# Chapter 7
# RFID-Embedded Smart Washing Machine Systems in the Big Data Era: Value Creation in Fashion Supply Chain

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## 1 Introduction

Home appliance brands such as LG, Samsung, and Whirlpool have all launched smart washing machines on Wi-Fi with special smart feature (Griffin 2015). Washing machine has been well developed to connect with database and internet. For example, Kobus et al. (2013) discuss the smart washing machine with a new sustainable technology, which can collect the real-time electricity consumption and production data from the washing machines and the solar panels. Washing machine now is able to access Internet. A natural question arises: How can we develop smart washing machine with Internet of things and better use of the collected data?

The new version of smart washing machine with radio frequency identification (RFID) sensor has been developed, which is able to detect what clothes in the laundry and adjust the washing settings automatically based on the weight and materials of clothes. This technology has received great supports from fashion retailers. For example, global fast fashion brand Zara has built their business around RFID technology (Bjork 2014), global sports fashion retailer Decathlon implemented RIFD

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B. Shen et al. (eds.), *Fashion Supply Chain Management in Asia: Concepts, Models, and Cases*, Springer Series in Fashion Business,
https://doi.org/10.1007/978-981-13-2294-5_7

tags into their products (Swedberg 2015). Both Zara's and Decathlon's use of RFID are to improve operation efficiency and inventory accuracy.

Fashion has a wide assortment of products, short life cycles, and high seasonality. Companies adopt forecasting methods to predict market demand. However, it may still have bias when companies use the statistical and intelligent algorithm based on the previous sales data (Ren et al. 2015). RFID is a critical enabler to enrich the customer experience and market information. It is desirable to collect information in regard to what consumers are wearing and their wearing frequency because this could imply real-time consumer behavior at the apparel use stage (i.e., real-time consumer preference). In this paper, an innovative RFID-embedded smart washing machine (RFID+SWM) system is proposed, in which RFID sensor is able to read tags in clothes (which have been inserted by RFID tags), and detect what washing cycle they should go on. This new system could collect, store, and analyze data from households' washing machines and is capable to overcome a wide range of obstacles such as monitoring real-time fashion preference and optimizing operations system.

Availability of such washing information will grow exponentially when this smart washing machine is getting popular in households. Collected data becomes extremely large and complex and is difficult to process them by using traditional data processing applications. Data has the potential to change business model design and decision making based on data analysis. The embedded RFID smart washing machine will produce greatly large amount of real-time data associated with what color, textile, style, brands of clothes the consumers are washing, and when and where they are washing. This real-time information can partially reflect what consumers are wearing. Given the information of what consumers are wearing, fashion companies can derive optimal solutions in terms of consumer preference and use analytics to improve operations performance in design, manufacturing, and retailing. Much of the existing research focuses on physical applications and hardware development. It is unknown that what exactly values and challenges in the development of such a RFID+SWM and its corresponding business analytics.

To the best of our knowledge, it is the first study to explore business values of RFID-embedded smart washing machine. It is worth discussing that how this business analytics of such management systems transform fashion business. It is concluded that the data collected via RFID+SWM can help manage fashion business from product design, production planning, and retailing management. The benefits include the apparel production process optimization from perspectives of quality enhancement (quality for shorten or extend product life cycle), sustainability (carbon emission and water use management), and operation strategies management (help meet supply and demand). More specifically, this study aims to answer the following questions.

(1) How the RFID+SWM system is developed to guarantee users' and relevant firm's benefits?
(2) What are the motivating factors that drive users to adopt the RFID+SWM system?
(3) What are the business values of the RFID+SWM system in the fashion industry?

This paper is organized as follows. The related literature is reviewed in Sect. 2. Section 3 describes development of RFID+SWM and Sect. 4 details the discussion in regard to adoption intention and business value. The implication and recommendation are given in Sect. 5. Section 6 concludes the paper with general remarks and potential future research.

## 2 Literature Review

Two streams of research relevant to this study are briefly reviewed below.

### *2.1 RFID Implementation in Fashion*

RFID technology has been widely employed in the various industries (Ngai et al. 2008a; Zhu et al. 2012; Laosirihongthong et al. 2013), such as aircraft engineering industry (Ngai et al 2007), food industry (Ngai et al. 2008b), and healthcare sectors (Wamba and Ngai 2015). RFID infrastructure consists of a transponder, a reader, and a data collection application (i.e., a software solution and an antenna). The data collection application connects with Internet and transfers the collected data to center servers for further data analysis.

RFID is also widely adopted in fashion supply chain (Quetti et al. 2012). Loebbecke and Palmer (2006) examined the benefits of the fashion merchandise manufacturer (i.e., Gerry Weber) who implemented RFID on fashion item, carton, and palette levels when trading with the leading fashion retailer (i.e., Kaufhof department store). They found that RFID is acceptable to consumers when embedding in the clothes and both parties enjoyed the substantial benefits in reducing operation time and labor cost when using RFID in the supply chain. Moon and Ngai (2008) provided five cases to describe the benefits of RFID in the fashion retailing. They proposed that RFID could enhance efficiencies of the customer relationship management, shop floor management, marketing and promotion, and logistics and inventory management in fashion retailing. Bertolini et al. (2012) examined the values of implementing RFID in the fashion supply chain. They claimed that the successful design and implementation of RFID in the fashion supply chain requires a close cooperation between users and developers. Zhou and Piramuthu (2013) studied the security property of RFID in fashion retailing. They proposed the authentication protocols to address the challenges in ticket-switching of RFID-tagged items in apparel retail stores. As high implementation cost is one of the main barriers in supply chain for RFID, Chan et al. (2012) compared the conventional bar code system and RFID in healthcare apparel inventory system. They found that supplier maybe worse off if the healthcare organization changes its scanning system from barcode to RFID or vice verse. Ngai et al. (2012) summarized the business of RFID in fashion manufacturing operation. This paper is innovative and different from previous literature of RFID implementation in fashion production and operation management. It takes a forward step to discuss the value creation from the RFID+SWM in the fashion business.

### *2.2 Business Analytics in Fashion*

Data provides new prospects to apply a variety of statistical and artificial intelligence techniques to measure business process management (Zhang 2012). Fashion industry is quite unique. Fashion trend is difficult to follow, monitor, and forecast. Effectively monitoring fashion trend and managing supply chain are challenging and not easily achieved using traditional approaches such as someone's experience and observation. Caro and Gallien (2010) investigated the fast fashion retailing assortment planning problem by using an optimization approach based on the data of Zara in retailing and supply chain. They found the optimal inventory allocation within the fast fashion supply chain network.

Business analytics represent a new era in large and complex data utilization. In the fashion industry, applications of business analytic are well explored in areas of social media with the growing popularity of Internet of things and availability of information (Ngai et al. 2015). It can analyze consumer postings, gauge the immediate impact of marketing, and understand the consumer's sentiment about brands and products. Social media is a platform to share personal perception and discuss what is happening. Data from social media can monitor the real-time perception that what people are talking (thinking) about the specific products or present fashion trend. However, thoughts and actions are not always consistent, and actions are more likely meaningful to future decisions (Hannah et al. 2011). Hu et al. (2016) studied the impact of social media's "liking and following" functions on operations and marketing policies. They found that recruiting influencers can help diminish sales' unpredictability. Fundamentally different from social media, the proposed approach in this paper traces and examines consumers' actions, the real-time data that what, when, and where people are washing (wearing) is captured. This data analysis can surely trace and monitor the consumers' actions on fashion.

## 3 Development of RFID+SWM System

In this section, we develop the architectural framework of RFID+SWM system. Figure 1 shows the overview of the proposed system. This figure helps to understand the maturity level of RFID technology in fashion and washing machine, and get the clear picture of the structure of the proposed system. As shown in Fig. 1, we describe the various stages in designing and developing the proposed system: (1) data capturing system, (2) data analytical center, and (3) big data and business analytics.

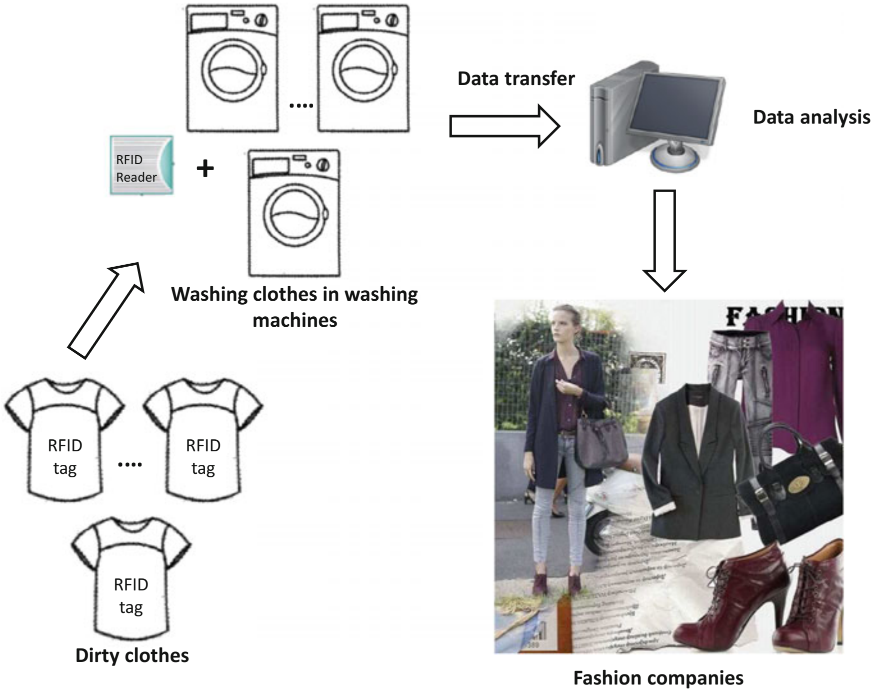


**Fig. 1** Overview of RFID+SWM system

## *3.1 Stage 1: Data Capturing System*

Data capturing system requires the installation of RFID tags and readers. To be tractable, all clothes are launched with RFID tags, in which some asset specific data including color, textile, style, brands of clothes, and when and where they are washing, are all collected. As all clothes will be washed by water, RFID tags must be waterproof. Moreover, the RFID readers are installed in the smart washing machine. RFID reader automatically detects clothes information (e.g., fabric type and colors) before starting the washing cycle. The RFID+SWM system captures digital processing of the tag content. Then, there is the hardware and software combination, which aggregates and filters the raw data for further processing. Afterward, data structure is formed, wirelessly transferred, and stored in data analytical center.

To develop the data capturing system, many fashion companies have inserted the RFID tags into the clothes (Loebbecke and Palmer 2006). Smart washing machine installs the RFID sensor with the strong IT application deployment, which gives the ability to process, store, and integrate the additional data from RFID. The data capturing system is the first step of RFID+SWM system.

### 3.2 Stage 2: Data Analytical Center

Based on the data collection from data capturing system, the data analytical center carries out some basic filtering, aggregation, and processing operations for data analysis. The basic rules of washing with regard to energy efficiency and sustainability are built into the data analytical center, which enables to capture what clothes are about to be washed, and provide the most suitable washing mode selection in consideration of best treatment of washing, minimization of carbon emission, water, and energy usage. To support the data analytical center online, the IT infrastructure integrates with RFID deployment and aims at supporting real-time operations associated with fashion supply chain management. Two aspects are emphasized regarding fashion supply chain as follows. First, the sustainability of entire fashion supply chain, including carbon emission, water footprint, and energy usage can be measured. Second, based on the frequency of washing, product quality can be better managed (if one type of products is more frequently washed, to extend the life cycle, its product quality should be better designed in production process with consideration of potential frequent washing in use). Afterward, the data analytical center uploads the data to cloud computing platform via Internet for storage and further analysis. This Web-based platform is built to enable company managers and supply chain specialists to retrieve relevant information.

### 3.3 Stage 3: Big Data and Business Analytics

Based on the data uploaded from heterogeneous household's washing machines, it needs to process online analytics, data mining, and automating decision system. A variety of statistical and artificial intelligence techniques based on real-time consumer behavior in washing are applied to measure business process management. After data mining, the implications to fashion and textile-related industry are able to be provided. Such business analytics from the proposed system helps industrialists to evaluate what, when, and where clothes are currently washing, as a result predict the consumer wearing behavior, and provide managerial insights to fashion supply chain. Moreover, from supply chain perspective, it can measure product's carbon emission and water footprint in both manufacturing and usage processes. This fundamentally changes the assessment of sustainability and reduces negative impact on environment. Figure 2 shows three steps in the architecture framework of the RFID+SWM system.

### 3.4 Example of Color Trend Forecasting

As mentioned above, some asset specific data including color, textile, style, brands of clothes, and when and where they are washing can be collected from RFID tags and

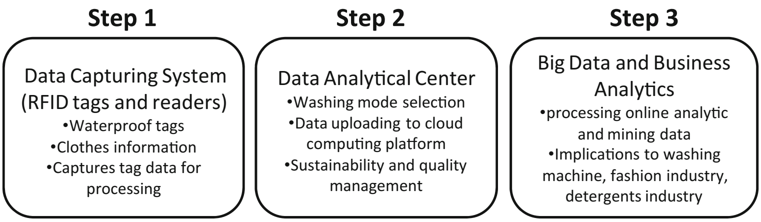


**Fig. 2** Architecture framework of the RFID+SWM system

readers. In this subsection, we take color forecast as example to show the forecasting procedure based on the data collected from RFID+SWM system. The quantity of clothes in specific color presents the popularity degree of a specific color. In other words, more quantity of textile in specific color in the future indicates much more popular of a specific color. We build up the extreme learning machine (ELM) forecasting model and evaluate the impact factors including style, material, size, weight, and gender on color trend forecasting by the ELM algorithm. The output of ELM model is the quantity of specific color.

Define the input variables as $x_i = (x_{i1}, x_{i2}, x_{i3}, x_{i4}, x_{i5})$, where $i = 1, 2 \ldots N$ denotes the number of samples and $x_{i1}, x_{i2}, x_{i3}, x_{i4}, x_{i5}$ represents the input variables style, material, size, weight, and gender, respectively, at each observation time period. The forecasting steps of our proposed color trend forecasting model based on ELM algorithm are illustrated as follows:

- Step 1: Extract the quantity data of clothes in one kind of color from raw data according to its color code.
- Step 2: Select the impact factors that have a significant effect on the color trend forecasting as the inputs variables of ELM algorithm.
- Step 3: Divide the input datasets into training, testing, predicting sets. Please note that the inputs of different variables are in the different ranges. Thus, the training and testing data are normalized before training and testing process, so that the inputs fall into a specific range. The normalization method for input datasets and the unnormalization method for output datasets follow the work of Huang and Babri (1998) and Frank et al. (2003).
- Step 4: Select the activation function of hidden neuron and the neuron number of hidden layer of ELM. The input weights matrix $W_i$ and hidden biases $K$ are randomly chosen in ELM algorithm, while the output weight matrix $\beta_i$ is determined analytically.
- Step 5: Compute the outputs of ELM forecasting model according to input training data and testing data and unnormalized the outputs. The predicted series of training data and testing data can be obtained.
- Step 6: Compute the predicted sales series of predicting data according to the input weights $W_i$ and output weights $\beta_i$ obtained by Steps 4 and Step 5.

With the above six steps based on ELM algorithm, the color trend forecasting can be identified by using data from RFID+SWM system.

# 4 Value Creation from RFID+SWM

## 4.1 Value of Users

Individuals are not willing to adopt a new technology if they cannot receive benefits after using it. It is thus significantly important to discuss adoption intention and ensure all involved individuals to implement a new system. In this subsection, the benefits of all involved individuals are discussed as follows.

First, fashion companies receive tremendous benefits from editing clothes information into RFID tags and inserting them into products. If the clothes with RFID tags are washed in the proposed smart washing machine, then what, when and where consumers wash are stored, traced, and analyzed. This analyzed result provides insights into consumer wearing behavior and helps re-engineer the fashion business processes in order to increase operational efficiency, and let match supply and demand. To remain competitive, re-engineering the business process achieves productivity gains and accesses to understanding consumers' preference and behavior. Moreover, after implementing the proposed system, product sustainability is measured in the use process. Thus, the sustainable fashion companies should carefully design product quality and manage sustainability in the consumer use.

Second, washing machine producers are beneficial with this information system adoption. RFID enables firms to generate information in terms of productivity and service effectiveness at the same time. Washing machine producers need strong management commitment to change the structure of washing machine business and invest heavily on R&D in such system. This investment could receive the significant great return and leverage benefits through information sharing across fashion supply chain. Such information sharing creates the great value and is critical for fashion supply chain. In the future, its business models may be changed: washing machine producers may not just sell the washing machine with a substantial upfront price, but a service of selling market information. Service is more lasting and creates large value (Spohrer and Maglio 2008).

Third, users are beneficial with smart machine for better decision making. Users are acceptable to wear the clothes with RFID (Loebbecke and Palmer 2006), and willing to use this kind of smart washing machine at home. People may repeat some actions and form an automatic response in stable environment (Verplanken and Aarts 1999). Thus, users may not have solid knowledge that which washing mode is suitable for clothes (e.g., wool-made clothes should be treated differently compared to cotton made one). This may lead to negative outcomes that the washed clothes are damaged, and extra energy and water are used. The proposed system can provide more customization with personalized services to users. Smart washing

**Table 1** Technology push and need pull factors for adoption of an RFID-embedded smart washing machine system

| Parties | Technology push | Need pull |
|---|---|---|
| Fashion companies | ◆ RFID tags<br>◆ Data mining<br>◆ Business analytics | ◆ Better quality control<br>◆ Better product sustainability<br>◆ Better knowledge of product usage |
| Washing machine producer | ◆ Information receiver and storage via RFID technology<br>◆ Cloud computing platform<br>◆ Business analytics | ◆ Better clothes treatment<br>◆ Value-added service provision<br>◆ Transform the awareness of sustainability |
| End-users | ◆ Smart washing mode selection | ◆ Customization with personalized services<br>◆ Extend product life cycle<br>◆ Increase sustainability |

machine with the RFID reader can read information from the tags attached to the clothes. This allows information about the fabric type and color to be collected from RFID-tagged buttons, helping users to avoid mixing white and dark laundry and optimizing the washing program based on the characteristics it reads from both the clothing and the washing detergent used. For example, if colored and white clothing items cannot be washed together or woollen clothing item cannot be washed together with a cotton clothing item, the smart washing machine can identify the color and the texture of the clothes based on the real-time information collected from embedded RFID tags in clothes. Therefore, to better maintain the quality of clothes and extend its life duration, consumers are willing to use the embedded RFID smart washing machine in daily time. Thus, the proposed system is able to better treat the clothes, extend the clothes' life cycle, and transform the awareness of sustainability.

Table 1 follows Shih et al. (2008) and Ngai et al. (2012) to use the concept of technology push and need pull to examine the adoption intention of RFID+SWM system. As shown in Table 1, this approach provides the key factors in the adoption decision of a new technology in the engineering/R&D management discipline.

## 4.2 *Value in Fashion Business*

Applying RFID in the smart washing machine is an innovative idea. Implementation of the new system implies the outdated processes are replaced. The value of such RFID technology is particularly apparent in the fashion industry. It contributes to real-time fashion trend management, increases efficiency in production planning, and enhances sustainability in fashion supply chain. The values of adopting RFID+SWM are as follows.

First, product design is enhanced based on the data of consumer behavior in use. Fashion designers can identify the popular styles, fabrics, and colors by using the data analysis from the proposed system. Moreover, the more sustainable product design can be inserted into the product development process with higher frequency of washing. For example, one polyester made item is produced in a relatively unsustainable manner, but it may be more frequently wore and washed by consumers; or one wool-made item is produced sustainably, but it may not be worn and washed frequently. Both scenarios are not enough sustainable if sustainability is considered as not only manufacturing process, but also consumer use process. Hence for product development, if the products are more frequently used, more sustainable materials should be made in the products.

Second, the proposed system helps better manage apparel production planning. It assists fashion managers to perform more effectively in strategic production planning. It has visibility of wearing in downstream customer sites so that proactive production decisions can be made. The proposed system provides higher visibility of sustainability in the entire fashion supply chain. RFID technology has the ability to provide an accurate data of carbon emission, water and energy usage in operation and production process. The proposed system would enable the supply chain operations to have visibility of the products' washing frequency as well as the carbon emission, and water and energy usage in washing process (Singh et al. 2015, 2017).

Third, the proposed system provides better visibility in fashion retailing management. It can monitor what consumers are washing and provide more accurate data for fashion trend monitoring and forecasting. By tracking the real-time washing items, fashion companies gain better visibility of consumer preference toward fashion products. More accurate real-time data can remove the human factor compared with the traditional fashion trend forecasting. The data analysis provides more accurate demand forecasting. Based on the washing data, it can analyze the fashion preference, provide the recommendation of fashion products development, and enhance the consumer experience.

Fourth, the proposed system can trace and monitor how consumer washes and treats the clothes. This knowledge provides information and managerial insights to product design, production planning, and retailing management. As shown in Fig. 3, the massive data of the consumer behavior at use stage can be analyzed in the proposed system. The analytical results can help decision making in fashion design, production planning, and retailing management.

With implementation of the proposed system, the new fashion supply chain system can become smarter than before. The new concept of smart fashion supply chain (SFSC) is proposed. SFSC is defined as a fashion supply chain is intelligent, interconnected, and visible throughout the entire channel. SFSC is capable of connecting all supply chain parties (i.e., designer, manufacturers, retailers, and consumers), learning and making real-time decision associated with product design, production planning, retailing management and use process by itself, as a result predicting the future development based on the results from data mining. Table 2 is summarized the business value-added framework for RFID-embedded smart washing machine.

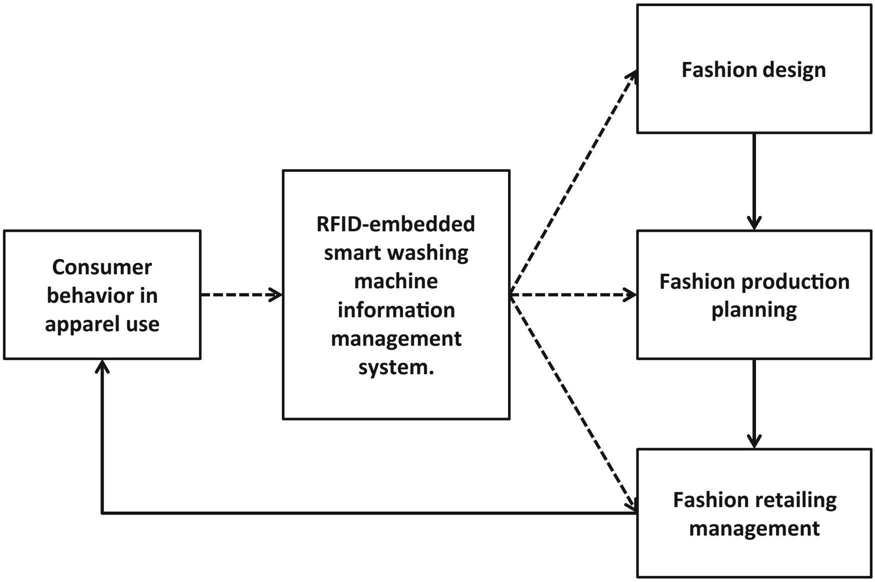


**Fig. 3** Flowchart of SFSC

**Table 2** Business value-added framework for RFID+SWM system

| Considerations | Details of business value-added |
|---|---|
| Operational level | Provide a platform for real-time business intelligence |
| | Ensure the suitable washing mode to minimize usage of energy and water, and carbon emission |
| | Interconnected within supply chain parties |
| Management level | Data mining and business analytics |
| | Learning and making real-time decision |
| | Predict what consumer like (i.e., forecast fashion trend) |
| | Better visibility of sustainability in the fashion industry |
| Strategic level | Better visibility of fashion trend and better decision making in production |
| | Tight collaboration between fashion companies and washing machine producers in information sharing |
| | Strong awareness of sustainability |
| | Smart fashion supply chain construction |

### 4.3 Challenges for Implementation

It had no equipment or technology which could monitor and trace fashion wearing behavior after purchasing. Implementing the proposed system can help fill this gap but may raise several potential challenges. First, the deployment of RFID tags should be attached to the entire fashion industry, rather than several brands. The adoption of RFID entails a large investment and requires careful planning. However, it has been largely evident that RFID technology could help better manage fashion supply chain. This challenge is addressed by the fact that whether companies can receive great more benefits from using RFID technology than investment. Second, it has challenges for washing machine producers to install RFID reader and corresponding systems if consumers are not willing to purchase such smart machines. Hence, efficient product promotion and favored prices should be provided to consumers. Third, privacy is a critical issue in consumer adoption. Consumers may be concerned with the privacy that what they are washing (wearing). Thus, it is important to avoid the privacy conflicts before consumers adopt this smart machine.

## 5 Implications and Recommendations

Data is essential components of managing decision making. Data mining, analytic applications, and business intelligence system are well integrated in the proposed system. The analytical results are actionable. However, the existing data is not capable enough to trace and monitor consumer wearing behavior in fashion. RFID technology can help collect customers' information in fashion stores. The data from RFID-embedded smart washing can provide immediate information of what customer are washing (wearing), so that fashion retailers can get better knowledge of consumer washing (wearing) preference and behavior.

The conventional fashion forecasting system is based on fashion show analysis, current market offerings, and art exhibitions. It is extremely challenging to predict dynamic consumer demand because the current forecasting tools may not be able to provide a real-time product life cycle from usage perspective. Through the RFID technology, the proposed system is able to accurately track the real-time washing behavior and predict what consumers may like. When certain types of clothes are mostly washed in households, it implies that consumers are largely wearing this type of clothes in a specific time period. As a result, fashion designers can identify the corresponding innovative design, fabric, and colors to satisfy customers.

Given the real-time information of clothes washing, producers can integrate the quality system with emission reduction through manufacturing efficiency. The proposed system can obtain data associated with consumer wearing behavior in use process. The results can improve (1) product development process from design innovation, (2) production planning process from quality management and sustainability perspectives, (3) retailing management process in better matching supply and demand, and (4) understanding of consumer wearing behavior in real-time apparel use. The proposed system is particularly important for large fashion brands with high market share (e.g., Zara, H&M) and high-end fashion brands. They can keep tracking product usage, monitoring fashion trend, predicting purchase time point, and location. Based on the data collected and business analytics, they can develop more desirable product lines, better stock plans, and identify brand/product authenticity. The RFID+SWM system can collect real-time information and increase operational efficiency. With more data available about which items are used by consumers, suppliers and retailers can boost profits and mitigate the risk.

Moreover, sustainability is one of the most important performance metrics. In the proposed system, the whole fashion product life cycle from sustainability perspective can be measured. Specifically, the proposed system can monitor product sustainability (i.e., carbon emission, and water and energy usage) in the use process. It is able to balance the product sustainability in manufacturing process and the use process associated with washing frequency. Afterward, the feedbacks can be sent to the manufacturers for optimizing production process and mitigating environment impacts. The proposed system can enhance accessibility and traceability in environment protection and integrate Corporate Social Responsibility (CSR) in supply chain.

Last but not the least, the proposed system can collect information, analyze new business opportunities and spark new business model. Internet and computing techniques have changed our life and business models tremendously. The proposed system provides an opportunity to create the new business models for both washing machine and fashion companies. For example, a producer of a smart washing machine could consider a "free washing" or "pay-as-you-wash" model in which customers pay nothing or little every time when they use the washing machine instead of making a substantial upfront payment. The machine producers can make profits from sharing washing data to fashion companies as service providers. The Internet of Things is able to facilitate these new business models and differentiate markets. Fashion companies may sell products to the potential consumers based on their washing machine location.

## 6 Conclusion, Limitation and Future Research

This paper describes the development of an RFID+SWM system with a focus on adoption motivation and value creation. Data collection, storage, processing, and other issues specific to analytics are incorporated into overall system design. The proposed system helps fashion companies to monitor consumer behavior in apparel use process. The proposed technology and developed prototype system transform fashion business landscape. The proposed intelligent decision support system delivers various values to optimize sustainability and quality management in production planning, and better match supply and demand in retail management in the fashion industry.

This study opens a new discussion in the fashion industry. More fashion companies are encouraged to incorporate the RFID tags into every piece of clothes items as well as the washing machine companies are encouraged to promote RFID+SWM system with financial support. The proposed system will transform fashion business models and present significant potentials to enhance firm's efficiency and sustainability.

This paper is beneficial to practitioners who interested in implementing an RFID system in the fashion industry. In future research, it would be significantly meaningful to investigate big data application based on the proposed RFID+SWM system. The empirical studies at both the macro- and the microlevels are suggested to investigate the factors that drive fashion business development in terms of big data and RFID.

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