; Shankar and Kumari, 2019) and health lifestyle technology application (Chen and Lin, 2018) literatures. These literature discussed the importance of H6 and H7 correlation as an indicator of technology adoption and diffusion of innovation in accepting the novel service, product or technology. In this study the author would explore H5, H6 and H7 link for the 3D Printing technology to understand consumer intentions to embrace technology.

- **H05**: PU positively correlates by PEOU
- **Ha5**: PU negatively correlates by PEOU
- **H06**: The intention to use 3D Printing is positively influenced by PU
- **HA6**: The intention to use 3D Printing is negatively influenced by PU
• **H07**: The intention to use 3D Printing is positively influenced by PEOU

• **HA7**: The intention to use 3D Printing is negatively influenced by PEOU

The hypotheses is designed to explore and build theory will help understand and develop consumer behaviour in regards to 3D Printing technology. The theory constructed is a combination of existing business model innovation studies (Cakmak, no date; Gal, 2019; Halassi, Semeijn and Kiratli, 2019; Holzmann, Breitenecker and Schwarz, 2019) and 3D Printing business impact exploration by academicians (Cantú and Jonsson, 2012; Steenhuis and Pretorius, 2016; Holzmann, Breitenecker and Schwarz, 2019). Additionally, Qualitative data provides significant depth to identify and describe patterns in the understanding of individual consumer responses, (Braun and Clark cited in Green, Davies and Ng, 2017) alongside the quantitative information collected from the questionnaire. Braun and Clark (cited in Green, Davies and Ng, 2017), highlight the need to describe themes as capturing something important in the data based on the patterns of responses. Perannagari and Chakrabarti (2019) referred showcased the potential usage of thematic analysis in technology domain. In this study one theme is developed - understanding 3D Printing to study the qualitative sections. The qualitative content identifies and captures consumer understanding of 3D Printing using perception as a subtheme to measure the 3D Printing understanding. This mix method develop the quantitative responses in greater detail. Further, the results obtained post data analysis will be discussed to develop business implications for SME businesses to pursue 3D Printing.
Data Analysis

The data collected will be analyzed, primarily, quantitatively for relations in the model, and developing insights in age segments and gender. To begin, a reliability testing using Cronbach’s alpha is conducted. The data will be tested and analyzed in statistical manner to present a deeper insight of the hypothesis developed. The data across both TR and TAM have been analyzed using descriptive and inferential statistics. The Non-parametric correlation test, Spearman’s coefficient for gauging the correlations is conducted across hypothesis variables. The qualitative question has been analyzed by developing a theme on understanding 3D Printing. The responses are graded based on a simple linear scale for consumers understanding of 3D Printing. Finally, business Implications are studied in sync with qualitatively and quantitative results, with the focus on SMEs to pursue 3D Printing Technology. In the next section, the results of the data analysis are presented.
Results

In this section the results are presented. The data collected from the Google Survey was analysed using Descriptive and Inferential Statistical tools on SPSS and EXCEL spreadsheet for insights and charts. On the overview, there are sequential milestones around consumer behaviour that deliver insights into 3D Printing readiness and perception. There is a strongly diminishing trend of participants from the awareness to perception of 3D Printing and finally the 3D Printing readiness. To elaborate briefly, the consumer awareness of 3D Printing is good with 82% of the survey participants aware of 3D Printing. But 70% have showcased poor to moderate perception of 3D Printing and further 77% participation have revealed that they have poor 3D Printing technology readiness. This statistical trend necessitates systematic analysis to evaluate and test the hypothesis developed. The data is first evaluated for its reliability and examined across various themes to develop compelling and valid insights.

Demography

To embark, the Demographic Distribution of the research participants, across the total 204 participants contributed in the study, is presented to highlight the survey reach in general consumers segment. The participant’s response are distributed across 4 age segments – 18 – 34 years, 35 – 50 years, 51 – 66 years and 66+ years, and gender of the participants. Referring figure 3 below, the majority participants are from the 18-34 years age interval. And other age intervals contribute to the study in lower percentage. Further, the participants split by gender are 74 Female, 127 Males and 2 preferred not to say. Thus, the initial demography analysis portrays the survey has collected data primarily in 18-34 years segment and Male dominated.
It is crucial to explore if the other segments are diverging to extremes in terms of the basic awareness of 3D Printing before proceeding with other statistical analysis.

**Figure 3: Age Segmentation of the Research Participants**

Further, the Total Participants (N) = 203 in the survey, 167 responded with a Yes for awareness of 3D Printing while 36 responds picked a No, showing the majority 82% of respondents are aware of 3D Printing, refer figure 4. Further, the demography split by age and gender provides crucial understanding of the 3D Printing Awareness present among participants. It is important to conduct separate segmented analysis to gain insights into specific segments but the purpose of the study is explore the consumer centric variables in terms of the 3D Printing for which closely related/clustered data helps develop reliable analysis. The age segmented split of 3DP Awareness, refer figure 5, is evenly segregated within the range of 75% to 85% among the dominant age ranges of the study viz., 18-34 years, 35-50 years and 51-65 years. Similarly, the gender-wise split for 3DP awareness, refer figure 6, showcases an equal distribution of awareness across all genders. The close clustering of segments suggests little impact of extreme cases and moderates the risk of divergent analysis.
Thus, we can conclude that all the segment’s data can be used to evaluate the hypothesis and develop business insight.

% OF PARTICIPANTS AWARE OF 3D PRINTING

![Pie chart showing 82% aware and 18% not aware of 3D printing.]

Figure 4: 3D Printing Awareness

Although, numbers of participants in each age interval vary, the overall percentage of awareness is relatively close, and for the limited sample generalised for consumer behaviour. Although the 18-34 years is slightly more dominant and probably influence the analysis, but only in moderation as the no extreme variation is disclosed. Similar analysis is spotted in the gender wise distribution of 3D Printing awareness, refer figure 6. Extreme segments if present would demand separate examination. As discussed, the closely clustered data presents a compelling evidence that all demographic segments can be analysed in one group rather than the necessity to segregate them into independent groups.

![Bar chart showing age segmented split for 3D Printing Awareness.]

Figure 5: Age Segmented Split for 3D Printing Awareness
Subsequently, the data collected from Google form was cleaned and coded for its computation inconvenience, and missing data. The author has deleted responses with many missing fields, edited Neutral option in few fields, deleted ‘No’ Consent picked fields for evaluating the data for educational purposes and participants with No selected for 3D Printing Awareness going ahead in the analysis. The reason for deletion are purely keeping up the ethical standards and uncluttering data for the ease of coding into the software. The Hypothesis and Correlation analysis are conducted over SPSS software while, descriptive statistics and visualisation is conducted on Excel Spreadsheet. In the next section, the author discuss the data for Reliability.

**Validity and Reliability Testing**

In this section, the author conducted validity and reliability test of the data collected. Validity testing is important as it portrays the data consistency in representing elements of the research across empirical literature and academic studies. As discussed in earlier sections, the face validity and content validity of question design is presented through academic studies of TR, TAM and novel-technology literatures, and additionally the scales are selected as per previous empirical studies and academic literatures (Davis, 1989; Lin, Shih and Sher,
2007; Roy and Moorthi, 2017; Chen and Lin, 2018; Raf Buyle et al., 2018) to maximizing response validity to the study.

Further, the reliability of the data can be judged based on consistency of measurement. Reliability testing is conducted to test whether the data is measuring similar variables. Thus, the Cronbach’s Alpha is computed for each variable to judge its reliability. An alpha value of greater than 0.7 signifies strong reliability. But according to Pallant (2010) for less than 10 items on the scale Cronbach’s alpha greater than 0.5 indicate strong reliability. The table below lists out Cronbach’s Alpha for all the measured variables of the study gathered from the survey.

**Table 3: Cronbach’s alpha for variables measured**

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Cronbach’s Alpha</th>
<th>No. of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimism</td>
<td>0.676</td>
<td>2</td>
</tr>
<tr>
<td>Innovativeness</td>
<td>0.652</td>
<td>2</td>
</tr>
<tr>
<td>Discomfort</td>
<td>0.351</td>
<td>2</td>
</tr>
<tr>
<td>Insecurity</td>
<td>0.179</td>
<td>2</td>
</tr>
<tr>
<td>PEOU</td>
<td>0.515</td>
<td>2</td>
</tr>
<tr>
<td>PU</td>
<td>0.72</td>
<td>2</td>
</tr>
</tbody>
</table>

In the table above, the Cronbach’s alpha for variables Optimism and Innovativeness fit the standard of greater than 0.5 form 2 questions measuring the construct. While Discomfort and Insecurity variables have a poor reliability as the value of alpha is significantly below the vital value of 0.5. Also the inter-item correlation for discomfort is 0.217. Since the Cronbach alpha for the 2 items was lower than 0.5 the items are not coupled together to form
the discomfort variables. The possible mismatch could be because one of the element was reverse coded, causing poor responses. Due to poor Cronbach alpha some item need to be deleted (Shelby, 2011, cited in Vuković, Pivac and Kundid, 2019, p. 11). Thus, only the primary proxy indicator relevant to the study was kept and other item was discarded. The item measuring the discomfort of consumers when using technology was coded to capture the discomfort variable and has a mean of 2.6 with a standard deviation of 1.018 across the 167 responses.

Similarly, Insecurity has an alpha of less than 0.5, with the inter-item correlation of 0.099 and hence it is concluded that the individual question elements were measuring dissimilar items. A similar explanation as per the discomfort section follows suit, the reverse coded elements failed to capture the full meaning of the participants response. Further, only the primary proxy indicator was kept for the Insecurity field for further analysis. The insecurity item has a mean of 2.56 and a standard deviation of 0.909 over the 167 responses. Finally, all the 4 variables discussed above combine to evaluate the technology readiness construct.

Next, the study concentrates at the Technology Acceptance Model variables like PEOU and PU under the lens of reliability analyse using the Cronbach Alpha. As indicated in table 1, the Cronbach’s alpha for PEOU is 0.515 and PU is 0.72 are both quality indicators of data reliability can be coupled together to form the variable construct. In the next section, the author evaluates the developed hypothesis based on the variables measured.
Hypothesis Testing

In this section, the hypothesis model is tested across the 7 hypothesis developed. The variables that form the constructs have been tested for reliability and coded to evaluate the hypothesis. In the first section the technology readiness and 3DP readiness are evaluated and in the latter section the technology readiness and acceptance model is tested for the data collected.

Hypothesis 1: Technology Readiness and 3D Printing

The 4 constructs of Technology readiness viz., Optimism, Innovativeness, Discomfort and Insecurity combine to present the technology readiness value for consumer. TR is developed based on a scaling of motivators and inhibitors (Burba et al., 2012, p. 21) and further diagnosed as laggards, average and skilful technology users. While 3D Printing readiness is analysed through qualitative responses from the participants. This hypothesis is tested using descriptive statistics, using frequency, to gauge influence. It is observed that Skilful user of technology have very marginally showcased positive influence on 3D Printing readiness. To represent numerically, 79% of Average users of technology have poor to moderate level of 3D Printing readiness while, marginally improved, 73% of skilful users of technology have same the level of 3D Printing readiness. Similarly, 27% of skilful user are comfortable using 3D Printing technology as compared to only 21% average user of technology. Refer the figure 7, for the graphical representation of the technological readiness plot against 3D Printing readiness. In conclusion, there is only marginally impact on the positive direction, that the technological ready consumers tend to have a better chance of being 3D Printing ready. Thus, the null hypothesis is accepted.

- **H01**: Technology readiness enhances consumers 3D Printing readiness
• **Hypothesis** (H1): Technology readiness has no impact or deteriorates consumers 3D Printing readiness

The importance of hypothesis (H1) is that changes in technology readiness of consumers can have an effect on 3D Printing readiness of the consumers. Also, since this domain is relatively new it is important to present a metric consumers can understand and subsequently be evaluated – thus, technology readiness of consumers in general consumption of technology products and services, and compare it with the new technology like 3D Printing. Based on analysis, the marginal positive correlation provides mild weight on the relationship between TR and 3DR. Further, an in-depth questions across both the aspects can help develop more meaningful insights. In the next section, the TR and TAM model hypothesis are evaluated.

**Hypothesis evaluation for TR and TAM models**

Based on the data collected, the hypothesis is tested for its significance and correlations. Since the variables were measure using Likert Scales it was understood that
Spearman’s Correlation testing is appropriate. Spearman’s coefficient method was picked for analysing correlations among data because the method does not require continuous level data or variables which are normally distributed. So the ordinal data was coded for purpose of finding correlations. In statistical relevance the Spearman’s coefficient, 0.1 to 0.29 are considered small effect sizes, 0.3 to 0.49 are considered moderate effect and coefficient above 0.5 are considered strong effect sizes in terms of correlations. It is important to note these value brackets as they shed light on the nature of correlations which helps to understand consumers in novel technology acceptance. Thus, the data was analysed for the 6 hypothesis, H2, H3, H4, H5, H6 and H7, using Spearman’s correlation and reported below in the table 2.

Table 4: Spearman’s coefficient for TR and TAM

<table>
<thead>
<tr>
<th>Variables</th>
<th>TR</th>
<th>PEOU</th>
<th>PU</th>
<th>Intent to Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEOU</td>
<td>0.266**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PU</td>
<td>0.333**</td>
<td>0.635**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Intent to Use</td>
<td>0.251**</td>
<td>0.117</td>
<td>0.160*</td>
<td>1</td>
</tr>
</tbody>
</table>

** Correlation is significant at 0.01 level (2 tail)

* Correlation is significant at 0.05 level (2 tail)

To elaborate on the table 4 results, the author first discusses the H2, H3 and H4 hypothesis which have technology readiness (TR) as the common construct and maps out the relations between PU (H2) – 0.333**, PEOU (H3) – 0.266** and Intention to use 3D Printing (H4) - 0.251** respectively. Firstly, the Spearman’s coefficient for H3 and H4 is within small effect bracket while for H2 is within the moderate effect bracket. Although, H2, H3 and H4
have a positive coefficient, H2 seems to be strongly related to the rise as compared to the other 2 hypothesis. This implies that changes in technology readiness can have meaningful impact on the PU. In evaluation of the hypothesis all the three H2, H3 and H4 have presented that the null Hypothesis is accepted.

- **H02**: Consumer technology readiness positively correlates Perceived Usefulness (PU) of 3D Printing
- **HA2**: Consumer technology readiness negatively correlates Perceived Usefulness (PU) of 3D Printing

- **H03**: Consumer technology readiness positively correlates Perceived Ease of Use (PEoU) of 3D Printing
- **HA3**: Consumer technology readiness negatively correlates Perceived Ease of Use (PEoU) of 3D Printing

- **H04**: The intention to use 3D Printing is positively influenced by Technology Readiness
- **HA4**: The intention to use 3D Printing is negatively influenced by Technology Readiness

In conclusion, the technology readiness construct positively affects the PU, PEOU and Intention to use 3D Printing. These developed correlations can be used as a measure for future studies. Next, we look at the correlations between technology acceptance constructs.
Subsequently the study evaluates the variable links for PEOU and PU (H5), and PEOU and Intention to use (H7). The author identifies a strong correlation between PEOU and PU with the coefficient value of 0.635, with 0.01 significance level. This strong correlation signifies that Perceived ease in using the technology can have a strong impact in consumers mindset in perceived usefulness of 3D Printing. Further, PEOU has a very weak link of correlation with Intention to use. Possibly because from analysis of Consumer Behaviour, the author identified a huge demand to use 3D Printing technology as compared to the relatively mix responses on perceived ease in technology consumption. The weak correlation can also signify a gap in technology understanding and presents opportunity for businesses to generate and deliver value to customers. These aspects will be discussed in greater depth in the business implication sections. For the results section, the author concludes that for both, H5 and H7, the null hypothesis is accepted.

- **H05**: PU positively correlates by PEOU
- **HA5**: PU negatively correlates by PEOU

- **H07**: The intention to use 3D Printing is positively influenced by PEOU
- **HA7**: The intention to use 3D Printing is negatively influenced by PEOU

Finally, looking at the hypothesis H6, correlation between PU and Intention to use (H6), we identify another weakly positive correlation. Academic literatures have focused on progressive developments in PU and Intention to use as closely related to successful acceptance of technology. Within the setting of this study, the link has been identified as a possibly gap in consumer perception of usefulness of 3D Printing and a relatively higher intention to use 3D Printing, as discussed in section on Consumer Behaviour, leading to a
lower Spearman’s correlation coefficient. To conclude, H6, the study identifies the null hypothesis was accepted.

- **H06**: The intention to use 3D Printing is positively influenced by PU
- **H6**: The intention to use 3D Printing is negatively influenced by PU

To present the overall conclusion, the 7 hypothesis were tested for their correlations across the different variables. It was found that in all 7 have the null hypothesis was accepted in varying degree of weak, moderate and strong correlations individually. In the next section, the results pertaining to Consumer behaviour are discussed.

**Consumer Behaviour Analysis**

In this section the consumer behaviour is selectively looked thought the aspects of intention to use of 3D Printing technology. In the earlier section the results related to hypothesis were presented and examined, which identified some weakly positive correlation across variables. This section attempts to present results that support the claims and observation made in the earlier section. At the same time, this section reports consumer behaviour preferences and choices towards 3D Printing.

**The Consumer Choice**

In this section, the data is analysed through a multi-method process to derive greater value and generate business insights. The intention to use 3D Printing is mapped based on the participants response for their ambitions to embrace 3D Printing. The nominal data is analysed for its descriptive statistics by presenting the number of individuals selecting a particular choice to embrace 3D Printing, at the same time quantifying percentage of
participants picking that choice. This computation helps develop greater insights into consumer behaviour towards embracing 3D Printing by narrowing on a different choices. As presented in figure 8, the different choices are mapped out on a pie chart for individual consumers response. Note that Individual consumer can pick more one preferred choice as per their demand and understanding. For example, the Aesthetic choice was picked over 101 times in the total response set, this forms 20% of the total choices picked. Also, 101 participants form the 60.5% of total participants (N=167) population, refer figure 9.

Figure 8: Respondents Multiple Preferred Domains for 3D Printing

Figure 9: Respondents (%) Preferred Choice per Domain
The above figures 8 and 9, present that only 3.6% have not picked any choice to embrace 3D Printing, implying the rest 96.4% have picked at least one choice to embrace 3D Printing. This statistics reports a strong demand for 3D Printing and intention to use the technology. The poor correlation identified for PU, PEOU and TR could be accounted to consumer behaviour which identified tremendous intention to use. Across the choices, educational use seems to be the most preferred choice with 23% of the total preferences. It is followed by creative use and aesthetics as the preferred choices with just over 20% recorded responses. Across the other option choice, participants picked engineering, architecture and medical equipment as independent choices of interest. These segmented choices present avenues to explore for greater acceptance of technology. Businesses can selectively look at these metrics based on their competencies and present value addition to customers.

**Technology readiness and consumer perception**

Further, to portray the variation of choices in terms of the preferred method to embrace 3D Printing, the participants were asked to pick a process most ideally suited to their
understanding and experience with technology. To develop in-depth insights the responses were evaluated across technology readiness parameter of Average and Skilful technology users. This combination explores the difference in consumer behaviours for 2 different set of users. It can be noted that 44.5% in average users preferred premade templates and basic category as a process to embrace 3D Printing. While 25% of skilful users preferred to model cad design for better accuracy. More importantly, 20% of average users have imparted their discussion to avoid using 3D Printing as compared to only 12% in skilful users Thus, the difference in technology readiness present varying process to embracing 3D Printing adoption. The figure 11, has 5 perception themes developed – Inconsequential, Basic, Intermediate, Advance and Expert. To elaborate the perception themes, they are based on understanding of 3D Printing from a general knowledge point which can possibly answer questions like, what is 3D Printing, knowledge of any key variables or have they heard about it. Based on the text response the classifications are made. The 3D Printing perception of the user data reports that 77% of users have below Intermediate understanding of 3D Printing, refer figure 11 below.. Comparing with skilful users of technology we find 59% below Intermediate understanding of 3D Printing.

![Technology User Level vs 3D Printing Perception Level](image)

Figure 11: Measuring 3D Printing Perception against technology readiness user map
The figure 11 summarizes an important point, that across both the technology ready consumers there is significant percentage of participants (consumers) who have poor perception of 3D Printing. If the participants set represents the actual consumer population, over 70% of them have a lower than Intermediate level of 3D Printing understanding. This is a significant number and efforts to improve perception can help 3D Printing embracement.

**Impact of Covid19 on Consumer Perception of 3D Printing**

Based on the data analysis, the Covid19 adversary has created a positive perception of 3D Printing. Questions pertaining to usefulness and willingness to explore 3D Printing due to practical usage of 3D Printing were asked. Over 70% of the participants agreed that they are looking at 3D Printing as an utility option to embrace for the future. The graphical representation below visualises the statistical segments.

**Covid Adversary and Positive 3D Printing Perception**

![Covid Adversary and Positive 3D Printing Perception](image)

*Figure 12: COVID adversary and positive 3D Printing perception*
Consumer Intention to use and Recyclability

The data was analysed for circular economy settings where the products are recycled and re-manufactured into new products. Presenting on the point, the participants showed a positive perception towards embracing 3D Printing as it upholds the recycling principle, refer figure 13. This presents an additional segment for 3D Printing technology in terms of utilising decisions by the consumers.

![Distribution of Consumer Perception for Recyclability](image)

**Figure 13: Distribution of Consumer Perception for Recyclability**

Finally, to conclude the results section, the author highlights a key trend that 80% of the participants are aware of 3D Printing, but among them 70% of participants have poor to moderate perception of 3D Printing and further 77% have poor 3D Printing readiness. The consumers yet have shown a strong inclination towards utilising 3D Printing technology. Thus, the gap between poor perception and readiness can present businesses opportunity to deliver value. In the next, the author will discuss some of the crucial areas that can drive businesses to pursue 3D Printing.
Discussion

In this section, the author will interpret the results examined in the previous section and discuss the business implications for SMEs to pursue 3D Printing. The primary aim of the study, to examine the consumer perception and readiness to embrace 3D Printing, is achieved in the previous section. In the discussion, the author will focus on secondary aim to explore consumer value segments based on the analysis to steer SME businesses towards 3D Printing.

To begin our exploration of consumer value for SMEs, the author first discusses the findings of the study. It was noted during analysis that participants exhibited a strong intention to embrace 3D Printing by picking certain preferred domains and willingness to participate in processes leading to purchase of 3D Printing goods or services. But on the other hand, the poor responses in the consumer centric variables like, 70% of participants showed poor 3DP perception and 77% of participant showed poor 3DP readiness, form the major hindrance in the journey to embrace 3D Printing. The study by Ariadi (2016) and Pasricha and Greeninger (2018) have highlighted similar instances of poor readiness towards 3D Printing. They showcased that the consumers had to indulge in straining activities like changing file format, understanding production process, dealing with print failures, and confusion on how during the use technology in manufacturing desired product. According to Tidd and Bessant (2013), the more ambiguous the benefits of innovation the higher the significance of barriers towards innovation adoption. Additionally, the barrier bandwagons occur due to combination of competitive and industrial forces. Thus, it is crucial the barriers be struck down for better market penetration. The difficulties will discourage the general consumers from picking 3D Printing over existing options.
Subsequently, for the hypothesis modelled all the null hypothesis were accepted. Implying the technology acceptance model is suited for studying 3D Printing to gauge technology adoption. Although, the Cronbach’s alpha values, refer table 3, are lower than reported in different TR and TAM literatures (Chang and Chen, 2016; Larasati, Widyawan and Santosa, 2017; Chen and Lin, 2018; Vuković, Pivac and Kundid, 2019), the significant difference was the depth of the questionnaire and a focused group of participants in their study. Many questions targeting the same constructs help get higher reliability in data. Similarly, focus group aids to lessen the diversification of responses. Further, the TAM framework employed bears the correlation linkage between variables as described by the empirical study but only poorly. According to Chien-Hsin Lin et al. (2005, p. 5), the poor constructs can be due restricted practical understanding of the technology. The poor to moderate influence of correlation coefficient values highlights the necessity of focused data collection, higher computation analysis and detailed speculations be employed. Similar technology acceptance studies, (Chang and Chen, 2016; Shankar and Kumari, 2019; Suleman, Zuniarti and Sabil, 2019) have practiced structural equation modelling, goodness fit index and root mean square error average statistical techniques to analyze the data. These techniques evaluate weights on the link between the construct variables but, these analyses did not meet the objectives of this study. This study explores the links for their correlational influence either positive, neutral or negative across the variables.

One crucial finding was the high positive correlation between PEOU and PU, refer table 4. This high correlation resonates with other TAM studies to identify the critical link in technology acceptance (Chien-Hsin Lin et al., 2005, p. 2; Vuković, Pivac and Kundid, 2019, p. 12). Further, PEOU and PU formed the mediating link to understand Consumer behavior
between TR and Intention to use. Another finding was that the participants measured average or skillful TR users of technology reported high poor 3D Printing readiness. This implies that even the skillful users displayed poor 3D Printing readiness, refer figure 7. According to Parasuraman (2000), technology readiness metrics presents an in depth understanding of the customers to embrace and interact with technology. This means with a poor linkage between TR and 3DPR implies that the consumers are alienated and ambiguous towards 3D Printing. It is pertinent that 3DPR is explored to find its impact on 3DP adoption (Roy and Moorthi, 2017, pp. 16–17). Thus, 3DPR as an independent construct needs further speculation to develop insights for consumer behavior.

Finally, data analysis of the consumer behavior segments conveys that most participants have intentions to consume services and/or products related to their preferred needs using 3D Printing technology. This segmented insights present businesses to take an opportunity to deliver value to consumers. The role of TR was to develop demographic segments while that of TAM was to present technology niche segments for businesses to focus (Chien-Hsin Lin et al., 2005, p. 5). In the next section the author will discuss value generation segments to steer SME businesses towards 3D Printing.

The 3D Printing Opportunity for SME Businesses

In this section, the author explores the role of SME businesses to adopt 3D Printing to deliver value to specific customer segments. The consumer behaviour plays a central part in developing business models in the digital value addition segments. According to Kotler, (cited in Kasahara, 2015, p. 10), a business should orchestrate operations in a customer-satisfying principles rather than be merely goods producing organizations. The consumer centric
development and digitalisation for SMEs is crucial as it allows for value addition and innovation based on consumer satisfying ideology. But as highlighted in findings there is gap in the consumer intentions to embrace 3D Printing and consumer perception and readiness of 3D Printing. Clayton Christensen stressed that, “Customers don’t buy products or services; they pull them into their lives to make progress” (Christensen and Dillon, 2020, p. 24). Thus, its crucial to make avenues to onboard consumers by addressing the gaps in consumer engagement.

Firstly, the SME businesses need to recognize consumers as a potential segment to pursue. Traditionally, businesses have been targeting B2B segment predominantly for 3D Printing technology related manufacturing or services (Locker, 2017). It is natural for businesses to exploit the existing infrastructure and value channels to generate revenue. But incremental transformation to lead B2C segment by targeting strategic niches through focused goals, addressing demands, customer learning and best practices can create stable markets (Tidd and Bessant, 2013, pp. 369–371). Drawing resemblance to point discussed, 3D Printing mostly catered to needs of B2B markets and technical specialties but can progress to potentially cater for consumers segments creating a hybrid market – niche and mainstream. The consumer willingness to embrace 3D Printed goods and services as identified in the data analysis strengthens the motive for SMEs to make the shift.

To grab the consumer intention to participate in 3D Printing it is important to recognize the pain-points in the consumer 3D Printing readiness. Developing software, learning portals, mobile 3DP and practicality to consumer demand improves the customer readiness which can sequentially steer businesses to create the infrastructure to engage B2C
segments (Ryan et al., 2017, pp. 15–17). According to Liu and Evans (2016, pp. 2–4), SMEs have limited financial and human resources to invest in capital intensive research developments but can focus on collaboration, strategic alliances and partnerships to generate value. To present examples, SMEs can focus on software improvement – feature development, niche design development, incremental product and process innovation and improving user experience on the 3D Printing technology to improve consumer readiness towards 3D Printing. Equipped with 3DP readiness consumers can think about engaging 3D Printing.

Secondly, the author reports that SME businesses are willing to participate in the 3D Printing technology. Based on the data analysed by Schniederjans and Yalcin (2018), SMEs have shown promise in adopting 3D Printing primarily on key drivers like performance expectancy, relative advantage, facilitating conditions, perceived usefulness, compatibility and trialability. Many of the SMEs are identified as innovators, early adopters and early majority towards adopting 3D Printing depending on the management’s drive to generate value addition activities. According to Tidd and Bessant (2013), early adopters play a strategic role in displaying positive acceptance of innovation by justifying the innovation through reference customers and present visible performance advancement, trigger word of mouth in communities, stimulate imitation to grow user base and collaborate with leaders. Additionally, Antonelli et al. (2015), identified that SMEs tend to be more profitable when they function in networks like cluster, competitive poles and specialized zones. The reasons for higher success are increased level of specialization, labor flexibility and productivity, cooperation and competitiveness (Antonelli et al., 2015). The combination of these tactics
enables SMEs to advantage of their networks to generate knowledge and deliver value to their customers.

Further, the investigating the relationship between firm size and entrepreneurial strategy in terms of adoption of innovation and perceived risks found that, the larger firms’ strategies are more innovation based with lower risk while small firms tend to have less innovation rewarding at a significant high-risk factor (Beggs, 2010; Marom, Lussier and Sonfield, 2019). This reinstates the need for SMEs to look at innovation selectively and with more focus on end customers’ demands to reduce the risk. According to Botha (2019), innovativeness alone doesn’t contribute towards product getting accepted in the market. Other external factors like desire for uniqueness, knowledge development, customer readiness and social acceptance have a varying degree of impact on the technology adoption. However, domain specific innovation which upholds customer-specific interest finds it easier to succeed in achieve greater market share (Botha, 2019). From the findings for this study, various consumer preferred segments emerged e.g., using 3D Printing for Educational and prototyping usage. They present SME businesses an opportunity to focus their attention on a specific domain for knowledge building, collaboration and gaining in depth insights into consumer demands to satisfy. The domain specific innovation improves chances for sustainable business at a relatively lower risk by targeting selected elements of the business model.

**Business Model Innovation**

In the previous section, the study highlighted aspects of consumer behaviour SMEs can target to deliver value in 3D Printing. In order to deliver value SMEs would need to embark on a 3D Printing transformation or a journey to understand value generation. Ryan *et al.*
(2017) presents research that exploits the various dimensions in 3D Printing scenarios to provide opportunities in multi-disciplinary gaps. These gaps reinstate that niche domains are in phase to be explored for opportunities to extend existing manufacturing capabilities or acquire new processes to strategically diversify. In this section, the author will discuss business models that have been realised to leading businesses in the 4th Industrial Revolution. 3D Printing has been identified as one of the core technologies for the 4IR (Müller, 2019). Within the context of this study the domain specific innovation segment can deploy Innovation as a service, Servitization of products and knowledge based 3D Printing services. There are other customer centric business models to choose from based on the management discretion to aid SMEs pursue 3D Printing (Müller, 2019). But grounded on the findings in this study, the author has decided to elaborate in brief the topics listed above.

To begin, Innovation as a Service can be employed to focus on Value chain rather than drilling deeper on the Supply chain foundation. According to (Bhatia, 2019, p. 2), small and large companies are participating in open innovation model to cater to innovation needs of the industry. If businesses keep the consumer demands central to their innovation it validates the technology that the consumer be more prepared to embrace it. Bhatia further highlights that, the shift from products to platform development leads to customisation and personalisation of technology. Innovation as a Service model can aid SMEs develop knowledge on consumer pain-points and extend the opportunity for consumers to leverage the features. Across the 3D Printing technology ecosystem, refer Appendix 4, SMEs can identify segments to deliver value.
Subsequently, the product Servitization concept can aid SMEs generate life time value by identifying value propositions to provide services to customers. According to Yong Se Kim (2020, p. 14), Servitization can be implemented across various spaces like product, customer, business model and service to help customers achieve activities and processes to reach the end goal. To explain Servitization the example of automobile manufactures is selected, automobiles are not only sold to the customers but also routine maintenance presents the businesses with a revenue stream and the consumers with longer serving product. Such avenues can be identified in niche domain-specific regions SMEs decide to cater. The digitisation of manufacturing presents businesses an easy access to leverage 3D Printing with spare components, remote and on-site manufacturing and R&D (Salmi and Ituarte, 2017, p. 21). Digitalisation, digital supply chain and design feature library can help consumer pick 3D Printing for its convenience and services (Garay-Rondero et al., 2019; Rachinger et al., 2019, pp. 13–14). To reinstate, it is vital to keep the consumer central in developing the service functions to be able to deliver value.

Finally, the customer knowledge management based business development can be pursued by SMEs which can as consultants to provide expertise in consumer behaviour, user experience or technical knowhow for a segment (Alani et al., 2019). The growing market implies additional information regarding niche domains like existing software apps used, ideal process time and combining traditional methods with 3D Printing (Salmi and Ituarte, 2017, p. 19). SMEs can pursue B2C segment through user experience, collaboration and strategic network to cater to needs of consumers. Further, this study has recorded a positive shift in consumer perception towards 3D Printing.
The Positive Shift in Perception

Perception of technology, as discussed previously, has credibility to either lead or reject technology acceptance. In this section, the author will explore the implication SMEs can view due the impact of Covid19 and the concept of circular economy on 3D Printing. Firstly, Covid19 pandemic has disrupted Supply chain, strained logistics and created un-forecasted demand scenario (Alicke and Barriball, 2020; Baig et al., 2020; IANS, 2020). The pandemic highlighted the importance of localised manufacturing to cater the basic needs of citizens. While locally manufacturing goods, the 3D Printing alternative can make a significant impact due to its personalisation, customisation and cost-effectiveness in manufacturing product. According to Laplume, Petersen and Pearce (2016, pp. 10–12), 3D Printing technology presents an advantage over traditional manufacturing as imported raw materials manufacture complete product assembly and components in the local regions. Thus, it presents an added advantage for businesses to set-up 3D Printing facilities in localised environment. But more importantly, based on findings consumers have a positive perception of 3D Printing for its usefulness in quick response against Covid19. Similar, affiliation by the public can be seen in news as it highlights its usefulness (Business Wire, 2020; O’Neal, 2020; Robert H. Smith School of Business, 2020). SMEs can tap this positive perception and showcase value addition in niche domains to deliver value to consumers. It is important to create an affinity towards the technology for it progress ahead.

Further, 3D Printing embraces the concept of Circular Economy, a loop of using recycled goods to manufacture new goods. According to Garmulewicz et al. (2018, pp. 14–16) and Pasricha and Greeninger (2018, p. 15), circular economy can produce zero waste manufacturing, and 3D Printing has the potential to make it a reality. Further, the zero-waste
concept has measured a tremendously high positive impact on consumer intention to buy 3D Printed products and related services. This presents SME businesses an alternative to create local employment and value addition by ways to recycle waste products into raw materials needed by 3D Printing. Thus, providing relief during Covid19 and circular economy ideology can aid to steer consumers in opting for 3D Printing. SME business can source these perception to help present a compelling stage for consumers to discover value.

Finally, the author holistically evaluates the research to identify the studies limitation and future research. This study measure consumer centric variables like consumer perception and readiness towards embracing 3D Printing to explore businesses value to deliver to its consumers. The hypothesis developed using empirical research of technology readiness and technology acceptance model to portray 3D Printing technology in the integrated TR and TAM model. But this study had to overlook on certain parameters in order to progress. In the limitations section, these points are discussed in greater detail.

Limitation

In this section the author will discuss the limitation of the study and chalk out options for future studies. To the summarize the discussion above, the study pursued a cross sectional methodology with an online questionnaire and targeted a population which was easily accessible through random sampling. Due to the Covid19 constraint, the author pursued a general consumer study with participants on an online platform for ease of access. The study has participants from various career fields, age segments and geographies, thus forming a general standpoint. A study with selective segments forming an interview or focus group would gather more accurate and reliable insights into consumer behaviour and developed
pinpoint business goals, as reported in similar literature (Chang and Chen, 2016; Chen and Lin, 2018, pp. 9–12; Vuković, Pivac and Kundid, 2019, p. 12). The moderate reliability values are due to the widespread in opinions across various questions. Smaller sampling niche presents greater likelihood of reliability and accuracy.

Secondly, on an empirical models point, the author refrained from using the extended TAM model— a successor of the TAM. Extended TAM was refrained because of its complexity and huge number of variables to collect and measure data, and develop correlations between variables given the less reliable random sampling of this study (Lai, 2017, p. 8). Finally, the author has developed limited business models theory within the literature. There are many innovations and business model patterns SMEs can target to pursue 3D Printing (Salmi and Ituarte, 2017; Holzmann, Breitenecker and Schwarz, 2019; Van Heck, 2019). Within the focus group such limitations can be addressed through interviews as data collected tends to be more reliable and develop clinical insights for businesses. Finally, these limitations can be addressed in future studies.

**Future Research**

This study was exploratory in its approach to study consumer behavior variables impacting 3D Printing. But for future studies, specific segments of the consumer studies can be pursued for detailed understanding of 3D Printing readiness and perception hypotheses to develop more accurate insights into the consumer behavior for adoption of technology. The niche segments can be examined through the extended TAM model extending on this study’s TR and TAM approach. Similar to this study the data can be interpreted for business implication. Subsequently, from this study the domain of Educational and Prototyping was
most picked, such domains can be independently targeted to delve deeper to find the consumer segments like age, professions that are most actively involved in it. Developing topics of specific domain can help businesses reach the niche that demand value. Finally, cross-sectional studies have limited duration of data validity due to changing circumstances. According to Ketchen and Bergh (2004), the cross-sectional studies should be conducted every 3-5 years depending on the dynamism of the market to collect relevant data and present accurate mapping within the new time horizon. The implications of the future studies will vary as per the data collected then. Thus, future cross-sectional research can compare and relate findings in this field to develop detailed insights into consumer behavior.

In conclusion, the growing power of consumers to pull demand and lead technology acceptance compels businesses to study consumer behavior. Although the poor 3D Printing perception and readiness, the strong intention to embrace 3D Printing offers SME businesses selected domains to explore and deliver value to willing consumers. Presenting Innovation as a Service, digital supply chain and consumer knowledge management are some approaches this study highlights for businesses development to steer SMEs towards 3D Printing.
Conclusion

To conclude, the study presents a combination of TR and TAM to measure and examine the consumer centric variables of readiness and perception towards 3D Printing technology for general consumer participants. Through data analysis it was vivid that there is a gap between intention to embrace 3D Printing and consumer ability to do it. The high awareness in 3D Printing was diminished due to poor 3D Printing technology readiness and perception. This offers SME business specific domains to generate value and develop solutions to mitigate the gap. Subsequently, the COVID19 impact and zero-waste ideology in manufacturing have brought forward 3D Printing into positive consumer perception. Finally, with the 4th Industrial Revolution in progress new business models, advance consumer centric technology and innovation streams present SME a chance to connect in the 3D Printing transformation.
References


EY Global (2019b) *3D Printing: hype or game changer?* Corporate. EY, p. 64. Available at: https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/advisory/ey-3d-printing-game-changer.pdf.


Appendix

Appendix 1: Information Sheet for Participants

RESEARCH PROJECT TITLE

An explorative study on a consumer centric approach to 3D Printing for SMEs

RESEARCH INFORMATION

My name is Siddhesh Dhage and I am a Master’s student at Dublin Business School. This survey is a part of Master’s Thesis under the supervision of Sinéad O’Brien. The study aims to examine the consumer perception and readiness towards embracing 3D Printing. This is an online survey typically takes 5 – 10 minutes to fill out and submit the survey. In this study, you will be asked to provide opinions regarding use of technology and perspective on 3D Printing to develop technology for consumers to use and benefit in an effective manner. Once data submitted, it will analysed by the researcher to develop insights to help the community develop solutions to improve technology usability and reliability.

CONFIDENTIALITY/ANONYMITY

The data researcher collects does not contain any personal information about you except your age, gender and education qualifications. The survey is completely anonymous and gathers no identifiable fields whatsoever. All grounds of Anonymity will be maintained through the reliable use of Google Forms. Further, this data will be used only for academic purposes and data will be deleted once analysed. This data will not be shared to any third party or corporate interests.
RISKS AND BENEFITS OF PARTICIPATING

There are no risks or discomforts involved in participation of this survey. Participation is purely voluntarily and there will be no pressure of completing. In addition, your participation will help the researcher to explore the areas to develop 3D Printing technology for efficient consumer participation and use. More importantly, your contribution will be appreciated to academic literature for develop studies for better usage of 3D Printing.

PARTICIPANTS’ RIGHTS

You may decide to stop being a part of the research study at any time without explanation required from you. You have the right to ask that any data you have supplied to that point be withdrawn / destroyed. You have the right to omit or refuse to answer or respond to any research question that is asked of you. You have the right to have your questions about the procedures answered If you have any questions as a result of reading this information sheet, you can ask the researcher before the study begins.

For any further information about this study you may contact me at siddheshdhage13@gmail.com and I will get back to you in 24 hrs.

If you are interested in participating please review the consent form by pressing the Next button in order to understand and agree the voluntary nature of participation.
Appendix 2: Informed Consent Form

I voluntarily agree to participate in this research study.

- I have read the information provided about this research and I understood the description of the research that is provided.
- I understand my participation in this survey is entirely voluntary and there is no obligation to agree to take part in this study.
- I understand I can cease my participation at any time without any penalty.
- I understand that I will not benefit directly from participating in this research and my identity will remain anonymous throughout the survey.
- I understand that my responses will be anonymous and it might not be possible to precisely extract my data after completion, as there are no personally identifying information attached to my responses.
- I confirm I had the liberty to contact the researchers for questions and seek clarifications if required.
- I confirm that I have read and fully understood the information provided and statements above.

By selecting yes below, I agree to the above points and to participate in the questionnaire voluntarily (Mandatory).

- Yes
- No
## Appendix 3: Questionnaire

### Table 5: Research Questionnaire

<table>
<thead>
<tr>
<th>Code</th>
<th>Questions</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEMO1</td>
<td>What is your Age?</td>
<td>Age Interval</td>
</tr>
<tr>
<td>DEMO2</td>
<td>What Gender do you identify as?</td>
<td>Gender</td>
</tr>
<tr>
<td>DEMO3</td>
<td>Are you aware of 3D Printing technology?</td>
<td>Yes, No</td>
</tr>
<tr>
<td>TAM_Percep1</td>
<td>In brief can you explain what is your understanding of 3D Printing?</td>
<td>Text</td>
</tr>
<tr>
<td>TR_3DP</td>
<td>Do you have experience in technology related to 3D Printing? (pick one that best describes the experience)</td>
<td>Single Choice</td>
</tr>
<tr>
<td>TR_OPT1</td>
<td>I prefer to use/try modern technology like latest smartphones, smart watch or internet banking</td>
<td>5 point Likert</td>
</tr>
<tr>
<td>TR_OPT2</td>
<td>I like technologies that allow you to tailor things to fit your needs</td>
<td>5 point Likert</td>
</tr>
<tr>
<td>TR_INN1</td>
<td>Do you find other people (friends /family /colleagues /acquaintances) coming to you for advice for new technologies</td>
<td>5 point Likert</td>
</tr>
<tr>
<td>TR_INN2</td>
<td>Do you enjoy the challenges of figuring out new gadgets</td>
<td>5 point Likert</td>
</tr>
<tr>
<td>TR_DC1</td>
<td>I feel comfortable when asking for help in customer support or forums of technology products or services</td>
<td>5 point Likert</td>
</tr>
<tr>
<td>TR_DC2</td>
<td>I am embarrassed when struggling with new technology in front of others</td>
<td>5 point Likert</td>
</tr>
<tr>
<td>TR_IS1</td>
<td>I trust shopping online from local shop website in terms of payment safety, product quality and delivery services?</td>
<td>5 point Likert</td>
</tr>
</tbody>
</table>
TR_IS2  I worry about the information you create/post online will be viewed by other people 5 point Likert

TAM_PEOU1  I believe that the use of 3D Printing is easy to explore, learn and utilize. 7 point Likert

TAM_PEOU2  The usefulness of 3D Printing during Covid19 has created an interest to explore 3D Printing 7 point Likert

TAM_PU1  I believe that 3D Printing is useful because it gives me the power to personalize to my requirements 7 point Likert

TAM_PU2  The usefulness of 3D Printing during Covid19 I believe the technology will be useful for my general consumption like household accessories, appliances or spare parts or any special customisation goods 7 point Likert

INT_TU1  What are the most likely criteria for customization you would pick to make products for better utilization Checkbox

INT_TU2  What would be your ideal approach to using 3D Printing technology? single choice

INT_TU3  3D Printing embraces recycled goods to manufacture new goods, does this ideology have any impact on your purchase decisions 5 point Likert
Appendix 4: The 3D Printing Industry as a Network Ecosystem

Figure 14: The 3D Printing Industry as a Network Ecosystem

Image Source: (Salmi and Ituarte, 2017, p. 13)
The image above is just a précis visualisation of the 3D Printing technology and its potential implications. 3D Printing is more than just a product manufacturing but in a whole can be viewed as an ecosystem. Across the core, SMEs can look to target certain specific areas which they are able to manage based on their strengths and weaknesses, network and willingness to pursue. In addition, upcoming technologies like AI, IoT and AR, add further dimensions for businesses to pursue 3D Printing.