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LEVERAGING ON THE DIGITAL TWIN FOR IMPROVING RETAIL STORE DAILY OPERATIONS MANAGEMENT

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ABSTRACT
With the fast development of IoT technologies and the potential of real-time data gathering, allowing decision makers to take advantage of real-time visibility on their processes, the rise of Digital Twins (DT) has attracted several research interests. DT are among the highest technological trends for the near future and their evolution is expected to transform the face of several industries and applications and opens the door to a huge number of possibilities. However, DT concept application remains at a cradle stage and it is mainly restricted to the manufacturing sector. In fact, its true potential will be revealed in many other sectors. In this research paper, we aim to propose a DT prototype for in-store daily operations management and test its impact on daily operations management performances. More specifically, for this specific research work, we focus the impact analysis of DT in the fitting rooms' area.

Keywords: Simulation, RFID Technology, IoT, Retail, Digital Twin in organization

1. INTRODUCTION
As the vision of the Internet of Things (IoT) is progressively becoming a reality, the worldwide number of connected devices is expected to increase and reach 125 billion by 2030 (IHS 2017). The idea that any object can be equipped with technology to become a computing device, interacting autonomously, in real time, with its environment is happening in various sectors. Accordingly (Bain & Company 2018) suggests that the combined markets of the IoT (i.e., hardware, software, systems integration and services) will grow to about $520 billion by 2021, more than double of $235 billion spent in 2017. In line with this emerging trend, the concept of Digital Twin (DT) has been brought to the scientific community at the beginning of this millennium by Michael Grieves and lately formally described in (Grieves and al. 2017). The idea underlying a DT is that each object, process or system can be replicated by a digital representation (Gartner 2019a), therefore creating two similar systems (twins) connected by a permanent real-time data exchange. The physical system produces operational data captured in real time by using technologies such as Internet of Things (IoT) technologies. This information is stored in a database that, depending on the stage and structure of the digital twin, processes it and then feeds a simulation model that replicates or mimics physical system operations in real time. Then, several runs of simulation scenarios allow a decision maker to adjust physical system parameters as well as operational rules to improve the efficiency and effectiveness of the physical system.
The advent of Internet of Things (IoT) technologies has largely contributed to the development of DT and their application show a great potential for operations management in different sectors (Gartner 2019a). However, the development and use of DT is still at its cradle stage with limited fields of applications. Moreover, it is interesting to note that DT is and will be among the strongest technological trends rising in the near future. Additionally, the application of DT concept won't be limited to the manufacturing sector anymore and will quickly take off to be deployed in a wide range of sectors as healthcare operations management and organizations management. In fact, in a recent survey from Gartner Research (2019b), the authors suggested that "the digital tweens are entering mainstream" in all kinds of organizations, as an increasing number of companies that have implemented IoT will have deployed a DT in the next year. It is in this vein that we focus our research project and suggest a DT framework for daily retail operations management.
Moreover, The Internet of Things (IoT) is attracting growing interest in the apparel retail sector. With the help of (IoT) technologies, retailers can now take advantage of new possibilities offered by various automatic data capture technologies such as Radio Frequency Identification (RFID) for item identification and tracking or Bluetooth Low Energy (BLE) technologies, for tracking consumers within stores. Implementing these technologies provides real-time visibility into customer behaviour and in-store items movements; enabling retailers improve the performance of store operations management.
In this research work, we aim to develop a DT framework for apparel retail store daily operations management. We first determine the appropriate technologies that can be

implemented at different levels of the store. Second, we develop a discrete event simulation model to represent daily store operations. Third we capture the store data through a physical prototype existing in our living IoT Lab. Finally, we run several scenarios and analyze them to improve our understanding of in store operations management performances.

The remainder of this paper is organized as follows: In **section 2**, we explore the existing literature regarding: i) RFID/IoT technologies application in retail, ii) modelling retail store operations and iii) applications of DT concept. **Section 3** describes the design science research approach followed to investigate the business case of applying a DT in a retail environment. We first, describe the problem from the field and the objectives of our DT model. This is followed by the design and development of our DT prototype aiming to (a) capture real-time customers' and products movements in a store (b) run a simulation model that replicates daily operations (c) automatically integrate collected RFID/IoT data to the simulation model (c) analyze this data to improve daily store operations management. **In sections 4 and 5** we share the expected outcomes of our DT model, present concluding remarks and future work.

2. LITERATURE REVIEW

This section is dedicated to the following fields literature review: i) RFID/IoT technology in retail; ii) RFID/IoT suitable solutions for in store daily operations management; iii) modelling retail operations, in particular those related to data analysis approaches & simulation studies; iv) finally digital twin concept and its applications fields.

2.1. RFID/IoT Technology

In recent years, among the technological solutions proposed to increase operations efficiency of apparel retailers', retailers chose to rely on automatic data capture technologies such as (i) radio frequency identification (RFID) technologies, for products; (ii) Bluetooth Low Energy (BLE) and Wifi technologies for in-store customer's tracking, through the use of their mobile phone or smart watch (Zaino, 2016). The gained interest in these technologies can be easily explained through the motivation of remaining competitive (Roberti 2018) by using real-time information to: (a) improve the customer experience (e.g., interactive journey) and (b) improve operations management performance (e.g., reduce operating costs, improve inventory management). Today we find more and more implementations of "connected stores", especially in the consumer sector, including the most publicized: Amazon Go and its promise of "no lines, no checkouts, and no registers" that was finally opened to the public in Seattle in January 2018 (Deirdre, 2018).

2.2. RFID/IoT Suitable Solutions for in Store Daily Operations Management

More specifically, in the retail/apparel sector, a recent study by Zebra (2017) has shown a very strong trend in the adoption of IoT technologies. Indeed, 73% of surveyed managers confirm that they are ready to adopt IoT solutions by 2021. This trend is similar to the trend of embracing data analysis solutions captured by IoT devices, with nearly 60% of managers planning a budget for acquiring such solutions.

Regarding RFID technologies, Zaino (2016) brought a similar conclusion suggesting that: «major retailers in Europe, North America and South America are embracing the technology to track and manage apparel and footwear, in order to improve inventory accuracy and provide customers with an omnichannel «anytime, anywhere shopping experience». Indeed, since the first RFID initiatives in the retail sector such as Walmart, Gerry weber, Macys, Zara, Decatlon, Celio, Scalpers, Marks & Spencer, and Kaufhof are leaning towards such technologies to identify customer preferences and customer behaviour. Numerous business cases can be found in the web site of (RFID Journal).

However, if the implantations of IoT / RFID technologies are increasing in recent years, their application is limited to basic operations management processes (e.g., inventory management, shelve replenishment) or used for marketing purposes (e.g., real-time advertising). Therefore, we still do not have a comprehensive analysis or study on the impact of RFID/IoT technologies on the floor space utilization and fitting room utilization. This is especially important, since fitting room are a classic bottleneck as well as a privilege space to interact with the consumer and understand its preferences.

2.3. Modelling Retail Store Operations

Most of the research work related to simulation in the retail is dedicated to modelling supply chain operations. Some studies relate to in-store operations management. Among them: Miwa et al. (2008) provide a very interesting study where data used for building in-store operations' simulation model is gathered through point of sales system. They use a discrete-event simulation model built with Arena. They assume that point-of-sale data is gathered every day and derive store performance measures using simulation outputs. It is interesting to note that even though point-of-sale gathered data can provide interesting information regarding the number of customers purchased items, checkout queue statistics, they miss a part of crucial information related to customers' in-store experience and behaviours. Wang Huiru et al. (2018) present an agent-based simulation model to represent wine consumers' behaviour and understand customers' motivation to select a specific wine among different wine brands. Shandong et al. (2018) provide a thorough literature review on retail store operations and identifies five main axes attracting research attention and activities: demand forecasting, inventory management, assortment and display, employee management and checkout of operations. One interesting concluding remarks of this research work is that research studies that deal with multiple store operations decisions, multiple themes and multiple products are rare. Moreover, traffic counters and real-time data are not efficiently used and open the door to several research opportunities. Tsai et al. (2015) provide a research work related to ours in which they study the impact of real-time analytics on checkouts, shelf replenishment and shelf allocation. They use a data mining approach to optimize shelf space allocation, taking into account customers' purchase and moving behaviours. Finally, Nervo and al. (2019) study the impact of RFID technology on retail operations and use a system dynamics simulation approach to assess the economic impact of item-level RFID technology on retail. They show that RFID technology can be used as a competitive advantage driver.

2.4. Digital Twin

Although the concept of digital twin is still at an infant stage, the literature shows several research papers revealing different terminologies used for describing the digital twin and suggest several definitions. However, the basic concept remains the same (Grieves and al. 2017). Werner Kritzniger et al. (2018) conducts a comprehensive literature review and classification of digital twin in manufacturing according to their level of integration. They provide three subcategories of DT, according to their level of data integration: (i) Digital Model where there is no automatic data exchange between the physical system and the digital system. The transfer of data is manually handled (ii) Digital Shadow, where there is an automatic data flow exchange from the physical system to its digital representation, but a manual data exchange from the digital system to the physical system (iii) finally, the digital twin, where automatic data exchange is in both directions. It is interesting to note that according to their study, only 18% of the studied papers really describe a digital twin and only one case study was implemented in a laboratory environment. Recently, Yu Zheng et al. (2019) changed this statistic by providing an application framework of DT and its case study, but still applied in manufacturing. Therefore, there is a significant amount of research opportunities related to digital twin conception and application in various sectors of the industry. In this research work, we propose to develop a digital twin prototype for organization suitable for in-store operations daily management. Moreover, with the help of the digital twin, we propose to take up the challenge discussed in subsection 2.2, namely, considering multiple store operations decisions, addressing multiple themes and multiple products.

3. RESEARCH APPROACH FOR BUILDING IN-STORE DIGITAL TWIN BUSINESS CASE

For this project we followed a Design Science Research (DSR) approach (Peffers, *et al.*, 2007). According to the scope of this paper, we focused on phases 1-4 of the DSR methodology presented in **Figure 1**.

3.1. Identify Problem/Opportunity From The Field

Phase 1: In today's retail's operations, a vast majority of retailers analyze in-store buying behaviours by making use of the point-of-sale (POS) system data. They gather information like (a) the number of buyers, (b) the number of purchased items by transaction, (c) the products most demanded, etc. Even though, a large amount of data can be captured from this end, retailers have no real visibility on what truly happens in stores. As an example, they have no knowledge on (i) what items are being tried in a fitting room (ii) among these items, which ones are purchased (iii) which items customers interact the most with (iv) in which fitting rooms (v) what is the utilization rates of each fitting room, etc. There is hence a huge unexploited potential for leveraging on products and consumer behaviours to help managers improve their operations and their in-store customer experience.

3.2. Defining the Objective of Our DT Store Prototype

Phase 2: To track in-store products and customers' behaviours, and more specifically in fitting rooms areas, the objective of the research is to build a DT prototype and assess its impacts on operations.

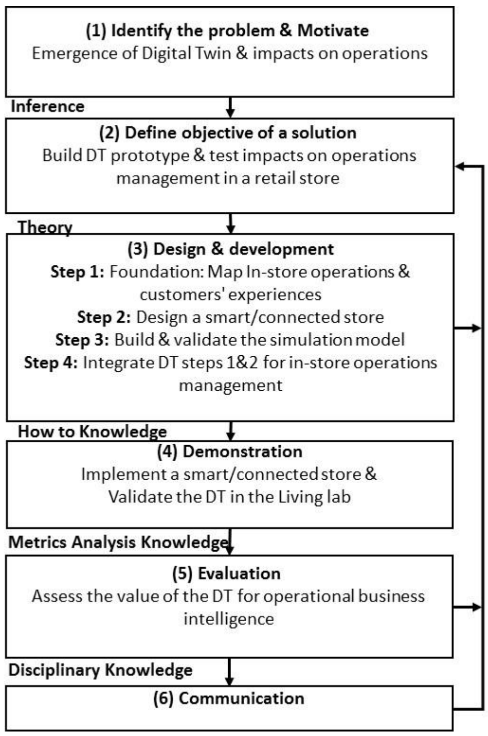

Figure 1: Research approach for building our case

3.3. Design & Development of the DT

Phase 3: The Design & development of the DT is structured in four steps. **The first step** is to map in-store daily operations to formalize customers' behaviours as illustrated in **Figure 2**. Information was gathered from a store in a fashion Canadian retail chain that includes 15 stores throughout Canada.

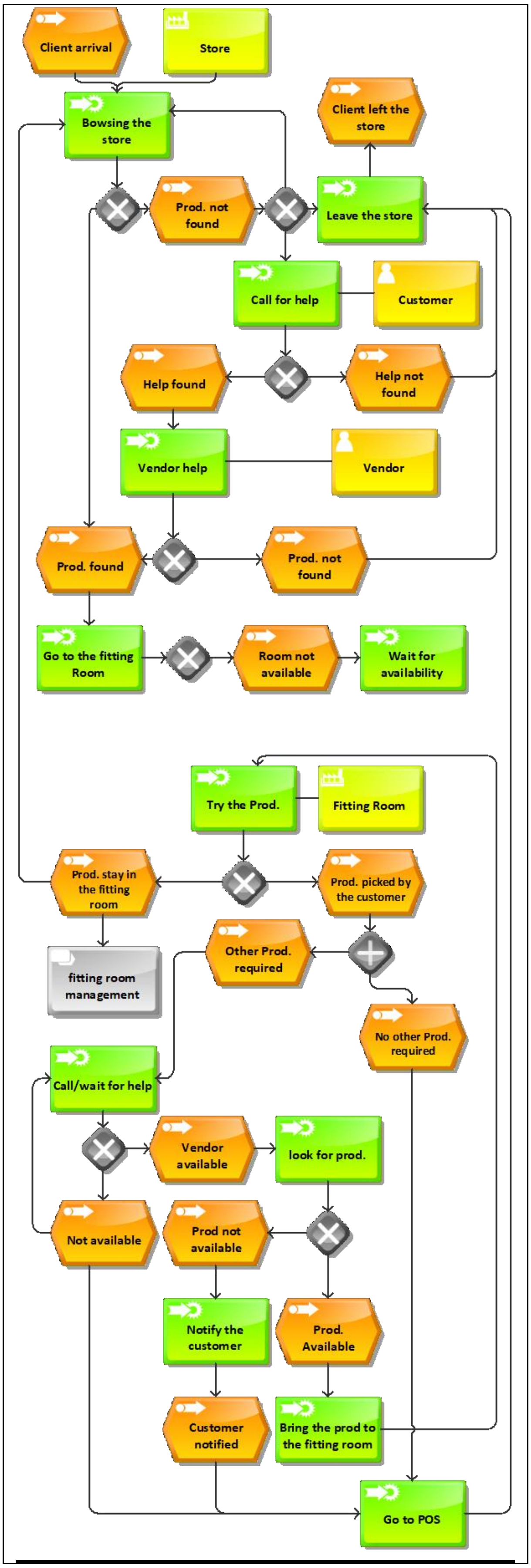

Figure 2: In-store operations map

The second step was to design our smart/connected prototype store. To track in-store customers' behaviours, we first selected suitable RFID/IoT technologies (i) to capture data related to items picked by the customer (i.e., passive UHF RFID technology) and (ii) to capture data related to the identification and tracking of the customers in the store (i.e., Bluetooth Low Energy-BLE). In order to leverage on previous research settings, our prototype was developed at the Montreal-based *IoT lab*, where various RFID and BLE technologies are available and were used for previous research in retail settings (Bendavid et al., 2018).

The third step consisted of building a comprehensive discrete-event simulation model for store daily operations and customer behaviours. The building of the model was done by taking in consideration criteria's such as uncertain customers' arrivals, service times and most interesting, uncertain customers' behaviour in fitting rooms. The simulation model was built using Arena software 15.0 by Rockwell automation. **Figure 3** displays the main view of this model.

Once the physical data capture infrastructure was designed, and the simulation model verified and validated, we therefore had to develop a first comprehensive DT prototype for store operations management by integrating phase 3's steps 2 & 3.
This integration represents **the fourth** and last step of phase 3. It is accomplished by: (i) integrating IoT captured data into a MySQL database through a Java software application (a detailed description of this part can be found in (Bendavid et al., 2018), (ii) perform statistical analysis through a python software application (iii) derive fitted distributions that are read from the Arena Model**.**
Figure 4 displays a sample of captured data analysis. One can see the distributions that are automatically fitted as soon as the python script is launched and then read by the Arena model through an Excel file at the beginning of the simulation.

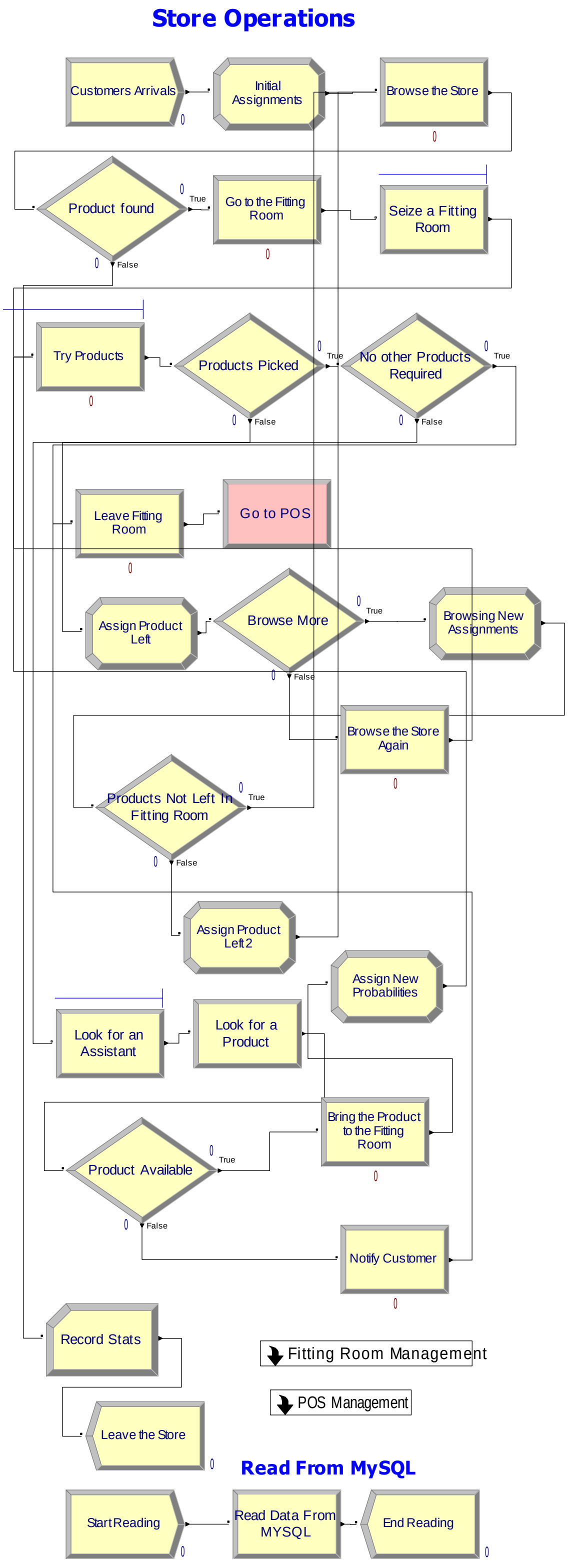

Figure 3: Arena simulation model for store daily operations

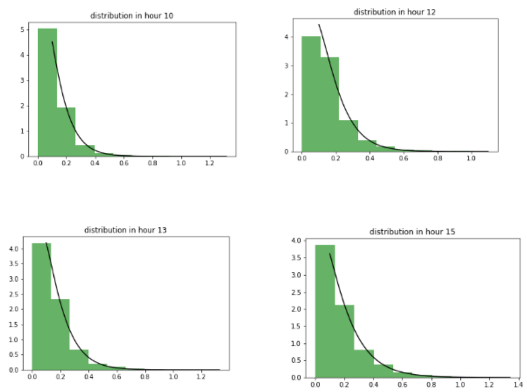

Figure 4: A sample of real time captured data analysis.

3.4. Demonstration

We are presently conducting phase 4 of this research project.

Phase 4: consisted of implementing a smart/connected store prototype at the *GreenUX lab* which is a close representation of a retail store, and validate the feasibility of the DT in this Living Lab. (i.e., the store). Beyond the choice of selecting appropriate RFID/IOT technologies to identify and capture data, specific locations were identified as "reading zones" for real-time items and customers identification.

To identify and capture customer-related data, BLE technologies (solution from *reelyActive*) were selected and implemented in three main locations (i.e., entrance, main store, fitting room). **Figure 5** presents how BLE technologies are used to locate customers within preconfigured specific zones within the store (with a radius of 3-4 meters). Hence, customers arriving at our "store" can be automatically detected using their BLE device (e.g., cell phone). As they move from zone to zone, their data is also captured by three receivers, with few seconds of latency.

Cameras already installed in the store can also be used to gather customers' movements, understand their behaviours and experiences. We plan to integrate them in a further phase of the project. Presently they allow us to capture sequences and review them afterward for analysis purposes.

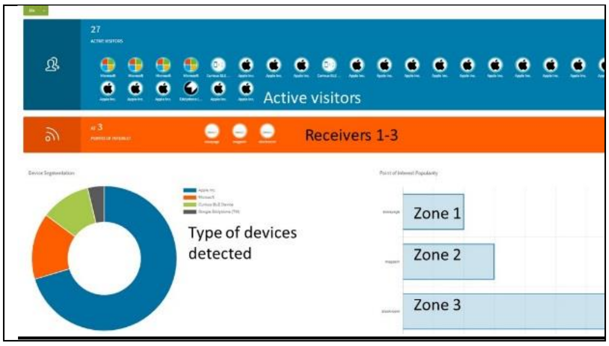

Figure 5: Using BLE to locate customers.

On the other hand, item data capture (identification and tracking) is done using fixed readers/antennas installed on the ceiling of the store. The system acts as a passive RTLS (Real-time location System) used for wide coverage. Technologies from *Impinj (xArray)* were used to demonstrate the feasibility of item tracking in three zones (i.e., back store, main store, fitting room). (**Figure 6.a)**. Items are automatically detected within one-two feet precision, and their movements can be followed in real time, contributing to the operationalization of a DT prototype.

Since the analysis of fitting rooms is important, within the scope of this study, we implemented a dedicated reader/antenna to increase the accuracy of the reads and the precision of location of data captured in this specific choke point. RFID readers detect items that are removed from the shelves and brought to other areas of the store. Once customers enter fitting rooms, RFID enabled *smart mirrors* equipped with RFID recognize items brought to and can display products' information as well as additional information, enabling customers to see other available sizes and colours (**Figure 6.b)**.

If a customer leaves the fitting room area without taking back the tried items, a store employee is informed through the system that an item has been left in the fitting room. This event triggers a request to pick up the items left in the fitting room and put them back on the shelves (**Figure 6.c)**.

Since the data is automatically captured from the daily operations in the store, the analysis of this data is continuously running, therefore generating new probability distributions and feeding the simulation model. By continuously generating updated data, this allows our DT to integrate new distributions fittings. Therefore, once the simulation scenarios are run, appropriate adjustments of operations management rules as well as policies are evaluated by the decision maker in order to improve store operations management performance.

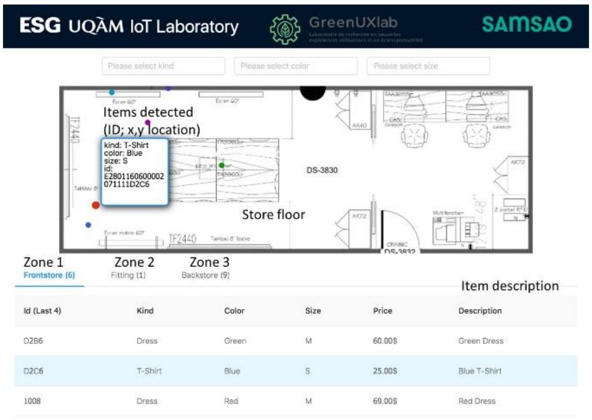

Figure 6. a. Real-time tracking of items in the store

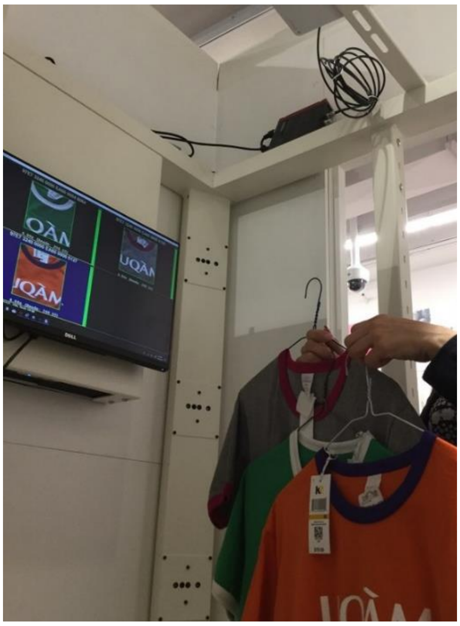

Figure 6. b. Real-time detection of items in the fitting room

Figure 6. c. Real-time visibility of fitting rooms by employees

<u>Figure 6</u>: Real-time visibility in the store

The next phase aiming at assessing the value of the DT for operational business intelligence is then planned with great expected outcomes for real-time decision-making.

4. EXPECTED OUTCOMES

In this research, we expect to show that the building of the proposed DT for the retail store will provide us with a huge amount of information to support real-time decision-making. **Figure 7** summarizes the envisioned work and fittingly proposes a high-level systemic view of the required components to design and build a DT.

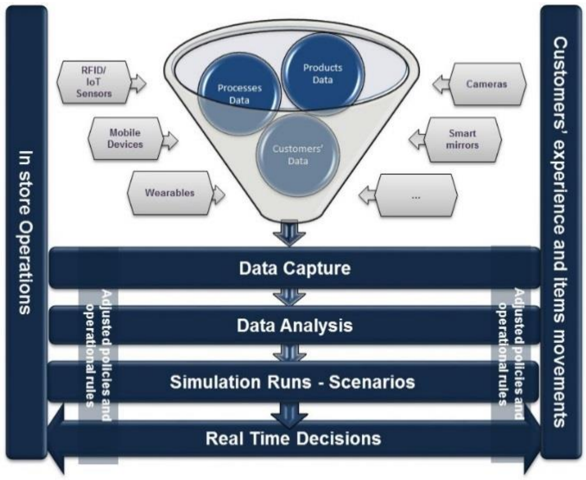

Figure 7: Integrating IoT Technologies to Simulation Modelling – a DT for Store Operations Management.

Since a retail store is a complex system, we decided to focus on the fitting room as a starting point to evaluate realistically the performance of the DT. The choice of focusing on fitting rooms areas is justified by the high potential for improvements. Indeed, as we know:

i. on average, only 1/3 of the customers that browse in the store will use a fitting room. This is explained by the fact that these fitting rooms are not properly located, or due to insufficient staff scheduling to assist customers or simply because they are always full when a customer wants to use them.
ii. Moreover, around 3/4 of customers that use a fitting room will purchase an item.

Therefore, it is obvious that one of the expected impacts of our DT utilization in this case is to make a better usage of these fitting rooms and consequently increase the number of customers that make a purchase. In our future research work, we would like to:

- Provide the real-time number of in-store customers and adjust staffing decisions consequently;
- Gather fitting room information to inform customers about rooms' availability and hence improve fitting room utilization rate;
- Increase the percentage of customers that browse the store and decide to use a fitting room;
- Increase customers' satisfaction by providing personalized support in the fitting room;
- Re-evaluate items on shelves after considering most tried/purchased vs. tried/not purchased items (i.e., items and customer behaviours);
- Identify and relocate forgotten items in fitting rooms.

5. CONCLUSION

The fast development of IoT technologies and their applications have raised a huge research interest in various sectors, among which the retail sector is positioned as an early adopter. While the real potential of such technologies and applications is being progressively revealed, this has given the rise of the DT concept and the idea that any object, process or system could be replicated by a digital representation with the objective to understand it, respond to changes and improves operations – i.e., add value (Gartner, 2019b).

Although the idea is interesting, putting it into practice by moving from the concept to the prototype of the DT is much more complex. Hence, in this research, besides presenting a digital twin prototype for in-store retail operations daily management, the main contribution is the operationalization of the main steps, and the main technologies required to build such as DT prototype. The work was conducted in the IoT lab and the GreenUX lab at ESG-UQÀM where some of the latest IoT technologies can be found.

The proposed DT in a retail environment is a first of a kind and constitutes a powerful tool to help organizations' managers to adjust their operational decisions on a regular basis. For instance, we explained how the implementation of a DT in a store can significantly improve fitting rooms' utilization, increase customer satisfaction, provide with a better staff scheduling and customer handling in fitting rooms.

The next step of this research is to run the prototype in a real in-store environment – i.e., in one selected store, to evaluate its real potential and most likely adjust some of the integrated applications.

Finally, this work highlighted some technical difficulties:

i. Firstly, from a data quality perspective, RFID and BLE data need to be extensively processed to provide accurate information and automatically feed the simulation model.
ii. Secondly, from a simulation modelling perspective, the automatization of fitting distribution still needs to be slightly improved, mainly regarding the choice of intervals to be considered in an operational day.

In our next generation of DT prototype for retail, we plan to (a) keep BLE as a preferred technology to identify customers and explore the opportunities of face recognition technologies to improve the accuracy of identification (b) use the latest passive RTLS technologies proposed by *RF Controls* (CS-445 antennas) to have a 3D visualization of items' location and movement. (c) run several simulation scenarios related to different retail stores in order to validate the robustness of our DT prototype.

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