A Data-Driven Business Model Framework for Value Capture in Industry 4.0

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Abstract. Manufacturing is undergoing a period of intense change as a result of advanced smart technologies, such as real-time sensors and the Industrial Internet of Things (IIoT). This has paved the way for a new era of digitized manufacturing known as Industry 4.0. It is anticipated that Industry 4.0 will be disruptive enough to present both new opportunities and threats to firms within a new competitive landscape. Manufacturers will be forced to adopt new business models to effectively capture value from the emerging smart technologies. A literature review revealed that few studies have addressed business models for Industry 4.0. Hence, this research addresses: *What fundamental principles should companies in the manufacturing industry consider when adopting a data-driven business model?* An analysis of four case studies on data-driven business models revealed significant common attributes. Through a SWOT analysis, twelve model principles for implementing a data-driven value capture framework could be identified.

Keywords. Industry 4.0, Digital Manufacturing, Data-Driven Business Models.

1. Introduction

Industry 4.0 is concerned with the creation of cyber-physical systems for production engineering and the realization of the smart factories of the future [1]. Cloud computing and the Industrial Internet of Things allow to integrate manufacturing facilities at geographically dispersed locations into highly agile production networks serving the Industrial Internet of Services [2]. A general trend towards servitization can be observed in the manufacturing sector [3]. This redefines the role of manufacturing in the global value chain as new value capture opportunities evolve and requires companies to adapt their business models accordingly [4].

So far, four new business model adaptations have been identified in the broader context of Industry 4.0 [5]: Pay-by-usage/subscription-based models; Technology platform models; IP-licensing models; and Data-driven business models. Each of these present viable options for effective value capture in the digitalized manufacturing era, but remain largely unexplored due their infancy. Although a literature review revealed a major gap with respect to new business models for value capture in Industry 4.0 in general, data-driven business models currently dominate the discussion. The aim of this research is to gain first insights into the broad question of what fundamental principles companies in the manufacturing sector should consider in trying to adopt a data-driven

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business model. Firstly, examples of data-driven business models currently being used in the industry where identified, along with common features via a Business Model Canvas (BMC) evaluation. Lastly, we identify twelve model principles that can be considered best practices for implementing data-driven business models.

2. Business models and Industry 4.0

As eluded to before, Industry 4.0 will bring about new forms of value creation that require new business model strategies to be adopted [6]. Today's business models and value chains will soon come under increasing pressure [7]. Big Data and digitization have already begun to challenge the use of traditional business models in manufacturing [8]. Khan and Turowski conclude that by looking at past disruptive technologies it is evident that there is a correlation between technological and business model developments, and that employing latest technology in conjunction with innovative business models fosters success [9].

According to Osterwalder, "A business model describes the rationale of how an organization creates, delivers, and captures value" [10]; it is the logic of how a company intends to make money. A business model is a framework that companies use to position themselves in the marketplace. For a business models to be effective, six key functions need to be fulfilled [11]: Articulation of a *value proposition*; Identification of the *market segment*; definition of the structure of the *value chain* within the company; estimation of the *cost structure* and the *profit potential;* description of the position of the firm in the *value network*, and the formulation of a *competitive strategy*.

Although numerous business model development and evaluation tools exist, the Business Model Canvas (BMC) by Osterwalder [10] is by far the most prevalent. Its advantages include: focus, easy to populate and update, a common intuitive language and layout, and that importance of the value proposition. A BMC is an amalgamation of 9 building blocks that relate to a key attribute of a business strategy [12]. (1) *Customer Segments*; (2) *Value Proposition*; (3) *Channels*; (4) *Customer Relationships*; (5) *Revenue Streams*; (6) *Key Resources*; (7) *Key Activities*; (8) *Key Partnership*; (9) *Cost Structure.*

3. Select case studies on existing data-driven business models

3.1. Pirelli

Pirelli have dominated the tire manufacturing industry for the past century. Since the 19th century, their business model has remained unchanged, focusing on the efficient production of high quality tires. However, in March 2016, Pirelli announced plans to adopt data driven business to complement its thriving manufacturing operation. This development is being spearheaded by Head of Data Science and Analytics, Carlo Torniai, who stated "There's a lot of untapped potential in the data we have in the company and my goal is to use it to build smarter solutions." [13]. This is driven by the ambition to embed sensor technology into every commercial tire. In doing so, they hope to generate huge volumes of useable data. Each tire sensor will be capable of recording pressure, temperature and wear statistics to enable condition monitoring of each tire. This data will be used to improve tire designs and also create a new revenue stream through the sale of data-rich maintenance solutions that aim to minimize vehicle downtime.

3.2. Caterpillar

After capitalizing on the post-war boom in construction, Caterpillar has asserted its dominance by exploiting the latest trends and innovations, diversifying beyond construction and into the mining and logging sectors. In 2015, Caterpillar announced its ambition to incorporate data-driven products and services into its corporate strategy. Caterpillar's group president for customer and deal support, Rob Charter, said "We can transform the mountains of incoming data – from a single machine or engine, an entire job site, the supply chain, a shipping location and much more – into valuable information for our customers and suppliers." [14]. Caterpillar will use data from embedded sensors to inform a new maintenance schedule revenue stream that uses data analytics to maximize the lifespan and efficiency of deployed equipment. To support this development, Caterpillar opened a Data Innovation Lab at the University of Illinois in 2016 to turn "customer and market data into valuable information for the growth" [15].

3.3. GE Oil & Gas

General Electric (GE) originated as an electricity company, but quickly expanded and diversified its operations. GE Oil & Gas (GEOG) was first established in 1994 and has a truly global presence across every segment of the value chain from drilling to end sales. Traditionally, GE's sales model has been product-centric; with customers purchasing machines, parts and maintenance at a fixed price. In 2015, the conglomerate announced that it was merging Predix, a data-driven analytics tool made by GE Software Center, into its oil and gas company. This merger will form a new organization named GE Digital [16]. GE Digital aims to embed sensor technology into all of its equipment, enabling communicating to the cloud. With the use of Predix the company will assess the condition and state of equipment and its working environment. Finally, they will capture value from the process by analyzing the data to identify opportunities to make equipment more efficient and productive. Where once it sold one off products, the company can now offer customers solutions, installing equipment that satisfies a specified requirement for an extended length of time.

3.4. The Weather Channel & IBM

The Weather Channel specializes in collecting metrological data and broadcasting weather forecasts across America. The success of the firm was immediate and lasting, with the organization catering for over 100 million households by 2010. Whilst the company did adopt a number of incremental innovations over its 35 year history, the business model and operations of the company have remained mostly unchanged. This all changed in 2016, when they were purchased by IBM and their new data-driven business mode, 'Deep Thunder', was unveiled. Deep Thunder collects data from over 195,000 personal weather stations mounted on buildings, in fields and even on aircraft to generate accurate forecasts with a resolution of 0.2-1.2 miles [17]. This is to allow companies to better understand how localized weather systems might impact on their business. Example applications include utility companies trying to manage the repair of weather damage to overhead power and telephone lines, agriculture, renewable energy and disaster relief.

4. The Hybrid Business Model Canvas

4.1. Populating a BMC Template

Each of the four examples of data-driven business models can be captured in a BMC template. The template has nine building blocks as defined in Section 2. Each template gives an interesting at-a-glance insight into a particular business model. However, the authors believe that a template combining all four business models into one 'hybrid canvas' gives greater insight into the key features of a generic data-driven business model. A Hybrid Business Model Canvas (HBMC) is presented in Figure 1, and color-coding represents prevalent attributes of the data-driven business models analyzed. Red signifies attributes present in each of the case studies, orange signifies attributes present in three of the cases studies, and green signifies attributes present in two of the cases.

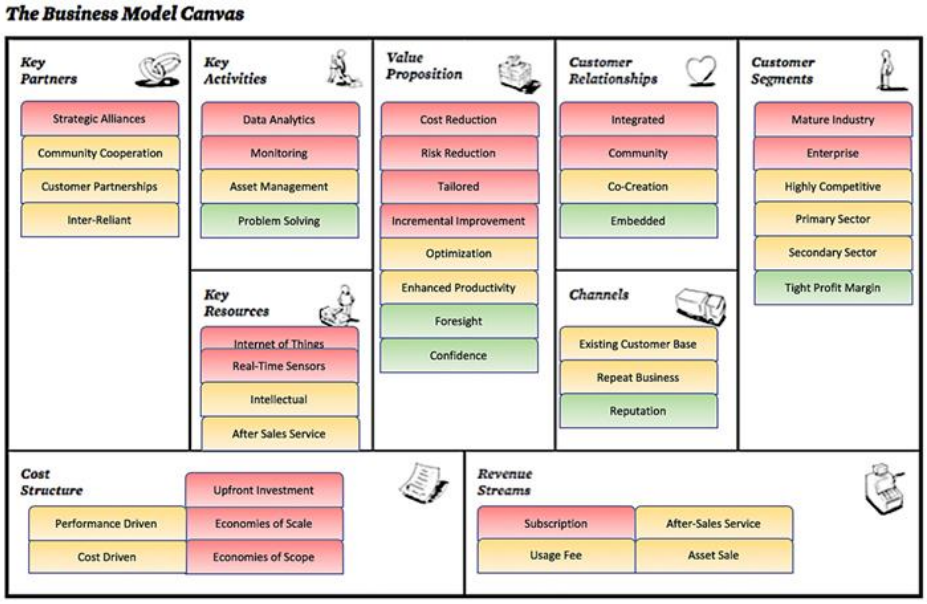

Figure 1. The hybrid Business Model Canvas populated from the case studies.

There is a high level of agreement in the Cost Structure segments, Key Resources, Value Proposition, Key Activities and Customer Relationships. This suggests that there may be key characteristics that are common to data-driven business models in general. Conversely, there are no common attributes within the Channels segment. This indicates that data-driven models cannot typically be associated with a particular customer channel. Instead, data-driven firms interact with their customers differently, depending on factors including: pre-existing revenue model, traditional product offerings and chosen target market. From the canvas it is evident that data-driven business will be most appealing to firms that are striving to minimize costs or maximize performance as part of their core business strategy. Specifically, these market conditions are most applicable to primary or secondary sector industries where the opportunity to add value is limited. It is therefore expected that the highest demand for data analytics will come from enterprises with operations in these sectors. This is an interesting revelation since it also suggests that the pricing of data-driven services is critical as the target market is typically price sensitive.

5. SWOT Analysis

5.1. Strengths

Financial: The HBMC suggests data is monetized as part of a subscription-based package. Data analytics adds the most value at a relatively low cost. This opportunity to augment capital sales income with a regular revenue stream is not only highly appealing but also likely to be disruptive to the competitive landscape. ***Competitive Advantage***: In manufacturing, the ability to offer an asset management service to complement equipment sales is likely to be a key differentiator for firms. Data-driven services can build customer confidence in regard to long-term equipment performance. This will be most significant for firms catering to other businesses as the value of asset optimization will be higher. ***Improved Product Performance***: Manufacturing firms will be able to obtain real-time statistics of operational equipment performance. This growth in information is likely to be an invaluable innovation tool for companies.

5.2. Weaknesses

Competitive Disadvantage: The HBMC suggests that firms from the primary or secondary sector constitute the majority of the target market. These sectors are highly competitive on price, and any cost that is passed onto the end-user as a result of data-driven business models could be detrimental; effectively pricing themselves out of the market. ***Market Channels***: There is no unifying attribute across all four analyzed business cases. This may be because data-driven business represents a brand new strategy unlike any previously exercised. Hence, in each case brand new customer channels must be generated in order to effectively capture value from the business model transformation. ***Financial***: High setup costs due to 'Upfront Investment' are a common feature. However, this does not stem from the cost structure tile. Instead, it can be traced back to the key resources segment. A reliance on the latest Industry 4.technology and internally-developed analytics are both closely linked with a company's ability to develop data-driven services. R&D required to create a data analytics system is likely to be a considerable expense to any manufacturing firm.

5.3. Opportunities

New Market Segments: Refined data is likely to appeal to a broad spectrum of new customers, transcending the traditional markets. The most evident example of this stems from The Weather Channel case, where it is expected that Deep Thunder will appeal to almost every enterprise. ***Economies of Scale***: Compared to the significant upfront development costs, the operating costs of data-analytics software will be almost negligible. It can be expected that there will be an extended payback period for manufacturing firms transitioning to a data-driven business model. Once the initial setup cost is accounted for, the profit margins on any additional monetized data is likely to be very high. ***Barriers to Entry***: Whilst a high proportion of firms are likely to struggle when first adopting a data-driven revenue model, manufacturers who are capable of transitioning will be able to operate in a somewhat depleted competitive landscape due to raised barriers to entry. The resultant benefits will be greater power to dictate market prices and increased brand security. Therefore, it can be concluded that if manufacturers are able employ a successful adoption strategy, which is likely to include partnering with organizations that have software expertise, there are considerable rewards to be gained.

5.4. Threats

Over Reliance: From analyzing the HBMC, it is evident that data-driven business is fully reliant on the co-operation of a community of organizations. Manufacturers need to work with customers, software companies and data providers. It is difficult to determine if this level of coordinated knowledge sharing will be feasible. Any breakdown in established business relationships has the potential to severely jeopardize the data-driven business model. ***Lifecycle Uncertainty***: Where manufacturing firms are aiming to use data to build comprehensive asset management systems, it may take years to collect enough data to prove the effectiveness of the service. This could deter potential customers from purchasing data analytics in the short term, until its true effectiveness can be justified. ***Extended Payback***: Whilst it is expected that data-driven services will be capable of reducing costs and/or maximizing performance for customers, it is likely that the improvements will be marginal. Enterprises may be intolerant of extended payback periods, especially when trying to satisfy the short term demands of stakeholders.

6. Closing remarks

To fully benefit from Industry 4.0, the latest technology should be complemented with new business models. One such model uses data for new product-service-systems and data analytics. Given the lack of understanding of data-driven business, four case studies were conducted and a number of common attributes and implementation best practices identified. This research is the first step towards understanding new business models for emerging technologies in digital manufacturing. This study must be expanded to more cases to refine the framework. Subsequent validation will be conducted by applying the framework to appropriate companies through consultancy.

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