How is Big Data Transforming Operations Models in the Automotive Industry: A Preliminary Investigation

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***Abstract* - Over the years, traditional car makers have evolved into efficient systems integrators dominating the industry through their size and power. However, with the rise of big data technology the operational landscape is rapidly changing with the emergence of the "connected" car. The automotive incumbents will have to harness the opportunities of big data, if they are to remain competitive and deal with the threats posed by the rise of new connected entrants (i.e. Tesla). These new entrants unlike the incumbents have configured their operational capabilities to fully exploit big data and service delivery rather than production efficiency. They are creating experience, infotainment and customized dimensions of strategic advantage. Therefore the purpose of this paper is to explore how "Big Data" will inform the shape and configuration of future operations models and connected car services in the automotive sector. It uses a secondary case study research design. The cases are used to explore the characteristics of the resources and processes used in three big data operations models based on a connected car framework.**

Keywords - big data; automotive industry; business model; operations model; connective capability

I. INTRODUCTION

As today's consumers are surrounded by connected devices, such as smartphones and tablets, the idea of connected cars is gaining in popularity. It is estimated that by 2025, all new passenger vehicles will be connected [2][4]. Yet, the connected car represents a major disruption to the automotive industry's traditional value creation model. A connected car can be defined as: "*a car that is equipped with Internet access, and usually also with a wireless local area network. This allows the car to share internet access with other devices both inside as well as outside the vehicle*"[1]. These services are made possible by a firm's capacity to capture and leverage high volumes of structurally diverse and high-speed data ("*big data*") generated by the sensors and embedded electronics of connected devices.

Two main service segments can be clearly distinguished in the growing connected car market: i. integrated product-services (to enhance the driver experience) and; ii. mobility services (to offer alternative modes of transportation from traditional private car ownership). Furthermore, moving into the service economy opens new streams of revenue for traditional manufacturers [6] and big data will enable superior value creation based on closer customer intimacy. However it also opens up the automotive industry to competitors from outside their traditional industry channel who are more proficient than incumbents at leveraging big data. In an industry unchanged in decades, these new entrants are finding ways to innovate and meet diverse customer needs for more information and mobility services, configuring their business and operating models around big data.

This work will help to identify from an operations perspective how big data is re-shaping the provision of products and services in the automotive industry, as it evolves towards further connectivity and autonomous driving. Whilst different models continue to co-exist, it is important for incumbents to understand how emerging operations models are configured compared to traditional models so that they can be proactive rather than reactive to the big data-driven disruption of the automotive industry. Big data is commonly hailed as the next frontier for productivity, innovation and competition [3]. As a complex and multi-faceted concept, it impacts on many things in different ways. Therefore, to narrow the scope of the study, big data is considered in terms of how it impacts on the way in which resources and processes are managed within an operation. This is justified because the way in which resources and processes in an operation are managed has a strategic impact on the organization [3]. It is therefore valuable to look at the configuration of emerging operations models to explore the impact of big data.

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As operations models are dynamic and fast-changing, the overall objective is to identify the characteristics of the emerging big data-enabled operations models in the automotive industry. To our knowledge, this topic has not yet been theoretically studied from an operations perspective and there is a need for work to fill this research gap. A conceptual framework of emerging big data-connected operations for the automotive industry is developed, based on the literature, and the underpinning concepts are examined through theory-guided case study analysis.

II. THEORETICAL FRAMEWORK

While moving to a consumer-centric service approach based on big data has economic benefits, there are operations challenges. The main challenge for incumbents is a shift in the nature of value. Operations models must be able to process information and customers more than raw materials. The basis for all connected car services is information. With customer value based on intangible services, each stage of the transformation process is different; resource inputs and process outputs have perishable value if not captured and consumed in time. The transformation process is shaped by new constraints, including a company's capacity to capture, analyze and leverage real-time big data in the operations model [7]. The characteristics of the operation's resources, processes and capabilities are described in Figure 1. The dotted line illustrates the scope of analysis in the case studies. In contrast to traditional operations models that predominantly process materials, emerging operations models in the automotive industry process information (big data) and customers. It is therefore proposed that big data and customers are the dominant transformed resources, while the dominant transforming resources comprise big data analytics (to extract insights from the real-time data captured) and vehicles (to physically transport the customers).

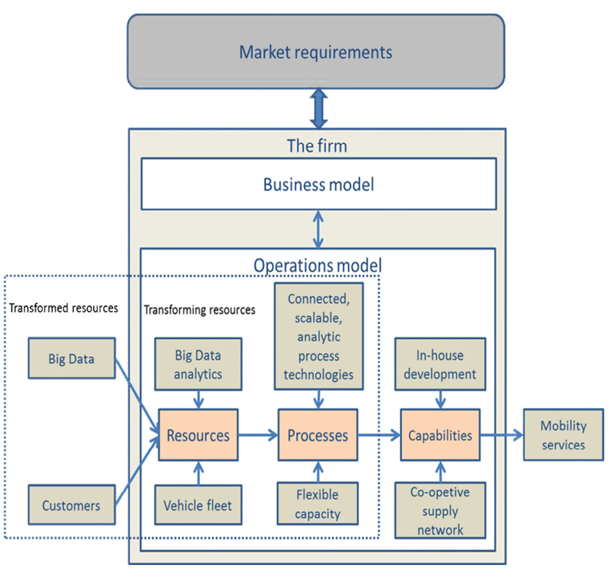

Figure 1: Emerging big data-connected car framework

III. RESEARCH METHOD

A multiple case study design was chosen to strengthen conclusions drawn from the cases and to increase external validity [8]. Three secondary cases were purposefully chosen according to the logic of theoretical sampling. That is, cases were selected based on the likelihood that they would critically challenge the predicted theoretical findings. This helps to confirm or advance the theoretical model. All the case studies were chosen according to their varying degrees of reliance on big data. As such, big data is the primary input into the operations model. That is, all services in the cases delivered to customers rely on real-time information extracted from big data. The first two cases Uber and Drive Now provide ride-hailing and car sharing services; the third case Tesla offers over-the-air software updates for its customers and customized services from: product design, through to purchase, product performance monitoring and after sales support. As their products diverge from the traditional offerings of the automotive industry, their operations models constitute "emerging" operations models.

IV. FINDINGS

Uber and DriveNow are examples of pure mobility services. Tesla is an example of a company using big data to deliver services related to its manufactured product, namely the owned electric vehicle. Despite these differences, several trends emerged across the three case studies. The operations outputs vary across the case studies. However, when compared to traditional operations models delivering a focused product, these emerging operations models have been designed to deliver a multi-variant consumer experience. For example, the operations outputs for Uber and DriveNow are to meet an immediate and real-time demand for flexible transport in urban environments.

In the case of Tesla, the service operations output is multi-faceted because Tesla provides a service offering based on a product, namely the vehicle that is sold to a customer. Tesla's service uses big data to understand, maintain and also improve vehicle functionality in line with customer expectations. It maintains vehicle functionality by collecting diagnostic data on individual vehicles, and improves vehicle functionality by aggregating driving data to understand driving conditions and vehicle performance, optimal locations are for charging stations. In terms of outputs that are software-based, such as those mentioned in the case studies, they are not constrained by time and space in the same way as tangible outputs. Updates to the service can easily be applied without physical presence or a mutually agreed time. One particularly noticeable trend across all case studies is therefore that of producing minimum viable products. This means that instead of delivering perfected products and services to customers, the company determines what is the minimum viable level for the service to work, produces that and then tweaks and perfects it based on how it is used and perceived by customers. It illustrates the importance of on-going relationships with customers, rather than ending the interaction at the point of sale.

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The concept of allowing customers to use unfinished products is novel in the automotive industry. With feedback loops and real-time monitoring enabled by big data, the customer becomes part of the operations improvement process. It enables companies eventually to deliver exactly what the customers want. Tesla is a key example of this. Its major software updates (new, improved features) are released on a yearly basis, while minor updates (bug fixes) are released on average every month.

The hardware suite required for semi-autonomous driving (named "Autopilot") has been fitted into Tesla's vehicles since 2014. It includes forward-facing camera and radar, 12 long-range 360-degree ultrasonic sensors, GPS and electric braking system. Whenever vehicles are in manual mode, Tesla crowd-sources the fleet's driving data. Using so-called "fleet learning technology", Tesla uses these datasets to train its driving algorithms which ultimately are what drives the car when in Autopilot. The first version of Autopilot was released by OTA software update in 2015, and is still in beta mode today. This means that it is the driver's responsibility to remain alert at all times. While Autopilot is engaged, signals are sent back to the Tesla HQ server whenever a driver intervenes (i.e., by adjusting the steering wheel or braking) or resumes control. Based on these aggregated driving datasets, Tesla identifies where problem areas are and is able to investigate and improve the software. As the fleet learns, improvements can be noticed in days.

Uber is another example of a company producing minimum viable products. Its underlying system architecture was developed by many teams in any way possible as it rapidly expanded in the first five years. The result was a mixture of architectures and as it developed and customers made known their preferences, new system architecture was developed to support new service features. DriveNow was established as a separate entity from its parents company BMW to benefit from the agility of a start-up. It encourages customer feedback and adapts its operations model to suit.

Across all case studies, customers are the predominant transformed resource. This is in contrast to traditional operations models which focus on transforming materials into a product. Moreover, all services delivered to customers in these emerging operations models rely on real-time information extracted from big data. Although there are differences between the models as to what information is collected and analyzed, GPS positioning is captured in all models. Not only does this help riders and drivers locate each other / a suitable vehicle, but the GPS data generated from usage also helps companies to understand customers' popular routes and improve service provision.

While in traditional operations models, big data is used to enhance visibility over existing processes, in emerging operations models big data is one of the primary inputs enabling the provision of the service. Because of this the service operations of the case studies rely more heavily on intangible inputs, namely information. The value of such information is specific to time and space and if it is not captured, it is lost.

In every case, the operations model is configured to provide a flexible and convenient service. Inherent in the provision of services is fluctuating demand [5]. With big data, the companies in the case studies are able to monitor supply and demand in real-time and even to identify challenges ahead of time. They configure their capacity to accommodate a certain level of demand fluctuation, but importantly they also directly manage capacity by influencing the levels of supply and/or demand. The intangibility of services means that they cannot be easily stored [5] and therefore customers are less likely to be willing to wait for services than they are for a finished product.

For Uber, flexible capacity is achieved by not employing its drivers or owning a fleet of vehicles. Demand and supply are managed by surge pricing. For DriveNow, service capacity is constrained by the size and functionality of the fleet; if customers do not find a car available in a suitably close location, the service is of no value. Flexible service provision is therefore enabled by deploying a large fleet and a small team of service agents who check tyre pressures, clean the cars and move them to more popular locations if necessary.

Supply and demand are managed through incentives for customers to park in optimal locations and fixed pricing. For Tesla's service delivery, flexible capacity is configured by designing the vehicle from the ground up to ensure that features can be updated safely via software updates over time. However, Tesla also has to manage the constraints of producing hard products vehicles and is constrained in the usual way for the manufacturing side of its product-service.

Tesla vehicles contain over 3,000 purchased parts sourced globally from over 350 suppliers. Tesla's supply chain is a "unique hybrid of the traditional automotive and high tech industries" which means its pace is faster than traditional automotive supply chains. If suppliers cannot keep pace, software development and manufacturing is brought in-house.

While other automakers plan their production layout to keep it the same for several years to minimize costs, Tesla's production engineers move machines around frequently as a learning exercise. The company uses Tableau visualization software to monitor its production lines minute-by-minute. In terms of its supercharger network capacity, Tesla decides where to locate capacity by collecting and analyzing driving data from its fleet. It takes into account route patterns and local driving conditions. Each supercharger station is itself connected to the Tesla network, both for monitoring and maintenance purposes, but also to let customers know availability via Tesla's vehicle Navigation system.

By design, all the case studies have a reliance on connectivity. Without connectivity in the process technologies, the big data cannot be created and captured. Tesla has the most advanced configuration for connectivity as its vehicles have been designed from the ground up for connectivity. This enables OTA software updates for all functional features of the car. The hard asset requirements of the vehicle and the production efficiencies mastered by incumbents mean that few new entrants could offer a viable competitive threat to incumbent automakers in the traditional arena.

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However, in the new market, new entrants are using big data to innovate entirely new operations models to deliver new products and services based on a closer understanding of customer's on-going needs. They are defining the strategic agenda for capturing, analyzing and leveraging big data in their operations models. Free from the organizational structures and investor commitments of the traditional players, the new players are better able to address fluctuating demand in the service area.

V. CONCLUSION AND FUTURE RESEARCH

Our paper explored how big data could enable the development of new operations models in the automotive sector and also suggested how these models could be evaluated across thematic categories of resources, processes and capabilities. Further it aimed at setting out a new research agenda that fuses and crosses the boundaries of operations management and big data technology. As the prominence of big data continues to develop and stakeholder groups become increasingly knowledgeable and engaged, there is considerable incentive for operations managers across industry sectors to consider the opportunities and challenges facing their processes and people, as well as the tools and frameworks they deploy for strategic and operational decision making.

The opportunities are not only in improving efficiency and effectiveness of their existing operations, but also in transforming their operations models, and in some cases, developing radically different new ones. They must become more customer-centric and service driven in this big data age. The automotive industry has evolved from Ford, to the TPS and post-Fordism, but now in the second decade of the twenty first century it is information and service not production driving the operations model. This is information driven automotive sector characterized by low inventory, customization, dissolvable supply chains, leasing, joint automotive/ICT ventures, Silicon Valley driven product R and D, the delivery of shared services and pooled capacity.

For organizations developing new operations models, the challenge is to build on and leverage the new digitized infrastructures emerging with smart and intelligent cities, in order to connect physical goods, services, and people (offline), with real-time data driven processes (online), in seamless O2O (online-to-online) operations. This requires a re-design of long run operational competencies and capabilities in order to respond to the rapidly changing city environments.

Despite the importance of operations management to big data implementation for both practitioners and researchers, we have yet to see a systematic framework for analyzing and cataloguing emerging operations models. As such, our conceptual framework makes an initial contribution to operations management theory in the big data context. This research only used three 'theory-guided' cases studies to illustrate the big data transformation of operations models. Therefore much more in-depth analysis and more detailed models are clearly needed to assist in the implementation of big data initiatives and facilitate new innovations in operation management. Some of the changes that operations and their connected supply chains face are revolutionary, and this requires careful consideration from both a practical and theoretical point of view.

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