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DOI:
10.1016/j.procir.2017.03.350

Document Version
Final published version

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 63 (2017) 680 – 685

www.elsevier.com/locate/procedia

The 50th CIRP Conference on Manufacturing Systems

The Role of Big Data to Facilitate Redistributed Manufacturing Using a Co-creation Lens: Patterns from Consumer Goods

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Abstract

Manufacturing digitalisation and the growth of big data promises to foster more responsive supply chains and to close gaps between manufacturers and consumers, leading to highly-connected manufacturing operations, mass customisation and more sustainable production. There is widespread recognition that manufacturing in broad terms is entering a new period of transition and change, aided by new technologies and business models and with multiple predictions that there will be significant reconfigurations in the geographical and inclusive distribution of manufacturing operations. A concept that can be used to describe this process of transformation is called *redistributed manufacturing*. This concept encompasses the empowerment of consumer-inclusive co-creation. In this paper, we investigate whether and how big data can facilitate redistributed manufacturing in consumer goods industries. The research sheds light on how businesses are starting to redistribute their functions among various stakeholders including consumers and co-creating value. The paper proposes a conceptual framework to stimulate and organise thinking about emerging interrelationships between big data, co-creation and redistributed manufacturing, built upon an extensive literature review and qualitative analysis of 15 cases from the consumer goods industry using primary and secondary data. Through these cases, we analyse existing co-creation practices in consumer goods industries, and how they are evolving their manufacturing configurations, their underlying drivers, the role of big data applications, and their impacts on the redistribution of manufacturing. Our analysis finds that big data applications are supporting and prompting redistributed manufacturing approaches in these consumer goods industries.

Peer-review under responsibility of the scientific committee of The 50th CIRP Conference on Manufacturing Systems

Keywords: Redistributed manufacturing; big data; digital manufacturing

1. Introduction

Digital manufacturing will penetrate and transform every aspect of our lives, and it is gaining traction in the UK, EU and globally. It emphasises the idea of consistent digitisation and collecting data from different sensors and other systems across productive units in industry. The utilisation of these data combined with other data sources will bring unprecedented opportunities, along with new risks, to business and society. Furthermore, it will define the modern manufacturing landscape and lead to better-integrated supply chains, interconnected systems, and stronger co-ordination. There will likely be significant reconfigurations in the geographical and inclusive distribution of manufacturing operations. A concept that can be used to describe this process of transformation is called redistributed manufacturing. This concept encompasses the empowerment of consumer-inclusive co-creation "a connected, localised and inclusive model of production and consumption that is driven by the exponential growth and embedded value of big data." [1]. The inclusive dimension, which is described as an "inclusive model of production and consumption" can be interpreted as a functional redistribution.

This dimension is comparable to concepts of co-creation or co-production. Coproduction refers to a "participation in the creation of the core offering itself", while co-creation

Peer-review under responsibility of the scientific committee of The 50th CIRP Conference on Manufacturing Systems
doi:10.1016/j.procir.2017.03.350

represents a higher order concept, which includes the idea that "value can only be created with and determined by the user in the consumption process or through use" [2]. Value co-creation can occur with or without co-production. However, both of these concepts illustrate that the consumer is part of the value creation process. The term "redistribution" in this context means a higher involvement of the consumer in the process of design or production.

This paper focuses on the inclusive dimension of the concept, investigating redistributed stakeholder roles in the consumer goods manufacture ecosystem. Co-creation implications have high impacts for end-user consumption in business-to-consumer (B2C) interactions. B2C is prominent in the consumer goods sector which is the focus of this study. Consumer goods comprise durable manufactures (such as refrigerators or electronic devices) and non-durable products (such as food, beverages, and cosmetics) that are purchased and used by individuals and households. Operations in consumer goods industries are valued at many trillions of USD worldwide, with most of these operations distributed and based on mass manufacture through multinational corporations and globally dispersed supply chains [3]. Consumer goods industries face many challenges and opportunities posed by evolving consumer demands and policy requirements. Thus, there is a case for re-thinking the way that manufacturing operations are distributed (redistributed manufacturing) and examining how existing operations to be digitised, localised, personalised and enhance the user-participation.

In this paper, we investigate whether and how big data can facilitate redistributed manufacturing in consumer goods industries using the co-creation lens. This research sheds light on how businesses are starting to redistribute their functions among various stakeholders including consumers and co-creating value. The study proposes a conceptual framework to stimulate and organise thinking about emerging interrelationships between big data, co-creation and redistributed manufacturing, built upon an extensive literature review and qualitative analysis of 15 cases from the consumer goods industry using primary data. Through these cases, we analyse existing co-creation practices in consumer goods industries, and how they are evolving their manufacturing configurations, their underlying drivers, the role of big data applications, and their impacts on the redistribution of manufacturing.

The next section of the paper introduces a literature review, which is followed by our proposed conceptual framework and a discussion of the research design. The case studies are then presented and analysed in detail and the findings are summarised. Finally, the conclusion discusses the study's contributions, limitations and pathways for future research.

2. Literature review

The review of literature is divided into three sections: First, we present the origins of the distributed and redistributed manufacturing ideas and highlight. The second section reviews the concept of big data and value creation. The third section elaborates on the co-creation term, and reflects on the family of co-creation concepts that are differentiated in different disciplines.

2.1. Distributed Manufacturing

Distributed manufacture is a term used interchangeably with distributed production in the engineering and operations management literature. It refers to networked production planning of geographically dispersed production facilities, for the purposes of agility–responsiveness to customer demand, and flexibility–robustness of the production network [4]. Distributed manufacture is also used in the literature as a foundation of "the distributed economy" – a more sustainable alternative to the status quo that is composed of local small-scale producers utilising local resources, and which encourages collective societal spirit [5]. It has been proposed that as a consequence of the full realisation of distributed manufacturing production and consumption, there will change in the roles of the actors within this socio-economic paradigm. This gives rise to prosumers [6] – consumers who collaborate in production activities [7]. The blurring of the limits of consumption and production, supply and demand is one of the fundamental themes that define co-creation [8].

Several authors in production economics literature accept that manufacturing has already been distributed with the wide adoption of Reconfigurable-Manufacturing-Systems (RMS) and suggest that the next paradigm will be based on cloud manufacturing [9][10], which builds upon the network of distributed manufacturing and leverages internet-of-things and big data [11]. Redistributed manufacturing is used by the research network RECODE to investigate the emergence of new manufacturing paradigms with changes in methods, locations, and roles (local and inclusive manufacturing) enabled (connected) by ubiquitous big data.

2.2. Big Data

Recent studies, for example the "Future of Manufacturing" report, place big data as one of the key supportive technologies for manufacturing [12]. To identify the impacts that big data can have for manufacturing businesses especially manufacturing configurations, possible ways of value creation need to be investigated. This approach is aligned with the definition of redistributed manufacturing which highlights that transformation is "driven by the [...] value of big data." [1]. To bring different types of value creation into one taxonomy, big data applications are handled similar to business model concepts. This approach was used by [13] to describe so-called data-driven business models. In the context of this paper, selected dimensions of data-driven business model concepts, data sources, and key activities will be used to identify different types of value creation.

A key element in the redistributed model is connectivity. Big data and the Internet of Things are instruments that enhance connectivity between stakeholders (consumers included) in a manufacturing ecosystem to an unprecedented level. As a result, the manufacturing value chain becomes more inclusive. Big data is already increasing the responsiveness of consumer goods supply chains [14], boosting product-service system innovation [15] and

increasing the speed and depth of market research [16]. This paper is focusing on the value capture of big data. We are not dealing with the technical aspect of big data such as data processing dimensionality and complexity.

2.3. Co-creation

Co-creation term was first introduced by [2] within one of the foundational premises of Service-Dominant (S-D) logic: "the customer is always the co-creator of value". The term was too encompassing during this time and following S-D Logic's introduction, several attempts were made to confine the term to a specific area or application. Following Vargo's definition, Ramaswamy defined it as "joint problem definition and problem solving" but added that "Demand and supply are emergent and contextual. Supply is associated with facilitating a unique consumer experience on demand." [8]. Interactive marketing literature embraced the term and gave it a more application-oriented definition, mostly relating co-creation to concepts arisen in the industry. Management Sciences literature took an integrative approach and combined the marketing and service definitions, often counting co-creation overlapping with open innovation [17]. Lastly, design research literature focused on mostly the creative aspect of co-creation, and elaborated on its use in new product development [18].

Despite numerous attempts to popularise the co-creation concept, it did not become a mainstream concept embraced by the industry. Nevertheless, it became a theoretical backbone for several concepts that reached out to the masses such as open innovation, crowdsourcing and mass customization, personalization. Roser states that these concepts can be called a "co-creation family of concepts" [19]. As mentioned above, given the lack of conceptual clarity, this research accepts co-creation defined by [2] as a term describing collaboration within a business ecosystem, inclusive of customer and not necessarily characterised by an innovative outcome. Several frameworks aim to analyse co-creation processes. We used eight highly cited papers as a basis to develop our conceptual framework (see table1). The criteria for shortlisting papers were: (i) relevance score to consumer goods manufacture, (ii) co-creation definition relevance, (iii) academic impact (measured by h-value). The last criterion's weight was the lowest, so as to ensure inclusion of several contemporary papers.

Table 1. Customer Co-Creation Process Literatures

Authors	Motivation	Co-creation forms	Engagement Properties	Big Data	Co-creation processes	Performance
Etgar et al. 2008	X	X	X	X	X	X
Hoyer et al. 2010	X	X		X		X
Sheth et al. 2007		X				
Roser et al. 2013	X	X	X		X	
Ramaswamy et al. 2013	X					
Romero et al. 2009	X	X	X			
Frow et al. 2015	X	X	X		X	
Greer et al. 2012	X	X		X		X

Co-creation motivation and forms have been investigated extensively in the literature [20] [21] [22] [23] [24] [25] [26] [27]. Interestingly, data-driven co-creation and digital platforms in this context have not been well researched and there is a gap in both major bodies of literature of distributed manufacturing and co-creation. Recently, [28] developed a classification of co-creation types in digital platforms. Furthermore, co-creation process performance measurement was not focused as brought up by [17]. This research aims to fill a gap in the co-creation literature by synthesising a co-creation framework that integrates data operations and performance measurement to the core co-creation framework to serve redistributed manufacturing.

3. Conceptual framework

Our conceptual framework builds on the prior literature review. The aim of the framework is to provide a basis for probing the impact of big data in redistributed manufacturing. The conceptual framework is illustrated in Figure 1. There are five dimensions to be considered in a co-creation process construct. Motivations are divided into two: firm motivation and consumer motivation. Both have distinct rationales and each is critical for the co-creation process. Co-creation Forms has two forms: Co-innovation and co-production. Engagement Properties consist of three properties: Depth (referring to the consumer activeness level, duration and platform. Digital Operations for Redistributed manufacturing is more data-driven on top of the co-creation platform. To identify these processes, data sources and data-processing activities must be specified. Redistributed manufacture (Re-D) was emphasized in the term to link back the co-creation to the connectivity theme residing in the definition of redistributed manufacture in addition to the inclusiveness property. Data source and activity categories have been developed based on data-driven business models [13]. Key performance indicators (KPI's) and tools for measuring the process outcome initiated by the co-creation process. Overall, we believe this framework contributes substantially to our understanding of the role of co-creation and big data in redistributed manufacturing (RdM) and provide a more in-depth understanding of the complexity of the RdM but also actionable insights for operation practice.

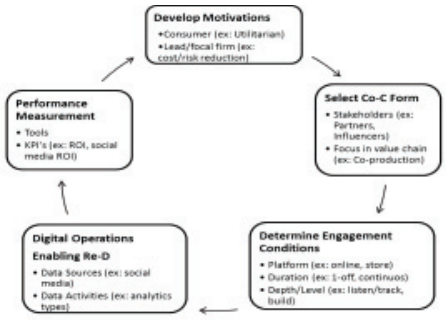

Fig. 1 Conceptual Customer Co-Creation Process Framework

4. Research design

Our study used an exploratory and qualitative approach. It embedded a multiple-case study based on the fact that the research investigated the impact of a specific concept (redistributed manufacturing) through an entire industry, something that requires multiple case studies in order to be reliable. Multiple cases enhance the reliability of the findings and minimise observer bias [29]. To screen for appropriate cases, a criterion-based sampling approach was used. In total 15 cases are chosen and analysed to provide a distinct contrast in terms of the characteristics of the products manufactured, the major type of market served, product life cycles, and technological intensity similar to [30]. The proposed framework was used as the analysis tool for the qualitative content analysis process. The information contained in each case was dissected and put into a category under each dimension of co-creation process. As a result, patterns in each industry could be identified. Semi-structured interviews were conducted, with open-ended questions and allowing the interviews to develop around the main stages of co-creation framework. Initially, interviewees were sampled purposively to represent each industry; but it soon became apparent that the stakeholder roles involved in co-creation processes were more complex than anticipated. Moreover, although retailers or manufacturers initiate the process often management and execution are done by intermediary firms. Therefore, they had to be included in the interviewee samples to accurately derive insights from the primary data. The practice of being flexible in sampling for the sake of capturing depth of the investigated phenomena is a common method known as "emergent sampling" and it is particularly suitable for exploratory research questions [31]. The final list of interviewees is presented below in table 2.

Table 2. Summary of the cases from the selected industries

Cases	Industry	Industry Size per employees	Interviewees Title
N1	Consumer Electronics	Enterprise > 250	Senior R&D engineer
N2	Consumer Electronics	Start-up < 10	Co-Founder
N3	Personal Care	Enterprise	Marketing Planner
N4	Personal Care	Start-up/SME	Technical product manager
N5	Fashion	Enterprise	R&D Engineer
N6	Fashion	Start-up/SME	Senior Manager
N7	Food & Beverages	Enterprise	Brand Manager
N8	Food & Beverages	Enterprise	Brand Manager
N9	Food & Beverages	SME <250	Marketing Manager
N10	Durable Goods Retail	SME	Co-Founder
N11	Durable Goods Retail	SME	Consumer Research Leader
N12	Durable Goods Retail	SME	CEO
N13	Durable Goods Retail	Enterprise	Head of Technology
N14	Durable Goods Retail	SME	Service Director
N15	Durable Goods Retail	SME	Co-Founder

5. Findings

This section presents the findings and provides a snapshot of the current situation in several consumer goods industries using the proposed co-creation process framework to demonstrate that RdM is concept that can help industries navigate pathways in the digital manufacturing era.

5.1 Food and Beverages

In this industry, the blend of co-marketing and co-design mixed in the use of social media to successfully introduce new product design (NPI). Overall, the process begins with shortlisting options for the NPI using traditional market research methods (e.g. market reports from third party consultancies, focus groups etc.), next social media activation comes into play, finally the options are crowdsourced in the social media or at a dedicated digital platform. The breakdown of the process through the use of our proposed framework: Lead-firm motivations are de-risking new product introduction and increasing speed to market. Customer motivations are monetary reward (in one case 1% of total first year's sales), recognition (in another case winner of a draw from the pool of participants becomes the flavour ambassador), and intrinsic motivations as curiosity and excitement. Co-design and front-end-design are finished by using the crowdsourcing. Co-marketing campaigns has a significant increase in word-of-mouth scores of the product were observed. Co-meaning creation to develop customer engagement motivations, novelty and creativity of the campaign was critical. Furthermore, influencers and interactive elements around customers were more successful in fulfilling lead-firms' motivations. For example, in one of the firms' campaign called '*Do us a flavour*', consumers

engaged with the brand by tweeting at the bus stops to augmented reality enhanced vending machines. Machines contained celebrity video footage, acting as if interacting with people on the bus stop and vending chips when customers were tweeted. *'Do us a flavour was a spectacular success. Over the campaign period, the 'Do us a flavour' idea outperformed category year-on-year sales growth by 68%. [company] also achieved its highest value market share for three years. It attracted a deep level of consumer interaction with the brand, with over a million flavour suggestions. Even more significantly, it showed how combining product development with a marketing idea could affect every aspect of the business" [N9- Marketing Director].* Interviews supported this fact that consumer goods industry is relatively pro-active in co-creation in general. Social media was a common platform that helped the co-creation process –either in the beginning or as a tool for lead user identification. On the other hand, for co-innovation, the core tool has been digital platforms in the large majority of cases, which enabled continuous dialogue and "drove action" - as N9, N15 put it. It has been revealed, through interviews, that these platforms drove co-creation for new product innovation and this is expected to continue.

5.2 Consumer Electronics

Compared to other industries examined, consumer electronics industry had the least amount of co-creation practices documented. It is hypothesised that it might be because of several reasons: Secrecy might be higher than the other industries, thus applications may lack visibility. With increased product complexity, customer co-creation opportunities might diminish, since collaboration requires more expertise and understanding on the customer side. Furthermore, at this company scale there was a clear pattern of developing and launching products using co-creation, therefore though data-driven side of the applications are weak, small scale companies utilise co-creation to the fullest. For example, the birth of Arduino and RasberryPi are similar in the sense that they were a mini-community experimentation in the beginning which spread over to a larger community collaborating. In the end, now with partnerships with other consumer electronics start-ups, they are bringing their core technology to the masses by using a simple and effective partnerships.

5.3 Fashion

Fashion has been found to use big data analytics surprisingly heavily. Two themes emerged in fashion. First, at the upstream, co-creation for on-demand production using multiple sources of customer data has been mostly applicable to fast fashion industry, which is as expected since the speed of identifying trends –regional or global and responding them one of the core competitive advantages of fast fashion. For example, H&M integrated multiple data sources for predicting accurately the manufactures' demands. They mined social media and integrate it with historical data for better forecasting. At the downstream, fashion retailers are following the pattern customising the last-mile logistics by managing distributed pick-up or drop-off locations. This is in fact co-distribution and results in supply chain complexity, again demanding big data analytics to orchestrate the logistics, as N6 mentioned. Indeed, for instance, footwear and apparel retailer Zalando launched 5,000 UK pick-up/drop-off locations, following the model introduced by Zappos in UK.

Although, firms are heavily involved in various co-creation forms and data-driven co-creation activities for the purposes of on-demand production. Companies that harnessed co-creation for on-demand production were fast fashion companies who had extremely short product launch cycles (ranging from few days to maximum a month). The key element in this model is two-way communication at the companies' retail outlets. Data from these channels are processed to pick up demand signals for a new product. This results in massive gains in supply response speed.

5.4 Personal Care

In the same vein as food and beverage, personal care industry uses the social media in co-design and even in co-conception, but iteratively and in different sequence. The process initiates in personal care with an ethnographical study of online content to drive radical innovation. This method first analyses online content, to target problems encountered by the users. Focus groups are then formed to gain a deep understanding of these problems and to identify potential solutions. Shortlisted solutions are carried to the social media again to get feedback from a larger set of consumers. One of the cases involved reaching out to online communities that are already formed around an influencer, for this second feedback stage. Finally, the tested solution proceeds to the development stage. Based on this method, a new deodorant - non-stain for black and white fabric – was developed by Nivea. They crawled over 200 social media sites in three languages to conduct an in-depth ethnographic research to understand customer problems. Then by engaging with an influencer – the Undershirt Guy and his audience, engaged lead users were recruited. Focus groups were organised composed of consumers and scientists to consider possible solutions. Lastly, the solutions were then tested again in the social media before launch.

5.5 *Durable Goods Retail*

Toys and furniture industry focuses on experimenting with mobile platforms to enhance user experience. It is a differentiating approach from co-creation perspective compared to other industries. For instance, LEGO Movie Maker allows users to produce movies based on the product set they possess, ultimately resulting in co-meaning creation. Furthermore, building of aftermarket services and its ability to create new revenue streams or improve the brand perception. Particularly, Co-production has been quite pervasive in durable goods. Significant time spent on this form of co-creation gives room for enhancing the firm-customer encounter. The theme identified in this industry was the fortification of the core product with digital applications,

which in some cases results in a product-service offering. For example, IKEA launched a virtual reality mobile application which allowed the user to choose a furniture from the online catalogue and place it virtually inside the room they plan to fill. The virtual furniture was embedded in the mobile camera vision on screen. The data collected from the app could possibly inform demand forecast. Application launch stimulates co-marketing as also in the case of Build-Your-Own-Bear. The company launched a social gaming app for children complementary to their core toy bear building workshops. Any child in-store can download the app and invite friends, which means the child becomes also the co-marketer.

6. Conclusion

This research has examined the foundational premises of redistributed manufacturing using the lens of co-creation. The conceptual framework and identified patterns can guide firms who are considering a shift to redistribute manufacturing: 1) experimenting with novel innovation processes by collaborating continuously with consumers. Intrinsic rewards as a motivation for co-creating are sufficient for consumers to engage in the process; 2) bringing stakeholders who are otherwise traditionally separate in the innovation process to drive innovation – these stakeholders can be within the company or external, e.g., retailers and manufacturers; 3) de-risking new product launch, blending co-marketing and crowdsourcing. The large-scale crowd engagement in social media platform often incentivises consumers; 4) being more responsive to the demand through continuous dialogue in multiple channels; 5) enhancing user experience and creating lasting customer relationship with the brand. Analysing product use data can to improve the design at a test stage in which designers are collaborating with consumers. When fully embraced, redistributed manufacturing can be a core strategy for firms. This research area can be further explored in depth with either multiple or single case studies, to verify assumptions in the redistributed manufacturing concept.

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