

PAPER • OPEN ACCESS

The interconnected fashion industry - an integrated vision

To cite this article: E Papahristou *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **254** 172020

View the [article online](#) for updates and enhancements.

Related content

- [Wearable Sensors: GUI-based software development for sensor data collection, data extraction and data analysis using Python frameworks](#)
S C Mukhopadhyay and T Islam
- [Big data in fashion industry](#)
S Jain, J Bruniaux, X Zeng et al.
- [Research on key technologies of data processing in internet of things](#)
Yangqing Zhu and Peiying Liang

The interconnected fashion industry - an integrated vision

E Papahristou¹, P Kyratsis², G Priniotakis³ and N Bilalis⁴

¹ Technical University of Crete, School of Production Engineering and Management, Kounoupidiana, 73100, Crete Greece

²Western Macedonia University of Applied Sciences, Dept. of Mechanical Engineering & Industrial Design, 50100 Kila Kozani, Greece

³Technological Educational Institute of Piraeus, Department of Textile Engineering, 250, Thivon & P. Ralli Str. 12244 Egaleo - Athens, Greece

⁴ Technical University of Crete, School of Production Engineering and Management, Kounoupidiana, 73100, Crete Greece

Email: kalaoglu@itu.edu.tr

Abstract. The internet of things (IoT) is transforming everyday physical objects that surround us into an ecosystem of information that is rapidly changing the way we live our lives. Any physical product can be more intelligent, more interactive, more trackable and more valuable by being connected via IoT. All industries, including Fashion, are expecting that the IoT will make real quantifiable impact that can be quickly translated into positive ROI for the business, and equally a positive return for consumers. In our research on the integration of 3D virtual prototype in the Textile and Clothing sector, IoT was of particular interest. The research was conducted using a combination of primary and secondary sources. First hand interviews to explore the impact of recent technology applications in the design and production of fashion products and the areas which are going to benefit most. The research has included several questions to interviewees who are executives in fashion companies or industry entrepreneurs with the aim to investigate what IoT represents and attempts to understand how IoT can support Fashion Design, Development and procurement as well as manufacturing.

1. Introduction

The IoT, firstly coined by Kevin Ashton [Executive Director of the Auto-ID Center in Massachusetts Institute of Technology (MIT)], as the title of a presentation he made at P&G in 1999, is a technical revolution that is bringing us into a new ubiquitous connectivity, computing, and communication era [1]. The “Internet of Things” is defined as sensors and actuators connected by networks to computing systems [2]. Based on [3], IoT is a notion that depends on interconnected physical objects. It creates a mesh of devices that are able to generate information. Sensors are around us like in cars, buildings, and smartphones that can collect data about our environment. IoT enables us to know things that need replacing, repairing or recalling. [2] has studied the range of IoT adoption rates, economic and demographic trends, and the likely evolution of technology over the next ten years, and has estimated that the economic impact of IoT applications could be from \$3.9 trillion to \$11.1 trillion per year in 2025 with an estimation that factories are likely to have the greatest potential impact from IoT use-as much as \$3.7 trillion per year.

The internet of things (IoT) is transforming everyday physical objects that surround us into an ecosystem of information that is rapidly changing the way we live our lives [4]. Any physical product



can be more intelligent, more interactive, more trackable and more valuable by being connected via IoT.

The research was contacted using a combination of primary and secondary sources. First hand interviews to explore the impact of recent technology applications in the design and production of fashion products and the areas which are going to benefit most. The research project gathered the opinions and experiences of experts with direct contact and use of technology solutions for the product development process like 3D and virtual prototype or PLM (Product Lifecycle Management); the selection of the sample was purposive rather than random. 100 Experts from four different backgrounds of the fashion industry were selected to participate in this survey contacting personal interviews. As Figure 1a shows, 43 “relatively unstructured” personal interviews were carried out; some of them in typing due to lack of time on their behalf or the time difference between countries. 34 didn’t respond at all, although they have been contacted with a coming-up e-mail twice. In the Figures 1b, 1c and 1d participants are categorised in some demographics; Gender, Age Group and Country of Work.

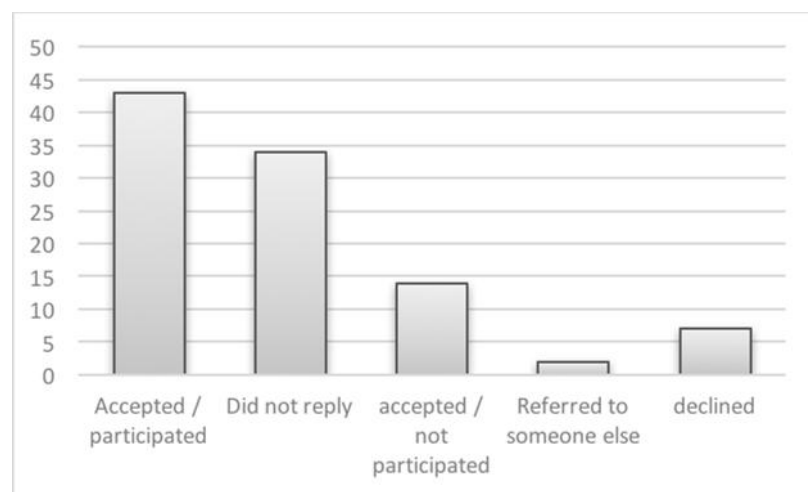


Figure 1a: Attribute- Response

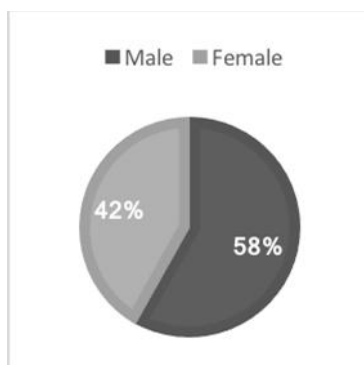


Figure 1b: Attribute- Gender

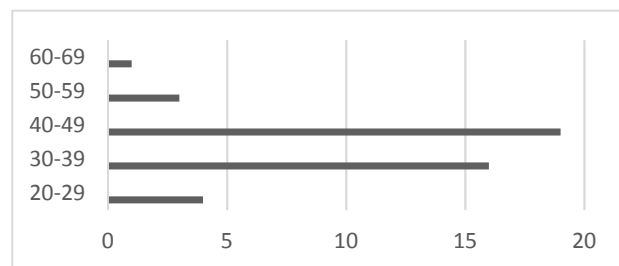


Figure 1c: Attribute- Age Group

The collection of primary data was not only relied on personal interviews but on surveys, notes, fieldwork and a combination of information types. The software NVivo was chosen as a state-of-the-art analysis tool for qualitative and mixed methods research.

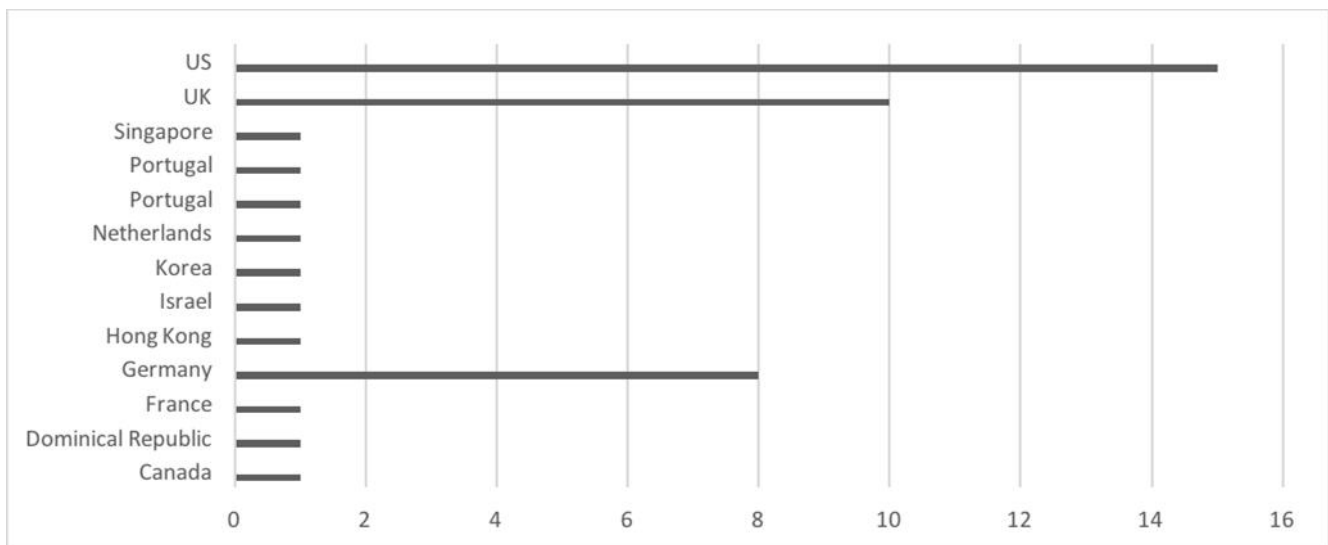


Figure 1d: Attribute- Country of Work

The research has included several questions to interviewees who are executives in fashion companies or industry entrepreneurs with the aim to investigate what IoT represents and attempts to understand how IoT can support Fashion Design, Development and procurement as well as manufacturing.

1.1 What IoT represents for the Textile and Clothing Industry

All industries, including Fashion, are waiting for the IoT to make real quantifiable impact that can be quickly translated into positive ROI for the business, and equally a positive return for consumers [5]. This research project explored the impact of recent technology applications in the design and production of fashion products and the areas which are going to benefit most. The research has included several questions to interviewees who are executives in fashion companies or industry entrepreneurs. As it was expected, apart from one IoT expert, all the rest responses came from participants with limited experience in IoT. However, they strongly believe that IoT applications will have a profound effect on the way companies and individuals access information and ultimately make decisions. Furthermore, IoT will enhance and evolve our ability to manage and process information giving companies better visibility into their supply chain regardless if they are physically vertical [6] [7].

For many, the fashion industry remains in the past. The notion of “seasons”, mass manufacturing, mass distribution of goods plus the lack of a new value system are only some of the obstacles preventing traditional fashion companies from evolving. The fashion industry as we know it today is over. In no way does it respond to the needs and values of consumers. The IoT is here and all around us and when combined with Virtual or Augmented Reality it will fundamentally change the way we relate and communicate.

If the Internet represents the democratization of information, IoT represents the democratization of big data. While there are already a few open source outlets of big data (data.gov, Google, cia.gov, amazon etc.); because of the means by which data is aggregated it can be very difficult to determine its quality and validity. However, it is believed that IoT will be a transformational trend in the short and long term. [8] posits that “what is underway is perhaps the most substantial change in the manufacturing firm since the Second Industrial Revolution, more than a century ago”. Microsoft’s Global Thought Leader believes it too although he states that they are probably not thinking of the fashion industry [9]. The VP of Gerber Technology on the other hand, classified IoT as the forth industrial revolution. In particular, he suggests the evolution as follows [6]:

1. Steam power makes mechanical production possible
2. Electric energy makes mass production possible

3. IT and computer technology allow for more manufacturing automation
4. Internet of Things makes networked manufacturing possible

An international Garment Industry Strategist [7], pinpoints some serious problems that will come to fruition such as:

- Few laws regulating IoT and the internet in general
- Limited protection of individuals from governments, organizations, other people etc

Barriers like these will be discussed as challenges further down. Furthermore, IoT will enhance and evolve our ability to manage and process information giving companies better visibility into their supply chain regardless if they are physically vertical [6] [7] & Figure 2. If the Internet represents the democratization of information, IoT represents the democratization of big data (Figure 3).

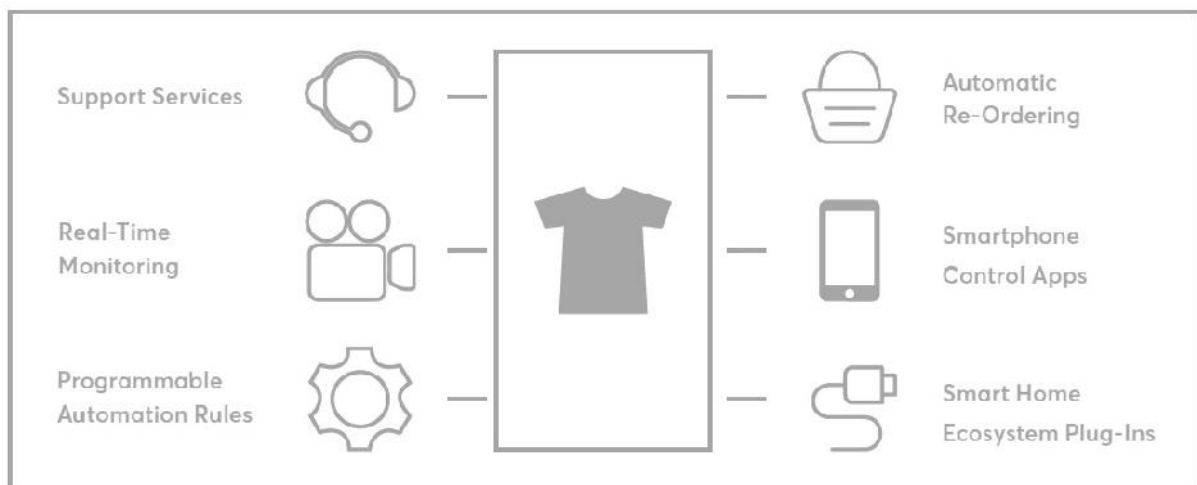


Figure 2: Connected Apparel Products



Figure 3: Internet of Things Connectivity

2. Cloud & “Big” Data

The notion of the Big data is related to the computer science since the earliest computing days. The data volume that goes beyond the processing capacity of the usual database and cannot be handled by traditional database techniques is called, "Big data." [10]. Whereas IoT mainly focuses on how to enable general objects to see, hear, and smell the physical world for themselves, and make them connected to share the observations [1], a huge amount of raw data is collected on an ongoing basis and makes it essential to develop new techniques able to transform raw data into valuable knowledge. The collected Big data may not have any value unless analyzing, interpreting, and understanding it. IoT will allow Big Data to be collected, aggregated and analysed, providing better pre-dictive analytics. A result will be lower inventories and even possibly on-shoring of manufacturing to keep manufacturing as close to the customer as possible; the right product, at the right place, at the right price [6].

Other studies argue that the application technology of IoT will bring with it a whole new explosion

of data that, if managed correctly, can be of enormous value to the contact centre and customer experience delivery. Contact centres will be able to gain more control of customer service by the Internet of Things providing them with new streams of information that is integrated into their existing infrastructure [11]. Primary research of this project also points to the same direction. Correctly managed data can also be an enormous value to the business and customer experience delivery. The value to customers can range from active service to aggregated performance, and sales analysis [6] [9].

The new product data is valuable by itself, yet its value increases exponentially when it is integrated with other data. Having the intelligence and a large data set from technology like i.e Bodylabs provides essentially a better way to fit clothing, a better way to size up and size down a potential customer's bodyscanning [12]. What is missing at the moment is the integration of these applications with PLM tools to provide feedback of how well the clothing of a company is fitting its customer segments [13]. Capturing such insights is the domain of big data analytics, which blend mathematics, computer science and business techniques [8].

Big data derived from in-store technologies can help drive content and promotions, as well as dynamic pricing, not to mention assist with inventory management by determining which products are in demand [14]. To better understand the rich data generated by smart, connected products, companies are also beginning to deploy a tool called a "digital twin." - a 3-D virtual-reality replica of a physical product [8].

In the fashion industry as this research argues, this digital twin is the virtual prototype which allows the company to visualise the status and condition of an apparel product that may be thousands of kilometres away, providing insights into how products can be better designed, manufactured, operated, and serviced. The powerful new data available to companies, together with new configurations and capabilities of smart, connected products, is restructuring the traditional functions of business-sometimes radically. This transformation started with product value chain. As it spreads, functional boundaries are shifting, and new functions are being created [8].

3. The Clothing Industry 4.0- IoF (Internet of Fashion)

[15], made a prediction arguing that in the future, there will be many applications developed to be used on mobile devices, providing apparel companies as well as consumers the opportunity to design, develop, visualize, and purchase apparel products fast. The virtual representations will look real, with virtual collections, dressing rooms, show rooms, etc.

The technologies are becoming more affordable, so that the so-called complex, expensive technologies used by high-tech industries such as aerospace, will be used for consumer products such as apparel. The new generation of consumers will not agree looking at a picture of an apparel product but will look for a virtual dressing room to experience virtual fitting before making a purchase decision. For this, the technological tools will become more available through the web and cloud-based applications on mobile devices. [2] identified nine settings where IoT creates value. Our research singles out two of them:

-) Retail Environments (Spaces where consumers engage in commerce) &
-) Factories (Standardized production environments).

Based on research and interviews, we believe that those are likely to have the greatest potential impact from IoT use. These applications along with modified hardware and operating systems embedded in the products, are series of layers known as a "technology stack" [14]. Smart, connected products require that companies build an entirely new technology infrastructure, consisting of these layers. This technology enables not only rapid product development and operation but the collection, analysis, and sharing of the potentially huge amounts of longitudinal data generated inside and outside the products that has never been available before. Thus IoT has the potential to support Fashion Design, Development and procurement as well as manufacturing but the vast amount of data provided to fashion businesses by IoT aren't still used effectively. We asked the participants if they expect a greater understanding of the value of this data, how to use it and make better decisions and how to pinpoint that data from sensors and connected technology is best utilised.

3.1 Challenges

The IoT offers several new prospects to the industry and end user in many application fields. The IoT needs theory, technology, architecture, and standards that join the virtual world and the real physical world in a merged outline. Some of the impediments to mass rollout of IoT are the following:

- Energy Source
- Education
- Data collection, Protection
- Security and privacy issues
- Standards confusion
- Fragmented supplier base
- Affordability
- Intellectual property
- Availability of the network

Although fashion companies (in their aim to achieve sustainable competitive advantage) embrace best practices across the value chain, they rarely integrate data, solutions, resources and processes from end-to-end. Most IoT data collected are not used, and the data that are used are not fully exploited [2] due to:

- Lack of understanding of the potential to use data
- Technical challenges including finding efficient ways to transmit and store data
- Analysing the data to derive actionable information

Furthermore, most of the IoT applications are focusing in Retail at the moment, according to [9] the explosion of data will affect not customer related things. Companies will have to invest in putting sensors and monitor the health of the manufacturing equipment first; long before start monitoring customer behaviour.

To make IoT data actionable in applications where human judgment is required, takes technical skills and an organization that is prepared to embrace data-driven decision making [2]. This statement, comes in total coincidence with what [12] has presented on the full adaptation of Virtualization technology as an integral part of the fashion product development. It is evident that the fashion industry is undeniably behind in terms of integrating IoT with the fear that IoT will only lead to more data and not necessarily a more comprehensive analysis. However, there are optimistic views that real-time access to supply chain information from fashion companies, as well as insight into the way consumers actually use and interact with their products/creations will be a good motive for the industry to embrace the technology enabling the IoT [7] [6] [9].

3.2 Opportunities of IoF in the design, product development and manufacturing cycle

According to CEO of Cisco [17] only 1% of the world's devices are connected today. This creates an obvious opportunity for those that want to connect all those devices but it's also a great opportunity for a number of new businesses to be created that can help industries derive value from all of the new data that will be available. Product development processes will also need to accommodate more late-stage and post-purchase design changes quickly and efficiently [16]. Smart, connected products also call for product design principles that depart dramatically from tradition [8]. [12] has identified that the implementation of Product Lifecycle Management (PLM) allows successful integration across the fashion enterprise: it is not just a technology, but a strategic business approach that integrates people, processes, business systems and information [18]. Leading companies in return from investing in IoT can orchestrate and collaborate regarding changes in the product development process as opposed to reacting to problems. Moreover, trend data shared with merchandise planning solutions that can use smart analytics and algorithms to predict the next design trends and colours [5]. AI-assisted Design systems can help designers by making more accurate predictions of what designs will work and taking over some of the repetitive tasks. Fashion designers armed with AIs will be able to come up with radical new ideas, amplifying their creativity rather than replace it [19]. Data-driven technology companies like EDITED and Stylumnia provide solutions to help clothing brands to prepare the next

seasons collections based on evaluation of consumer behaviour. Buyers and merchandisers use that information to address gaps in their own assortment, while designers use it to detect trends in their early stages and develop product accordingly.

Embedded computing sensors will not only be found in clothes. Manufacturing equipment capabilities go beyond the production of the physical product; for example, spreaders, cutters and sewing operations could all use IoT to communicate pertinent real-time information providing visibility across the entire product development process and supply chain [6]. According to [2], the major applications of IoT in factories are:

- Operations optimization
- Predictive maintenance
- Inventory optimisation
- Health and safety

Machines increasingly can be linked together in systems tracking feedback on status of products and even the health of the manufacturing equipment. Shop Floor Control Systems help to achieve real-time manufacturing visibility and control by removing traditional infrastructure requirements an adopting IoT technologies for the factory floor. These systems enhanced with tablets which can scan QR codes and feed real-time data into a production management system/ERP, operators can view files, such as PDF's, videos, images that are connected to the item scanned. Data feed also included real-time tracking of WIP and promote Lean or team based manufacturing with a team login versus individual [20] [21].

Benefits for the consumer

IoT technology has the potential to drive down the costs of goods and services. By comparing usage patterns from smart, connected products, companies can gain a sharper picture of product use and provides much finer customer segmentation. Customers of companies that operate IoT systems, ultimately will be the ones to capture the most value in the form of convenience, lower prices, higher quality, better features, improved service and more attractive customised promotions.

Benefits for the companies

Companies that use IoT in novel ways to develop new business models or discover ways to monetize unique IoT data are likely to enjoy more sustainable benefits. To remain competitive, companies would need to master new ways of operating and learn to collaborate closely with technology and data vendors.

Although it all sounds promising and uniquely positioned to disrupt and transform the fashion supply-chain paradigm [5] work still needs to be done in beacons and we need to be mindful or worried about the backlash from consumers; *“consumers may reject this. I think it is a dance we are doing with the consumers, a fine line that we don’t want to cross over too far. It sure is exciting. IoT is the new Mega Trend; it is going to sweep through, it will be rough early on but I think the companies who see the future in this and have the capital to spend their money to update their equipment, they are going to be moving ahead”* [9].

3.3. Opportunities of IoF in retail

Currently, fashion brands and retailers work with a limited amount of data, to predict what products to order and when to discount or replenish them. If they predict wrong, the result is loss of income due to mark-downs, waste and popular items selling out. By analysing large amounts of data (i.e the browsing and shopping history of every single one of a fashion brand’s online customers, as well as those of its competitors) AI and machine learning can tell a retailer how to align product drops to match demand, and even how to display products in a store to sell as many as possible [19]. Machine learning can also enable brands to finely personalise their offerings to each market, or even, each individual customer. Adobe, in a recent study presenting the Retail Stores of the Future [14], pinpoints *Personalisation* as one of the key focus areas. Retailers can use solutions like interactive screens, beacons, geo-conquering and geo-fencing to deliver more personalised content based on customer’s interactions, interests, and location.

RFID chips embedded within products can track product engagement as customers touch and pick-up products. iBeacons as well, an advanced location transmitter that can incorporate alerts for deals and accept mobile payments from customers, can provide big data analytics for businesses. Augmented reality with hand control will allow customers to perform iconic gestures. This development combines AR, hand tracking face recognition and the ability to work in virtual space.

-) Automated checkout
-) Smart CRM
-) Real-time in-store promotions
-) Layout optimisation
-) Inventory shrinkage prevention, are the largest applications in retail environments in potential
-) economic impact of the IoT.

As with other accelerated technologies as 3D virtual visualisation and 3D virtual prototyping, adoption of the above applications remains uneven in the retail industry with larger chains usually leading the way. In order to make economically attractive the IoF, the RFID tags need to become so inexpensive to be used in every single item. Advance is needed in data analytics to take full advantage of the potential to combine IoT data with other data to provide all the prolonged benefits [12].

3.4. Scenarios / Cases for Clothes of the Future

With the IoT any physical product when connected can be:

- more intelligent
- more interactive
- more trackable
- more valuable

An initiative from two companies, Avery Dennison and IoT start-up EVRYTHNG, will create 10 billion apparel and footwear products with unique digital identities and data profiles in the cloud over the next three years [22] [23].

Avery Dennison (a packaging and labelling company that puts label on products for brands like Nike, Adidas, Hugo Boss and Evrythng (IoT platform backed by Cisco and Samsung) is collaborating to digitise world's biggest brands' products by giving each one a unique software identity that connects them to the web. Avery Dennison will attach special labels, sometimes including sensors, to clothes when they're manufactured which function as unique identifiers for each piece of clothing, and the data is stored in a platform developed by Evrythng. Those products from some of the world's biggest fashion and performance apparel and footwear brands will be able to:

- Connect to smartphones to trigger applications and services
- Provide manufacturing history
- Generate real-time data for new applications and direct customer conversations
- Be tracked in real time from factory-to store-to home triggering alerts if they have been diverted or tampered with
- Participate in various after-sales loyalty schemes or recycling programs

4. Conclusion

While the Internet of Things is certainly generating lots of interest and publicity, consumer adoption is not there yet. Forrester reports that only 7% of online adults in the US are using connected home devices, although, more than 50% are interested in using them [24]. It is apparent that the IoT is changing, and the following years are going to be exciting for businesses, analytics and growth. The fashion industry and its consumers need to understand and embrace these changes to capitalise on the benefits of the going interest in connected technology. Furthermore, Business users of IoT technology will need to change their systems and organizations in order to make the most of the Internet of Things. They will need to invest in capabilities, culture, and processes as well as in technology.

Businesses that fail to do so are likely to fall behind competitors that do. Smaller companies will need to find ways to obtain data on the scale required to compete with larger companies that will have

access to sufficient data in-house [2]. As it was presented in subsection 3.1, data privacy and security which for many researchers is the vulnerability of the internet of things, is a topic needed to be squared up to. Real transparency involves managing and interpreting tremendous volumes of extremely granular data, running the gamut from retail intelligence to thread production, and from robotic manufacturing facilities to returns information [2]. The goal of IoT is to provide access to those streams of previously inaccessible data, and then to analyse it, making it accessible via PLM at any stage of the product lifecycle, and using it to inform future design, development, distribution and retail strategies.

For many, the fashion industry remains in the past. The notion of “seasons”, mass manufacturing, mass distribution of goods plus the lack of a new value system are only some of the obstacles preventing traditional fashion companies from evolving [7]. The IoT has the potential to change the dynamics of the supply chain as a whole; forged relationships by companies that share a common attitude to transparency and value. Innovation in production like the smart factories combined with IoT can give consumers the ability to configure or customise their products, and then to monitor them all the way through automated production, altering the way fashion companies plan, create, source and sell their products.

References

- [1] Ding G, Wang L and Wu Q 2013 Big Data Analytics in Future Internet of Things, *National Natural Science Foundation Of China*, pp 1-6
- [2] McKinsey & Company 2015 The Internet of Things: Mapping the Value Beyond the Hype, June 2015, available at <https://www.mckinsey.de/>
- [3] Cyril C, Jimenez M, Mosser S, Riveill M 2014 “An Architecture To Support The Collection Of Big Data In The Internet Of Things,” *IEEE 10Th World Congress On Services*, 2014, pp 442-449
- [4] Dassault Systemes, 2015 How IoT is Changing Human Interaction, video available at: [Internet of Things - Dassault Systèmes](#) retrieved 20/12/2015
- [5] Harrop, M., (2016), WhichPLM: *The Internet of Things- Transforming Fashion*, available at <http://www.whichplm.com/> retrieved 10/03/2016
- [6] Jouriles N 2016 IoT and the fashion industry- Personal Interview (2016, May 10)
- [7] Birnbaum E 2016 IoT and the fashion industry- Personal Interview (2016, June 1)
- [8] Porter E M and Heppelmann J E 2015 How Smart Connected Products Are Transforming Companies *Harvard Business Review* October 2015
- [9] Tiffany R 2016 IoT and the fashion industry- Personal Interview (2016, February 5)
- [10] Aly H, Elmogy M and Bakarar S 2015 Big Data in Internet of Things: Applications, Architecture, Technologies, Techniques, and Future Directions, *International Journal of Computer Science Engineering* **4** No.6 pp 300-313
- [11] Kosaraju R 2016 Internet of things- Keeping the Best Things First, 20/01/2016 available at: <https://www.linkedin.com/pulse/> accessed on 31/01/2016
- [12] Papahristou E 2016 *Effective Integration of 3D virtual prototype in the product development process of the textile/ clothing industry* PhD Thesis, Technical Uni of Crete, School of Product Eng Mng
- [13] Liao J 2016 IoT and the fashion industry- Personal Interview (January, 6)
- [14] Adobe Marketing Cloud 2016 White paper: *Retail Stores of the Future: four key focus areas for building them today*, available at: adobe.com accessed 10/06/2016
- [15] Senanayake M 2015 Product Development in the apparel industry, pp 21-57, *Garment Manufacturing Technology* A volume in Woodhead Publishing Series in Textiles
- [16] Porter E M and Heppelmann J E 2014 How Smart Connected Products Are Transforming Competition, *Harvard Business Review*, November 2014
- [17] Howarth P 2014 To the Point on the industrial IoT- Cisco, in the *Industrial Internet of Things Report*, McRock Capital
- [18] d’Avolio, E., Bandinelli, R., Rinaldi, R., How product development can be improved in fast

- fashion industry: An Italian case in Product Lifecycle Management in the Era of Internet of Things, *12th IFIP WG 5.1 International Conference, PLM 2015* Doha, Qatar, October 19-21, 2015 Bouras A, Eynard B, Foufou S and Thoben K.D (Editors), Springer pp 718-737
- [19] Abnett K 2016 Is fashion ready for the AI Revolution?, *Business of Fashion*, April 7th 2016 available at [/is-fashion-ready-for-the-ai-revolution?](#) accessed 07/04/2016
- [20] Simparel 2015 White Paper The Fashion ERP Software Landscape - Future Trends available at: <http://www.simparel.com/resources/apparel-software-white-papers>
- [21] Hanson L 2016 Texprocess 2016: *Tex +Tech = An Industry at a Crossroad*, 24th May 2016 available at: <http://www.whichplm.com/> accessed 25/05/2016
- [22] Meyer D 2016 Exclusive: Internet of Clothing is coming through huge label deal *Fortune* April 18, 2016 available at <http://fortune.com/2016/04/18/evrythng-avery-dennison/>
- [23] Wong I J, 2016 Coming soon: The internet of clothes, *Quartz*, April 18th 2016, available at <http://qz.com/664059/coming-soon-the-internet-of-clothes/>
- [24] Doyle A S, Moore M C, and Morgan L 2006, Supplier management in Fast Moving Fashion Retailing, *Journal of Fashion Marketing and Management* **10** No.3 pp 272-281
- [25] Hanson B 2016 Redefining the Product LifeCycle: Application of IoT in Production in *The WhichPLM report- 6th edition, The Internet of Things Issue* pp 40-52