Design Product Service Systems by using hybrid simulation: a case study in the fashion industry

Fani V.*, Pirola F., Pezzotta G.**, Bandinelli R.*, Bindi B.***

** Department of Industrial Engineering, University of Florence, Italy (virginia.fani@unifi.it, romeo.bandinelli@unifi.it, bianca.bindi@unifi.it)*

*** Department of Management, Information and Production Engineering, University of Bergamo, Viale Marconi, 5, Dalmine BG, 24044, Italy (fabiana.pirola@unibg.it; giuditta.pezzotta@unibg.it)*

Abstract: Nowadays, companies operating in different markets are re-thinking their business model in order to increase their environmental sustainability. In the fashion industry, an unexplored way to address environmental problem is the introduction of a sustainable-oriented service to the traditional production and distribution processes, with the establishment of the so-called Product Service System (PSS). This paper presents the preliminary results of an ongoing research on the definition of a new business model for the fashion industry, related to the possibility to rent a specific item (i.e. a bag, a shoe, a dress) using different channels (i.e. store, e-commerce etc..). SErvice Engineering Methodology (SEEM) and hybrid simulation have been used in order to define and assess the proposed model. AnyLogic® has been used in order to validate the model, composed by a traditional discrete event representation of a store and an agent-based part, where the Persona model has been introduced in order to describe the behaviour of the customer.

Keywords: Product Service Systems, PSS, Fashion, Renting

1.Introduction

Nowadays, environmental sustainability projects are becoming mandatory in every type of industry. This topic has been addressed since several years in the fashion industry and several actions have been carried in order to increase the products and process sustainability, starting from the reduction of substitution of raw material (Karaosman et al., 2020), social sustainabilities' actions (Ciarapica et al., 2017) etc..

This paper deals with the introduction of a sustainable-oriented service model to the traditional production and distribution processes, with the establishment of the so-called Product Service System (PSS). In particular, the paper aims to propose hybrid simulation as a decision-making tool to better engineer the delivery process of a new PSS thanks to the integration of customer behaviours simulation within the service delivery process simulation.

The business model that proposes this type of system is called *Fashion Renting*, promoting collaborative consumption based on providing a new PSS business model focused on the rental of clothing and accessories for every occasion. It has been spreading in several international markets, allowing companies to remain competitive by combining environmental challenges with the satisfaction of customer needs.

Starting from this point, the paper is structured as follows: Section 2 describes the background focusing on Fashion renting business model and PSS engineering, with a special focus on the SErvice Engineering Methodology (SEEM), Section 3 describes the objective of the research, Section 4 describes the application of the case study in the fashion industry and Section 5 highlights some remarks and conclusion.

2.Industrial and scientific background

2.1 Fashion renting as a new business model

Fashion Renting is a business model that allows people to rent clothes, shoes, bags and other accessories, whether high Fashion or not, at an affordable price. According to a study reported by Research and Market, the global online clothing rental market was worth $1.26 billion in 2019. Future prospects predict that by 2025, this market will reach a value of $2.08 billion, showing a CAGR of 8.7% between 2020 and 2025.

Fashion renting is an innovative business model that ensures a longer life cycle for clothing products, reduces the consumption of raw materials, promotes environmental sustainability by producing fewer carbon emissions and offers the opportunity to wear high-end, trendy fashion items even to consumers who cannot afford to buy them. This last aspect potentially allows the mass market to have access to the high-end fashion market, and economic aspects by reducing the overconsumption of clothes. (Lang et al., 2020).

Renting designer clothes or fashion-related accessories is not an entirely new phenomenon, but while historically it was limited to special occasions, current Fashion renting allows consumers to also rent clothes to wear in everyday life. (Lang and Joyner Armstrong, 2018)

In order to better understand the phenomenon of Fashion renting, some cases already present in the market are here after presented.

Rent the Runaway was one of the pioneers of Fashion renting, born in 2009, it offers the possibility to rent designer clothes and accessories for a period of 4 or 8 days or, through a monthly subscription, you can have new clothes once or twice a month. Rent the Runway started as a clothing rental platform, but now also has stores in New York, Chicago, Washington DC, San Francisco and Los Angeles. It makes available items from a wide range of brands that can be worn at ceremonies, events, but also in everyday wear for both adults and children.

DressYouCan is a showroom located in the center of Milan, where customers can rent clothes and accessories and take advantage of consulting and tailoring service. It allows a fixed rental duration of 4 days and 3 nights. The range of articles available allows customers to rent clothes for every occasion for men and women.

Twinset in September 2019 activated the service of rental clothes called *Please don't buy*. It is a collection of exclusive and unique formal wear, intended only for the rental service. It offers the possibility to try on the garments in the boutique and rent them for 4 days and then return them in the same boutique. The motivations that pushed Twinset to include this collection are dictated by the desire to pay more attention to sustainability.

Revest is an atelier located in the center of Milan that offers the possibility to rent clothes and accessories of more than 100 high fashion brands; it is also possible to give one's own clothes to Revest to share one's wardrobe with an economic return.

In all cases seen, the service guarantees in the rental price insurance that covers accidental damage, laundry and tailoring service for cleaning, sanitizing and any repairs of the articles.

2.2 SErvice Engineering Methodology (SEEM)

Manufacturing companies encounter many difficulties in formulating a service-oriented value position (Gaiardelli et al., 2021). These are related to factors such as market norms, customer's preferences and the definition of processes, methods and techniques required to support its design and engineering. Designing and developing solutions that simultaneously cover both tangible and intangible aspects are far from manufacturing competence. Above all, manufacturing firms generally do not think systematically about both aspects, because historically, services have always been managed either by the after-sales or marketing departments. Designing and developing a PSS is a complex task mainly due to the long and unpredictable lifecycle and the number of interactions among all the actors involved (Doualle at al. 2020).

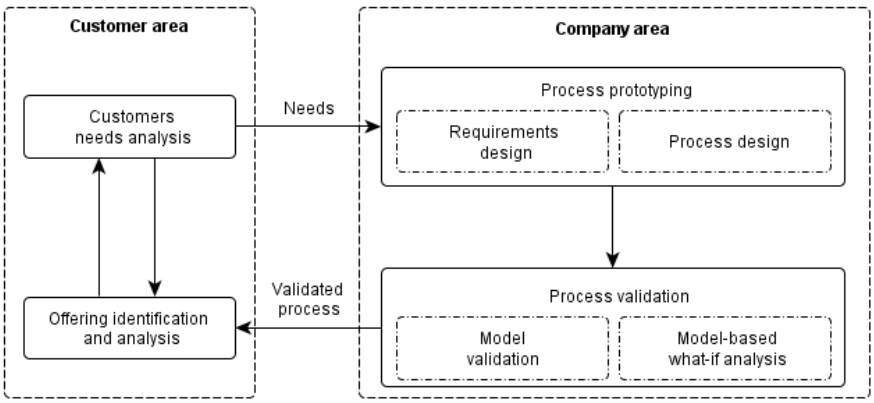

Figure 1: The SErvice Engineering Methodology (SEEM) (Pezzotta et al., 2016)

Among the more recent methodologies, the SErvice Engineering Methodology (SEEM) (Pezzotta et al., 2016) focuses on engineering and re-engineering the service offering taking into account both customer and company perspectives. SEEM aims to support companies shifting from a traditional product business offering to one with a more advanced service value proposition. In particular, SEEM supports companies in engineering and re-engineering their PSS while balancing the value perceived by customers with the service delivery processes' internal efficiency and productivity. The SEEM framework, shown in Figure 1, is divided into two main areas:

I. Customer area – the analysis of customer needs, representing the starting point to design new product-services, and the re-arrangement of the company service portfolio.

II. Company area – it deals with the engineering and validation of the service delivery process considering the company's external and internal performance.

As shown in Figure 1, the first two phases belong to the customer area, while the remaining two address the company area.

In the *Customer needs analysis* phase, the Persona Model (PM) is proposed as a tool to collect and present information about customers (Pirola et al., 2014). This tool is based on *Personas*, fictional people describing the prototypical users of a product or service in terms of demographics and main values or needs.

Personas are developed based on the customers' needs and outcomes (expressed or not expressed), analysed through feedback and complaints analysis (if an offer already exists),

market research, interviews, focus groups, or more innovative tools such as sentiment analysis.

In this phase, the customer journey map can be also adopted as a useful tool to highlight all the client's decision-making moments and all the interactions between client and company.

Process Prototyping includes: the generation of the concept(s), the evaluation and selection of the concept(s) to be added to the value proposition and, finally, the delivery process's design. In this phase, the Product Service Concept Tree (PSCT), based on design thinking principles, is used. The purpose of this tool is to support the analysis of customer needs, summarized in the Persona model, defining the relationship between customer needs and provider's resources.

The concepts defined through the PSCT are evaluated using the Engineering Value Assessment (EVA) (Rondini, Bertoni, and Pezzotta, 2020), a multi-criteria decision making approach to support the selection of the most suitable solution(s) to be added to the company offer.

Once selected, the solution is designed in detail. Product and service design activities will follow separate paths by staying connected thanks to work done in these preliminary phases. The method proposed to describe the service delivery process is Service Blueprinting. In re-engineering, this phase involves mapping the existing process (if any) and identifying possible alternatives for improvement.

Process validation assesses the performance of the alternative service delivery processes previously designed, as well as identifies the most suitable process and its best resource configuration. To this end, SEEM adopts a process simulation approach since it allows for the dynamic analysis of a system (the service process, in our case) under different conditions and scenarios.

Offering/value proposition identification and analysis is a post-launch confirmation of market acceptance. KPIs are defined to monitor performance and have an effective and efficient value proposition with a close market fit. The analysis carried out in this phase can then be used to start a new design or re-engineering process.

In this paper, only few SEEM phases have been used, since the service proposed on the market was already identified. In particular, Persona model and the customer journey have been used to analyse customer behaviour. The customer journey has been included in a blueprinting map to prototype the company process. Then, to validate the identified Fashion renting service process, this paper proposes to use discrete event simulation in combination with agent based simulation. This would allow engineering the new Fashion renting services focusing on both the customer behaviour and the company process.

2.3 Hybrid simulation

In the area of simulation many paradigms exist. The most common are Discrete Event Simulation (DES), System Dynamics (SD) and Agent Based Modeling (ABM). Hybrid simulation, that is a combination of these three paradigms, is also available. DES offers great potential as a means of describing, analysing, and optimizing service delivery processes (Laughery, Laughery, et al. 1998) and supports their systematic and optimized engineer, even in low-tech industries such as the fashion one (Fani et al., 2017). ABM, instead, models individuals' behaviour, through a bottom-up perspective in which agents have their own state and become active elements of the model. SD and is largely used to analyse the dynamics of a system (Sterman 2000).

To properly design a new PSS and to engineer its service delivery process also considering customer characteristics and needs, DES and ABM are selected. Indeed, DES can represent the service process as a set of activities while ABM can easily represent customers' behaviour (Rondini et al., 2017). The quest for the adoption of the two simulation approaches simultaneously spurs the adoption of hybrid simulation since the early stage of the design of a PSS. Indeed, hybrid modelling grew out from the need to combine the advantages of two or more of the "pure" approaches (DES, SD, ABM), integrating in one single model functionalities and features from the different techniques (Lättilä, Hilletofth and Lin 2010).

3.Objective

This research aims to exploit the use of a hybrid simulation model to support the traditional fashion supply chains to engineer the delivery process of a new PSS focused on the Fashion renting model. The topic is rather innovative since the literature has dealt only with collaborative consumption and mainly focuses on consumers' attitudinal behaviours instead of how to structure the service delivery process and the related supply chain management to satisfy the different customer needs. Furthermore, so far SEEM applications have only dealt with discrete simulation without considering its integration with agent-based simulation paradigm.

4.Model implementation

In the following, the Fashion Renting service design is described by reporting the activities carried out in each of the SEEM phases adopted.

4.1 Customer Analysis: data collection and analysis

The objective of the customer analysis phase is to understand and classify the customers' needs to characterize different Personas. Through the administration of a survey, data were collected and analysed regarding the needs and perceptions that potential customers have of the rental service and Fashion renting in particular.

The survey was structured in thirteen closed-questions. The survey was disseminated through social networks and 421 responses were collected. The first questions aimed at defining a personal profile of the respondents, then, having clarified what is meant by Fashion renting, the questions investigated more specifically the respondents' interest in Fashion renting service specifications.

Cluster	Respondents	Avg day dresses rental	Avg day bags rental	Avg day shoes rental	Avg day accessories rental	Availability in the shop	Subscription
1	65	12	30	15	18	Not so relevant - rent scheduled in advance	Interested
2	49	6	6	7	22	Relevant	Not interested
3	280	5	4	41	4	Not so relevant - rent scheduled in advance	Not interested

Table 1: Cluster characteristics

To develop proper Persona models, the data collected were analysed using cluster analysis and for each cluster, a profile of a typical client was drawn up.

Cluster analysis groups observations based on their similarity. It creates clusters by minimizing the elements' logical distance and maximizing the distance between clusters. The software used to implement the cluster analysis was Stata, through the non-hierarchical algorithm K-means (Kaushik, & Mathur 2014).

Since the customer analysis scope was to identify the customers' needs interested in Fashion renting, data relating to respondents who did not show interest in the Fashion renting service were removed, leaving 394 valid responses.

For the Cluster analysis, the following data have been studied:

- Length of rental time required by respondents for each category (clothing, bags, shoes and accessories);

- Importance of immediate availability of the chosen item in the store;

- Willingness to sign a subscription

The algorithm chosen to carry out the cluster analysis, i.e. the K-means, foresees to define a priori the number of clusters. Considering the sample size and the number of variables used in the cluster analysis, 3 clusters have been identified as the optimal number, as the distinction between the different groups formed is clearer.

In Tables 1, the number of respondents in each cluster and their main clusters characteristics are summarized.

4.2 Customer Analysis: Persona model

Alan Cooper invented the Persona model (Cooper 1999), a tool to describe archetypes of users/customers with a certain behaviour or need. These must be illustrative of specific segments of a potential customer for the product or service under consideration.

It does not define the profile of a real person, but the Persona created represents the main characteristics with certain patterns of user behaviour, goals, and motivations that are useful when designing the product or service. The description also contains invented personal details to make it more real and create empathy.

According to the process, it is important to identify and define a limited number of primary Personas with certain needs that must be met. The needs of each Persona must

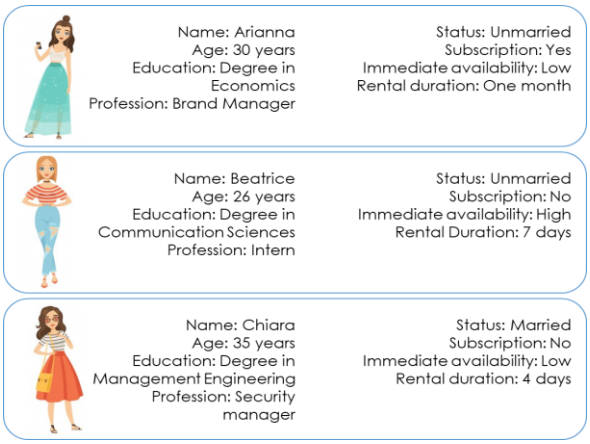

Figure 2: Persona Model

be different and not overlapping. Considering the data collected and the Customer analysis carried out, 3 Personas interested in Fashion Renting were created, one for each cluster analysed.

Figure 2 reports a summary of the main characteristics of each Persona, based on the data summarised in Table 1.

4.3 Process prototype

Once the Personas interested in the Fashion renting service have been identified, the SEEM suggests evaluating how customers interact with the company offering this service. This is modeled through the customer journey, representing the journey undertaken by the each Persona when purchasing a product or service, from when the need arises until the product/service is bought.

To analyse the same process from company point of view, the Service Blueprint mapping is used. This method adopts a customer-focused approach to innovate and improve service, outlining the customer journey and the company service from back office to front office processes. Then, starting from the customer journey, a detailed model of the activities carried out by the company has been developed.

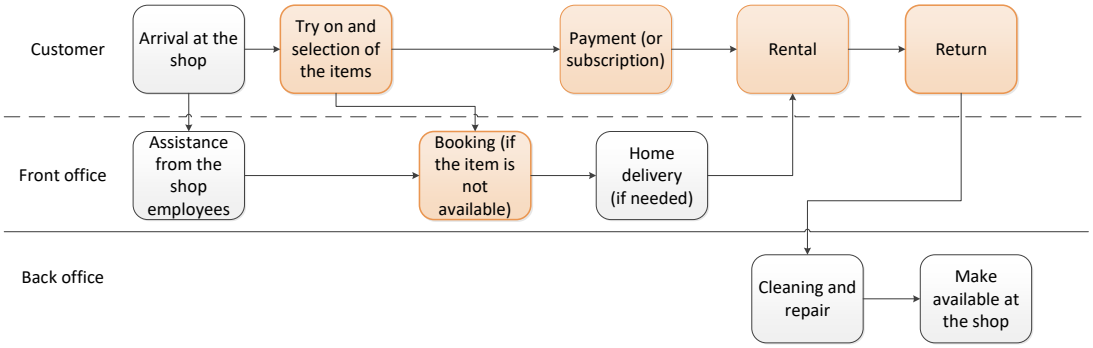

Figure 3: Blueprinting map

Due to space constraints, Figure 3 reports, in a Blueprinting structure, the main activities of the overall process, dividing them in customer activities (i.e. customer journey), front-office activities and back-office activities.

In orange the main phases influenced by the needs of the different Persona are highlighted:

- selection of ore or more item: Personas have different interests in renting varied types of items.
- interest in booking a not available item: Personas organize themselves differently, some book in advance (Arianna and Chiara), others rent only the items available in the store (Beatrice)
- subscription available or not: Customers can have an active subscription (Arianna) or pay for a single rental
- rental duration of the different items: as shown in Table 1, every Persona has different needs in terms of average rent duration.

The overall customer journey and service delivery process designed have been used as a static model to create dynamic models in the next phase.

4.4 Process validation

Once the Personas are defined, the journey and the blueprinting maps have been designed, and the activities affected by the type of Persona have been defined, it is possible to create the dynamic model that can be used to validate and assess the developed service.

With this particular scope, a Hybrid simulation approach has been selected (Rondini et al., 2018) with the aim to understand how the different Personas, with their specific behaviours, interact with the service delivery process. In particular, ABM and DES are used since agents can be used to model the individual behaviour of customers, while the service delivery process can be described through DES.

The model has been implemented using the software AnyLogic®, a commercial tool able to implement an hybrid model, where the ABM model can natively interact with the DES one.

4.4.1 Agent based modeling of Persona

The first step of the development of a hybrid simulation model has been the creation of the agents involved in the process such as the customers. Using as a starting point the "typical clients" obtained from the Persona model, a statechart was developed which provides the description of the agents' behaviours by dividing them into the clusters they belong to, as shown in Figure 4. A statechart is a visual construct that enables to define event- and time-driven behaviour of agents. Statecharts are made of state and transition. A state represents the condition of the agent and also a set of reactions to external events. The reactions in a particular state are defined by transitions exiting that state. Each transition has a trigger (e.g. a message arrival, a condition, a timeout). States, transition, parameters and variables used in the statechart derive from the data collected through the survey previously described.

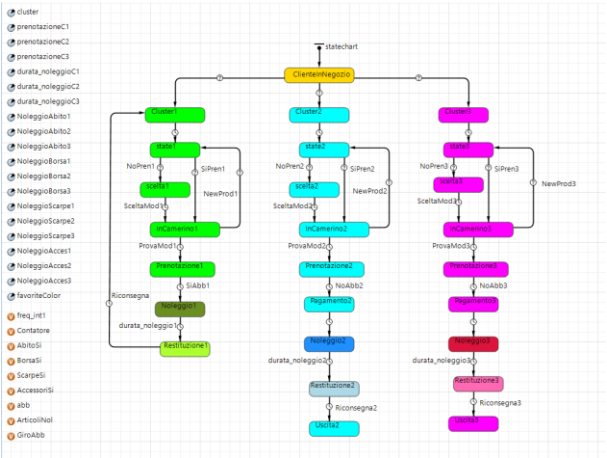

Figure 4: Persona Model Statechart

4.4.2 Discrete event simulation

Through the discrete events simulation, it has been developed the model that represents the customer path and the company process from the customer entrance in the store until the end of the rental and laundry service. The discrete event model has been implemented using standard AnyLogic® agents as source, delay, select, service, according to the blueprint map described in Figure 3. The customers enter from the source from a rate schedule arbitrarily chosen, that is with a frequency of arrival of two customers/hour during the assumed timetable of opening from the 8.00 to the 20.00 every day. Along the process each Persona follows a specific path aiming at maximising its needs as specified in the statechart reported in the ABM.

5.Results

In order to verify the consistency of the model, a set of input data have been defined and a specific set of KPIs has been chosen. Starting from this specific set of data, the output of the model has been compared to the input files, in order to validate the expected relationship between the input and the output.

The goal of the first test was to validate that the 3 clusters generated by the model were proportional to the distribution of the customers obtained from the Cluster Analysis. Subsequently, it is verified that for each cluster the proportion between customers with reservation and customers without reservation was fixed in the different simulation runs. In addition, the number of items that each agent was willing to rent at the same time was detected.

Next, some operational indicators where evaluated. In particular, the lead time of the process (measured as the moment in which the customer enters in store until the restitution of the articles after the rental) for every cluster has been determined. Moreover, the lead time of the laundry service has been collected. Hereafter, due to the limit space, only a subset of the results are reported. Fixing the simulation time in 70 days, a warm up period of 40 days has been defined. Consequently, for every run, a period of a month has been analysed.

Regarding the distribution of agents within clusters, Table 2 shows the data obtained from the Cluster Analysis and the data extrapolated from the 40- and 73-day model statistics.

Table 2: Distribution of agents within cluster

	Cluster Analysis	40-days simualtion	73-days simualtion
Cluster 1	16.5 %	16.1 %	16.4 %
Cluster 2	12.4 %	9.8 %	10.1 %
Cluster 3	71.1 %	74.1 %	73.5 %

The values appear to consistently according to the data entered as input into the simulation.

Table 3 shows, as a percentage, the agents for each cluster who show up at the store having already made a reservation in the past.

Table 3: Agents with reservation

	Cluster Analysis	40-days simualtion	73-days simualtion
Cluster 1	58.5 %	64.1 %	63 %
Cluster 2	0 %	0 %	0 %
Cluster 3	58.6 %	60.9 %	59.4 %

Again, the experimental data are consistent with the parameters used to build the model.

After these considerations, it can be said that the behaviour of agents, represented in the agent-based model through the statechart, is well integrated in the discrete-event simulation.

The reported statistics have the scope to validate the hybrid simulation like a suitable instrument to the modeling of a complex system like the system product service tied up to the specific case of fashion renting.

In spite of the limitations due to the lack of real data, it has been possible to draw up a model in a position to simulating the behaviour of the various agents and the evolution of the process in the time and consequently to observe the way in which the two types of simulation interact between they.

6. Conclusion

The phenomenon of Fashion renting is opposed to the widely established business model of fast Fashion, ensuring a longer life cycle of clothing, reducing the consumption of raw materials, the pollution generated in the production phases and at the end of the life cycle of the articles, in order to promote environmental sustainability.

From the studies in the literature and from the analysis of the data obtained with the questionnaire, it has emerged that the motivations that lead consumers to adopt the rental service of fashion items are varied. They are dictated by the possibility of wearing high fashion garments that would not be accessible with a traditional system of sale, to take advantage of an infinite and shared closet of articles of the new collections, not only to be able to follow the latest trends, but also to contribute to the development of a model able to promote environmental sustainability.

The implementation of a product service system (PSS) has proved to be an appropriate solution for the introduction of the Fashion renting service both within an already established production reality that wants to maintain its position in the market and in a small growing reality. For the development of this system, the structure proposed by the SErvice Engineering Methodology (SEEM) has been applied. In order to fulfill the objectives of the first phase of the SEEM, that is to know the needs and expectations of consumers, it was essential to involve them already in the early stages of the design of the PSS. The definition of Persona models and the Service Blueprint was necessary to analyse the customer's journey and in particular the way in which they interact with the business process. In doing so, it is possible to offer a service that is appropriate to the needs of consumers, while efficiently balancing internal and external company performance.

To such scope, in order to realize the third phase of the SEEM, the hybrid simulation has been adopted, that combines discrete event simulation and the simulation based on agents. It has turned out to be a suitable instrument to the dynamic representation also of a complex system as the one introduced with the case of study. The simulation based on agents, through the statechart, deals with the modeling of the different behaviours adopted from the customers during the process and at the same time the discrete event simulation represents to the best the structure of the process.

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