Internet of Things for a sustainable food packaging ecosystem insights from a business perspective

Michail J. Beliatis
Dept. of Business Development and Technology
Aarhus University, Denmark
ORCID: 0000-0002-7902-6144

Nipaporn Lohacharoenvanich
Dept. of Business Development and Technology
Aarhus University, Denmark
nipaporn.lo@gmail.com

Annabeth A. Aagaard
Dept. of Business Development and Technology
Aarhus University, Denmark
aaa@btech.au.dk

Karthikeya S. Acharya
Dept. of Business Development and Technology
Aarhus University, Denmark
ksacharya@btech.au.dk

Mirko A. Presser
Dept. of Business Development and Technology
Aarhus University, Denmark
mirko.presser@btech.au.dk

***Abstract*—Managing waste in a sustainable way is a challenge in our symbiotic society. This study focuses on developing a sustainable solution for the waste management of disposable food packaging. For the proposed solution, the designed model is an amalgam of the Internet of Things technologies together with alternative methodologies for managing in a sustainable manner the disposable food containers. Meanwhile, the solution promotes the development of localized socio-economic ecosystems for a circular economy. A blueprint has been developed based on systematic analysis of the acquired qualitative and quantitative data in addition to a pilot run in the city of Uppsala, Sweden for verifying its viability. It is found that the proposed model although tested on small scale is feasible upon consideration of the local society's habitual gestures and peculiarities.**

Keywords— sustainable cities, reusable food packaging, Internet of Things, business model innovation, value creation, ecosystem

I. Introduction

The paper is divided in four sections, the first section describes the problem of accumulative waste coming from food packaging and our motivations to carry out this case study in relation to usage of IoT digitalization technologies and business models innovation (BMI) methodologies. This can lead to the development of potential businesses while it facilitates the solution to the problem to some extent and also assesses the socio-economic impact to a degree. In section two the methodologies, which were used in this study are described in order for conducting the survey and for testing the developed model with citizens in Uppsala city, Sweden. Section three, elaborates on the IoT technological solutions and the architecture of the developed platform to empower the recycling and tracking of reusable plastic food containers. Emphasis is given on the findings from the users' survey about demographics, the pilot deployment for testing out the minimum viable platform (MVP) and for business model innovation. The fourth section concludes with key recommendations on the business viability in a global scale and improvements for future scaling up scenarios both for the technological and business aspects.

A. Motivations

Climate change, waste and pollution are environmental problems, which have been discussed for decades, while sustainability has become a hot topic to cope with the problems in the long term. Additionally after the announcement of United Nation's Sustainable Development Goals (SDGs), more and more companies and societies are taking proactive steps towards developing sustainable solutions. Food is one of the human basic needs. Nowadays consumer behavior has changed towards easy and fast consumable food. Takeaway food is one of the popular options. However, it generates a huge amount of disposable waste every day. The replacement materials of disposable food packaging does not exist yet. Meanwhile, recycling is not the best solution based on the waste hierarchy [15]. Hence the motivation for this study is to enable the higher steps of the hierarchy, which is reuse. This is enabled with the utilization of Internet of Things (IoT) technologies for improving the efficiency of the process, and establishment of a cloud based credits ecosystem to meet the local community requirements. Although there are some existing reuse programs, they are either in closed systems like within universities and hospitals or they are businesses which rely on the awareness of consumers, like the example of GoBox. This project aims to validate the reuse concept for food containers/packages in Uppsala, Sweden, as a first step on establishing a solid business case for IoT smart packaging concept to be used in Scandinavian society.

B. IoT technologies

The terms of technology and innovation are often discussed together nowadays. The path of innovation through the centuries is complicated [1]. Benoit Godin, a Canadian historian, has researched on the history of how innovation is framed. He found that the previous terms were imitation and invention. Innovation began to associate with science and industry in the nineteenth century during the industrial revolution but focusing on technical invention[1]. There are many technology innovations, which have created a change in our life such as 3D printing, Internet, transportation etc. Internet counts as an important innovation from the past few decades. However, the economic gains from the Internet will come from the applications that have yet to be developed [1] such as IoT and digital servitization.

IoT has been a hot topic for many years. The concept of IoT was not officially named until 1999 by Kevin Ashton, who is credited by most sources as the person who coined the concept [2] [3]. His idea of IoT was originally focused on using radio frequency identification (RFID) technology to connect devices together, while today's IoT relies on IP networking to let devices exchange information [3]. IoT is a broad term referring to the global network interconnecting smart object by extended Internet technologies supporting RFIDs, near field communication (NFC) tags, sensors, actuators, microcontrollers etc. In addition, it is a set of applications and services, which influenced by technologies such as mobile phone and cloud computing, opens new business and market opportunities [4]. As RFID was the start point of IoT, wireless sensor networks (WSNs) are another foundational technology for IoT, which mainly use interconnected intelligent sensors to sense and monitor [5]. The advance of both RFID and WSN significantly contribute to the development of IoT [5].

Nowadays, the phone has become a necessary item in our lives. Perhaps no other device in history has embedded itself so successfully in the lives of everyday consumers than the smartphone [6]. Smart phones commercially launched from Ericsson, Nokia, Blackberry, etc. The initial launch of mobile phones were primarily aimed at business people until Apple launched the first iPhone in 2007 aiming at the everyday user [6]. This has become the smartphone revolution and a turning point for the market [6]. The innovation by mobile phone has gone beyond than what pioneers expected. It has become a handy tool for people to create and innovate a new way of life.

In order to connect products with the users of mobile phones, there are a number of widely used technologies such as RFID, NFC, barcode, QR code etc. Each technology has different advantages, limitations and hardware/software. QR code is a cheap and easy to interface technology just with the camera of smart phone. QR or Quick Response code was developed in 1994 by the Denso Wave Corporation, a subsidiary of Toyota [7]. Although QR codes were originally used for tracking parts in automotive manufacturing they have been widely used in other areas such as commercial tracking, entertainment, in-store products and any application, which aims at smartphone users [8]. In this study to enable an IoT based reusable food containers ecosystem, mobiles phones equipped with an in house developed application were used. The mobile phone application enables the reading of QR codes for the purchase of food containers and stimulates the ecosystem by means of generated redeemable credits, where they are used to reward the users of reusable food packaging.

II. Methodology

The combination of two distinct methodologies were involved in this study. The first is based on the three cycles methodology [9], while the second on the Six Sigma industry driven methodology for eliminating defects. The design cycle of the three cycles methodology is the core cycle which is based on rapid iterations between design and evaluation of the artifact. This cycle runs based on the inputs of both the relevance cycle and the rigor cycle. The requirements and feedback of the field testing are from the relevance cycle to evaluate and improve the artifact. Meanwhile, the design and evaluation theories/knowledge/experiences are from the rigor cycle [9]. The design cycle iterates more times until it generates the required output for the relevance cycle and the rigor cycle. Six Sigma uses a five step problem solving approach called DMAIC; Define, Measure, Analyze, Improve and Control [10]. DMAIC is widely used in quality and process improvement. Parts of both these methodologies have been applied in this research design, as shown in the Figure 1. The middle flow diagram demonstrates the process steps in this study. Meanwhile, both left and right sides are aligned with the aforementioned methodologies.

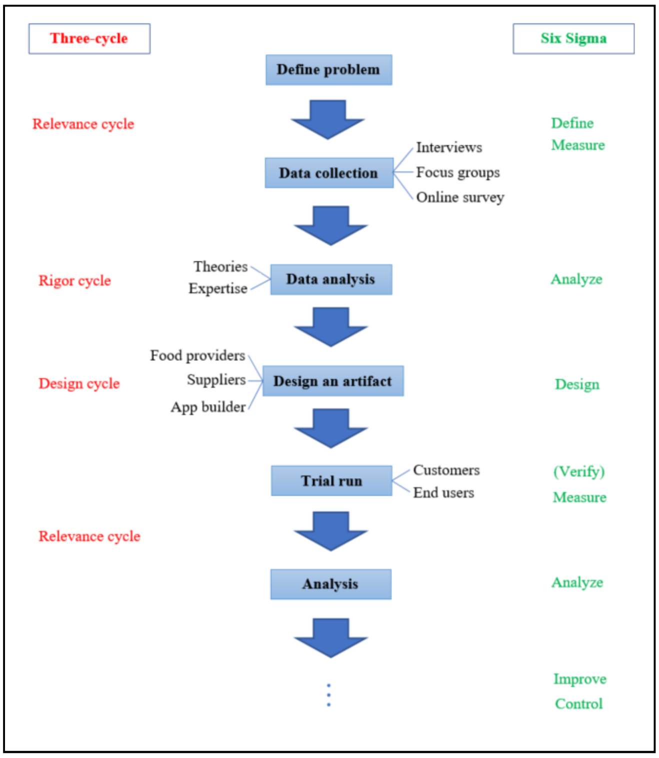

Fig. 1. Flow diagram of overall research design for this study

For the implementation of proposed methodology, the background problems have been investigated and the problem statement is defined in the first step. This is considered as a part of Define phase in Six Sigma. The consumer behavior of takeaway food was collected via contacted interviews, focus groups and an online survey. This can be considered as the measure phase in Six Sigma. However, these two steps are not clearly separated and both steps are in relevance cycle within the Three-cycle view, which receives the requirements from environment. After completion of the data collection, analysis was undertaken using relevant contemporary theories and the expertise, to define the root cause of the problem. Consequently, these steps were carried out to design the IoT based prototype in the next step. This step in the Analysis phase in Six Sigma can be considered as the Rigor cycle. During the design of the artifact, food providers, suppliers and mobile application builders enabled a functional ecosystem for the trial run. The mobile application was developed, and the food containers were sourced and ordered in this phase. Furthermore, a food provider agreed to participate for the trial run. This scheme can be considered as the design step for both Six Sigma (DFSS) and the Three-cycle view. The field trial test was conducted and the acquired data analyzed as part of the relevance cycle of Three-cycle. For DFSS, this step of DMADV; Define, Measure, Analyze, Design and Verify [11] is normally the verification phase but in this study, it could be considered as a phase where feedback from both customer (food provider) and end users (customers of food provider) were collected. Hence the outcomes of the trial are considered as the analysis phase for DFSS, as DMAD-MAIC (Define, Measure, Analyze, Design-Measure, Analyze, Improve and Control) [12]. However, since this study was time bound, the phase of Improve and Control were not implemented. Ultimately, the research design was planned and each milestone was broken down to activities with their individual time schedules. The total time for the study was limited to 19 weeks.

III. Pilot Study, Findings and Discussions

There are numerous critical environmental problems that need urgent action. Controlling waste and pollution are one of them. However, it is not a problem for one person, one company and/or one country to solve. Finding valid and sustainable solutions will require multiple stakeholders and engaging with multiple ecosystems. The takeaway food business as an ecosystem in its own right is growing. An outcome of this growth, is that disposable waste, which is inseparable from takeaway food also gets produced, increasing every day. While it is not possible to erase the convenience of takeaway food, it is more realistic to address the issue in a more sustainable. Towards such an attempt this study aligns with waste management on EU's waste hierarchy. Where it tends to move the stage up from disposal to reuse instead of focusing what materials to be disposed. This study aims to find a holistic alternative, while taking specific steps to implement small change raising the awareness level at a local level of a Nordic city of Uppsala in Sweden. Thus, the following research questions emerge:

- How can the return system of reusable food containers be applied in Sweden and the Nordic life style?
- How can IoT technology assist in finding solutions and what suits the behaviors of consumers using reusable food containers?
- How can this sustainable project be developed into a sustainable business model?

In order to get appropriate answers and verify similar concepts of food package return systems (PRS) such as the US based GoBox or Togo program in Sweden or what has to be adjusted to improve the IoT PRS for Scandinavian countries, an empirical trial study was conducted at the city of Uppsala in Sweden. The return system is based on an easy return concept. The food providers offer an option of reusable and returnable food packages instead of the disposable one to their customers who are the members. The customers can easily confirm their validity to use them by showing the confirmation message on the mobile application. When the customers finish their food, they can look for the return stations wherever they are to drop off the food packages.

A. Data collection

Uppsala is a student city, hence the process of data collection was planned to balance the background of interviewees. The data was collected from Uppsala municipality office and people from around city center by interviews, focus groups and online survey. The qualitative data was collected by interviewing the consumers in the focus groups and individuals. The questions led the interviewees to discuss about their behaviors of take away food practices and how they see the disposable food container as a problem. In total 150 people responded for the online survey. Most interviewees either avoided or were careful to answer questions regarding the environmental issue. This could be interpreted that they already knew the problem very well and felt guilty, but still continued doing it despite knowing the harmful effects on the environment. In the focus group, the participants expressed themselves and agreed more when others in the group started to give their opinions. However, the interviewees who came from other countries had different background based on the cultures they came from. If they are from the countries where the waste management was stricter and more serious, they tended to keep their habits despite their move geographically to Sweden.

B. Customer behavior

The collected data on consumers' behavior revealed the following trends. More than half of the respondents or 119 respondents which represents 79 percent, buy maximum a few times per month. The most famous places to purchase takeaway meals in Uppsala are the takeaway shops for food such as pizza, kebab, etc. 71 respondents scored for these places amongst 237 answers representing 30 percent. Fast food shops were only a bit lower than take away shops representing 28 percent. While food trucks had the lowest score with only 7 percent of people buying take away food from them (see Figure 2).

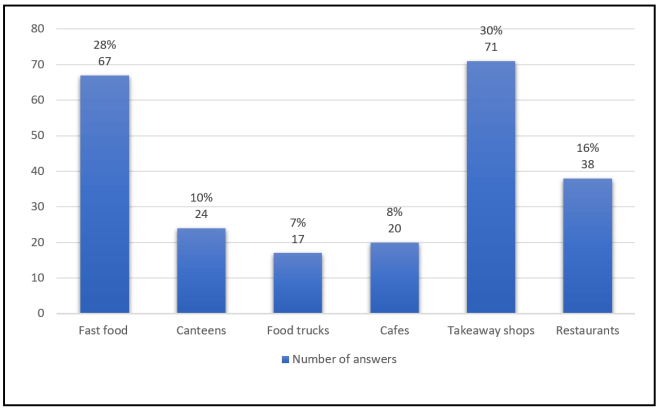

Fig. 2. The places where people buy their takeaway food in Uppsala

In terms of awareness of the problem with disposable food containers, the data analysis shows that male respondents were less aware of the disposable food containers problem at 75 percent, while 81 percent of the female respondents reveal awareness of the problem (Figure 3a,b).

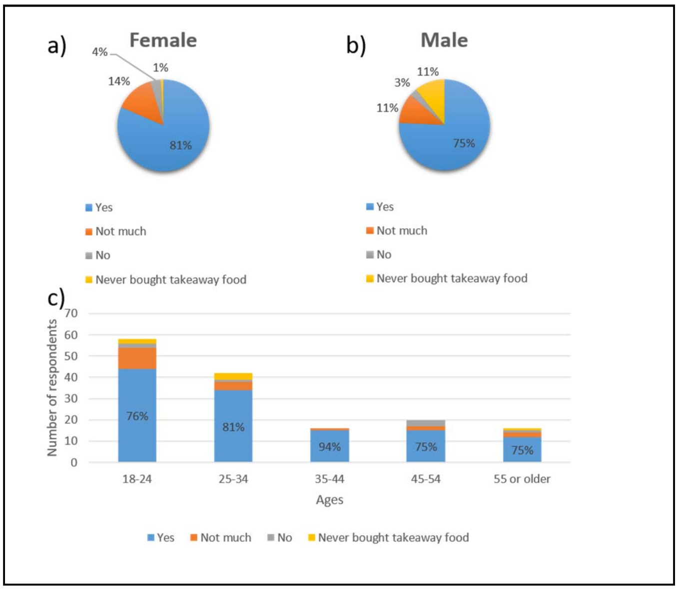

Fig. 3. The awareness of respondents for to the problem with disposable food containers according to their genders, a) female, b) male and c) their ages.

However, more males never bought takeaway food than females at 11 percent and 1 percent respectively. It might be that males were taking food from the house if they are married or lived as couples. There were two age ranges, which are slightly more aware of the disposable containers problem than other ages, these age ranges are 25-34 and 35-44 as shown in Figure 3c. Furthermore possible obstacles for the offered service were investigated. The top three reasons mentioned by the respondents were, firstly the convenience of drop off locations reason with 27 percent based on 240 answers. Meanwhile, the complication of system and hygiene were the second most concern of respondents, both at 19 percent. The issue of extra cost can still be seen as a reason at 14 percent.

C. *IoT innovation for food smart packaging reusability*

There are numerous ways to create a return system for the reusable food containers. Each one will have their advantages and disadvantages. In this study the IoT solution is based on the development of a mobile phone application called ReTak available both for Android and iOS operating systems in combination with QR code tags for the food packages purchase and return to stations. This proposition requires low investment and is easy to scale up in the future. The data collected from the QR codes are transmitted for storage within a secure cloud database available from “https://cloudstitch.com”. Doing so the data becomes accessible from each mobile application on real time ensuring the correct amount of returned packages involved and redeemable credits can be assigned for each user. The credits on each mobile application are again stored securely in the cloud database eliminating any fault problem when customers close the ReTak application. Both version of iOS and Android mobile applications were created for the pilot run via “https://thunkable.com” a block-based mobile application builder on the web (Figure 4). The customers need to have the mobile application installed on their personal devices and registered with their name and email address in order to use the service (Figure 4a,b).

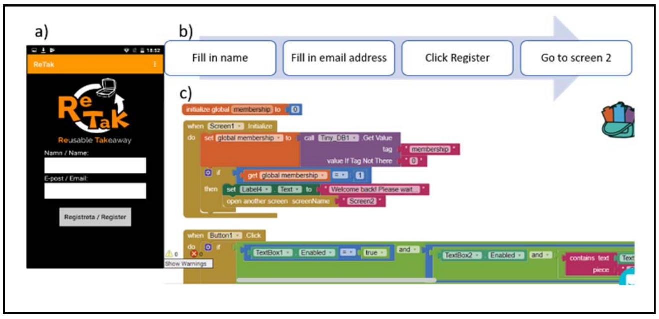

Fig. 4. The registration screen at mobile application b) the process which user has to follow and c) a snapshot of the block-based code.

For the pilot run one credit was given for free since the payment on the mobile application would be too complicated at this stage. The QR code was used to confirm the taking away and returning process (Figure 5a,b). The designed architecture allows the customers to keep the container overnight and return it later to collect the credits or when they decide to order take away food again (Figure 5c).

To get a better understanding of where added value lies in terms of IoT ecosystem we utilized the IoT Business model innovation tool [17] to map our IoT platform with in the different layers:

1) The device layer – Return station; QR code, (for future; sensor, displays, etc.), mobile phone with camera, (for future- food containers with traceability devices)

2) Connectivity – through a mobile network

3) The cloud – Cloudstitch (for iOS), Airtable (for Android)

4) The application – mobile application (credits, payments, information and location of food providers and return stations, etc.)

5) The service – partners who collect the food containers from the return station

D. *Pilot run outcomes*

The pilot study was designed to take place at a local fast food truck "Curry buddies" whose owner was interested to support the study. They sell “Desi” fast food, and were located near the city center, which was also ideal for the trial. Purchased reusable food containers made of Polypropylene (PP), which are food grade, microwave and dishwasher safe were used with attached ReTak stickers for verification. For return station, a Bin was purchased from local IKEA store and a sticker with the QR code was mounted on the bin.

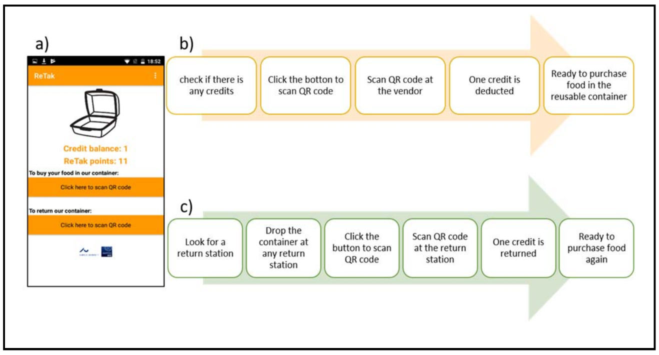

Fig. 5. The screen of mobile application with calculation of credits and QR code scanning functions b) the process for the user to buy food using this application and c) for returning container and rebuy food.

The food containers were collected and cleaned every day. At the food provider, laminated ReTak signs were provided as a stand from a local stationary shop to show that the reusable food container option was available including instructions for use. A reusable food container was displayed together with the sign for demonstration purposes in addition to attracting more attention. The sign contained a QR code with a numeric code of the vendor (Figure 6a). The platform trial, ran for one week in the late April period from 10:30am to 8:00pm from Monday to Friday. From the collected data, there were 26 reusable containers out of 86 total sold; one compartment container and 13 reusable ones out of 58 total sold and two compartments containers representing 30 and 22 percent respectively. If both types of containers are considered, there were 39 reusable containers among total sales of 144 containers for all five days, which represent 27 percent of the total sold disposable containers (Figure 6b). Furthermore, among 27 percent of participants, which used the reusable containers, the return rate was investigated. There were 26 one compartment containers used but 24 containers were returned. Meanwhile, there were 13 two compartments containers used but only 8 containers were returned. That means 7 containers in total were missing among 39 containers (Figure 6c).

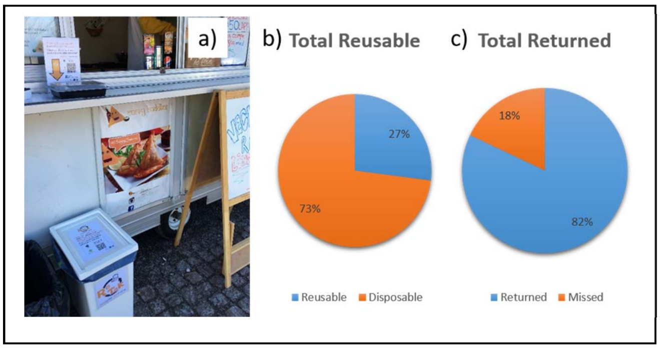

Fig. 6. A picture of the fast truck with QR codes and the return bin during the trial run b) The percentage of reusable containers versus just disposable containers which were used totally in the trial c) The percentage of returned versus sold reusable containers in the trial.

Although the study was very limited, the pilot run shows that the concept of reused food containers is viable and scalable with the aid of IoT technologies and the developed blueprint design could be the foundation to build a sustainable business in Uppsala, Sweden to support a local economy ecosystem.

E. Business model innovation and value generation

With an emphasis on sustainability, the process is designed to keep the carbon footprint as low as possible, which implies using very low levels of energy wherever possible. Figure 7 shows the flow cycle of reusable food containers in the system indicating the possible value creation streams.

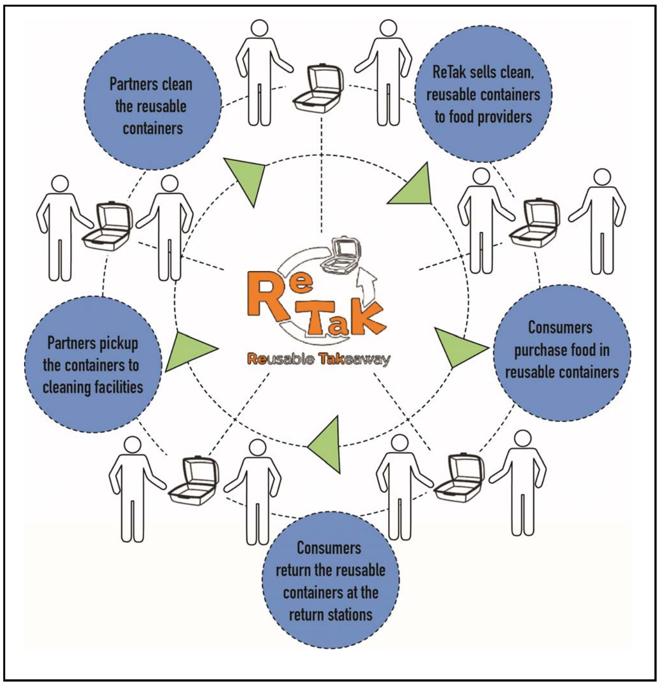

Fig. 7. The flow cycle of reusable food containers in the proposed circular economy ecosystem.

The reusable food containers are cleaned and sold to any food providers. When their customers purchase the food they can agree to use the reused containers by showing the confirmation on the mobile application. After the customers finish enjoying the food, they can drop back the containers at any nearby return station and use the mobile application to confirm the return and gain some credits. The business partners pick the containers up and deliver them to the nearby cleaning facilities that are also partners in the ecosystem. After all the containers are cleaned, the partners pick them up and either deliver them directly to nearby food providers as requested or store them in nearby warehouse for future use. The partners can be the same or different stakeholders. The overall process aims to utilize the least energy possible, which is why it is important to keep the operations within a local ecosystem in a city. In exploring the dimensions of this business model innovation we have applied the St. Gallen Business Model Navigator framework, [16], which is based on four core components that make up the core of any business model.

1) The Who indicating that the customer segment is the most focal point in the business model. In the case this implies the consumers that are both users and customers in B2C. They pay to be a member to use the service while they receive the service from the customers who are the food providers as well.

2) The What refers to the service or product being offered to the customer, and how it creates value for them. In this case it refers to the tangible value which is brought to users, which are the clean reusable food containers and the service of not having to worry about cleaning the containers due to the customer-friendly and easy-to-use mobile application. The return stations are provided for users to return the containers easily. The food providers can be satisfied with the process as convenient as using the disposable one. The customers also receive the intangible values which is the environmental friendly image.

3) The How entails activities necessary to deliver the product, and what capabilities and resources are required. In the case, the primary activities are, providing, collecting and cleaning the reusable containers. The providing and collecting process are including in the operation of mobile application and return stations. The secondary activities are marketing for the food provider and educating both food providers and consumers regarding the waste problem. The return system requires technology tools to support both software and hardware. The cloud database is the key element along with the user interfaces via mobile application. The return stations need technology to be secured and accurate, for this perhaps there could be some sort of blockchain technology involvement. The necessary training in using these technologies optimally is also to be considered. A network of partners is necessary to ensure support for logistics and cleaning process.

4) The Value refers to how the business will be acquiring profits of the setup. In the case, the value/income of this BM is from selling the reusable food containers with the service of picking up and cleaning to the food providers (customers). Meanwhile, the users pay the fee for membership to use the service.

IV. CONCLUTIONS

The main idea of reuse and return system is broad and can be applied into various business models, in particular the ones which involve IoT. This study is only a part for the idea verification in the aspect of takeaway food containers since it had a limitation of time, resources and finance. However, there are numerous ways to continue for future works. This could be part of smart city architecture where the return system of food container is installed as part of the infrastructure for the city and relate it with smart waste collection IoT solutions [13]. This would be in good alignment with United Nation's Sustainable Development Goals (SDGs) [14] on sustainable development in cities and communities. In terms of target users, it could be focused on the employees in the office areas or people in the residential areas. Food festivals is another possibility since they have no cleaning facility and have no other choice rather than using the disposable containers. It could be expanded to supermarkets where the clean reusable containers could be provided from the dispensers for containing any consumer products such as, meat, cheese, salad, etc. These ideas will need to be investigated and studied further to verify their feasibility and sustainability.

On the technology part IoT search engine services such as the ones proposed by the IoTCrawler EU H2020 project [18] for crawling the available return stations near your location could be highly beneficial. Furthermore smart tags with enhanced capabilities such the ones researched by TagItSmart EU H2020 project could be an additional advantage for use on food containers to ensure an extra level of security, and traceability as well as monitoring their hygiene history. Low energy Blockchain technologies for verifying the authenticity of the credits and reusable package in combination with a suitable mobile payment system would be highly useful for the customer's convenience and for further stimulating the local circular economy ecosystem.

ACKNOWLEDGMENT

MJB would like to thank Aarhus University's Research Foundation (AUFF) for the awarded grant entitled "IoT cross-disciplinary university test bed".

REFERENCES

[1] Green, E. (2013). Innovation: The history of a Buzzword. The Atlantic. Retrieved from https://www.theatlantic.com/business/archive/2013/06/innovation-the-history-of-a-buzzword/277067/

[2] Foote, K.D. (2016). A brief history of the internet of things. Dataversity. Retrieved from http://www.dataversity.net/brief-history-internet-things/

[3] Tozzi, C. (2016). IoT past and present: The history of IoT, and where it's headed today. Channel Futures. Retrieved from http://www.channelfutures.com/msp-501/iot-past-and-present-history-iot-and-where-its-headed-today

[4] Miorandi, D., et al. (2012). Internet of things: Vision, applications and research challenges. Ad Hos Networks 10(2012), pp.1497-1516.

[5] Xu, L.D., et al. (2014). Internet of Things in Industries: A Survey. IEEE Transactions on industrial informatics, 10, no.4, pp.2233-2243.

[6] Pothitos, A. (2016). The history of the smartphone. Mobile Industry Review. Retrieved from http://www.mobileindustryreview.com/2016/10/the-history-of-the-smartphone.html

[7] Ohigashi Oasay, L.H. (2011). QR Codes in the Library. Journal of Electronic Resources in Medical Libraries, 8:3, pp.294-301

[8] Tiwari, S. (2016). An introduction to QR code technology. 2016 International conference on information technology.

[9] Hevner, A.R. (2007). A Three Cycle View of Design Science Research. Scandinavian Journal of Information Systems. 19(2), Article 4.

[10] Montgomery, D.C. and Woodall, W.H. (2008). An overview of Six Sigma. International Statistical Review (2008), 76, 3, pp.329-346.

[11] Pyzdek, T. (2003). The Six Sigma Handbook. USA: The McGraw-Hill Companies Inc.

[12] Narasimhan, K. (2002). Design for Six Sigma: Launching New Products and Services without Failure, The TQM Magazine, 14, no. 4, pp. 264.

[13] Beliatis, M.J, Mansour, H., Nagy, S., Aagaard, A., Presser, M., (2018). Digital waste management using LoRa network a business case from lab to fab. IEEE Global IoT Summit 2018 in Bilbao.

[14] Sustainable Development Goals, United Nations, http://www.un.org/sustainabledevelopment/news/communications-material/, accessed 01-July-2018

[15] 360 Environmental (2011). Defra publish guidance on applying the waste hierarchy. Retrieved from https://www.360environmental.co.uk/news/375/

[16] Gassmann, H., Frankenberger, K., and Csik, M. (2014) The St. Gallen business model navigator. Working paper: University of St. Gallen: ITEM-HSG.

[17] Aagaard, Annabeth; Presser, Mirko; Beliatis, Michail; Mansour, Hussam; Nagy, Szabolcs. A Tool for Internet of Things Digital Business Model Innovation, IEEE Globecom 2018

[18] Skarmeta, A. F.; Santa, J.; Beliatis, M. J.; Presser, M.; et al. IoTCrawler: Browsing the Internet of Things. GIoT 2018 Proc. , IEEE Commun. Soc. 2018.