Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 120 (2023) 1618–1623

www.elsevier.com/locate/procedia

56th CIRP Conference on Manufacturing Systems, CIRP CMS '23, South Africa

Modelling the operations of a circular economy fashion start-up

Javier de Olañeta[a], John Patsavellas[a,*], Konstantinos Salonitis[a]

[a]School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield, Bedfordshire, MK43 0AL, UK

* Corresponding author. Tel.: +44-7736-246-809; *E-mail address:* john.patsavellas@cranfield.ac.uk

Abstract

This paper presents a case study of Pantala, a fashion start-up, intending to operationalise a circular supply of luxury womenswear through a monthly subscription-fee model. To optimize the company's cashflow and ensure success, the operational flows were modelled and analysed through discrete-event simulation techniques, with a focus on inventory management and minimizing operational costs. Simulation results demonstrated a high level of accuracy in predicting system performance, with an average relative error of less than 5% for most performance indicators. Insights are provided into the benefits of using simulation modelling for operational planning and optimization of complex systems, especially in the case of start-ups.

Keywords: start-up; circular fashion; discrete-event simulation; e-tailing; fast-fashion; reverse logistics.

1. Introduction

Start-up companies tend to experience unique challenges when it comes to scaling up in size, usually due to the need for investment in infrastructure which requires substantial capital and operational know-how. The all-too-often crisis of dealing with increasing amounts of orders, results in many premature failures. Specifically in the business of fast-fashion, the requirements of speed, consistency of service, and the reality of low margins, tend to be barriers both for starting-up and scaling-up new fashion business initiatives.

An additional contemporary challenge for any start-up nowadays, is to demonstrate genuine efficacy of sustainable operations. This is a particularly thorny issue for the fashion industry, that is responsible for 10% of all human carbon emissions which according to Business Insider India [7], is more than all international flights and maritime shipping combined. Furthermore, it is the second-largest consumer of the world's water supply whilst up to 85% of all textiles go into landfill each year [7].

Pantala is a fashion start-up, founded by 4 young entrepreneurs, backed by private equity and start-up accelerators. The company operates as an online business that provides designer-brand clothing and accessories directly to consumers on a "rent-and-return" basis. The business is based on consumers willing to pay a low monthly subscription fee, in return for being able to rent three items per month, valued on average at €600. The value proposition fulfils the need for "more-access, more-often" to better fashion, in a circular flow as an affordable sustainable alternative to fast, throwaway fashion. The enabler of that value proposition is the concept of reuse and resale of designer fashion through the deployment of reverse logistics. However, the complexity of supply chain nodes involving a large number of suppliers and consumers,

10.1016/j.procir.2023.12.005

along with the need for precise scheduling, generated the need to plan Pantala's operational flows as accurately as possible before its go-live stage, in order to optimise cash burn-rate and protect its credibility. Given the utility of virtual prototyping of flows via simulation and modelling, which is increasingly a key Industry 4.0 component, the aim of this research was to pre-model flow complexity to ensure Pantala's "go-live" operational success.

2. Pantala's circular concept and operational system

Pantala's operations system consists of a linear flow in which every single process strictly adheres to an operational calendar. Activities occur in a chronological order and are closely related to each other. As can be seen in Figure 1, some actions have sequential dependency on preceding activities and can only start once others have finished:

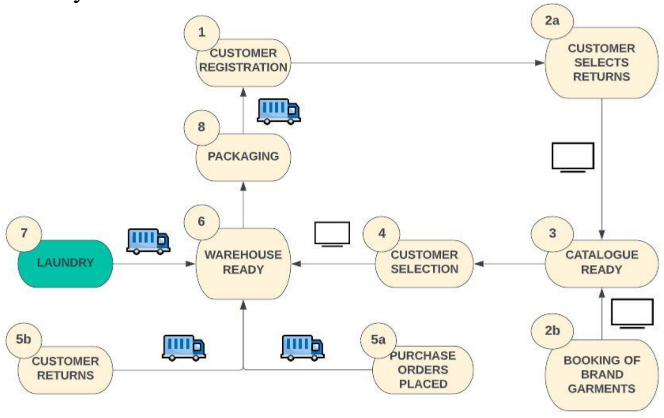

Fig. 1. Process Overview

Actions 2 and 5 refer to two different set of tasks as these occur simultaneously in parallel.

From an operational point of view, activities 2 (booking of brand garments) and 6 (receiving items in the warehouse) represent the two greatest challenges, as both require a highly detailed netting calculation around the properties of "style-colour-size". At the inception of the business model, it was not quite clear how Pantala was going to handle the aggregation of consumer demand and send the purchase orders to the fashion brands, as both processes needed to be clearly defined. There were a lot of variables that Pantala has had to control efficiently in order to secure the desired amount of inventory in their warehouse at any given moment. Many key actions depend entirely on Pantala's operations team know-how as they are the only ones who carry them out.

The draft warehouse and the different workstations were envisaged in the following way:

1. **Arrivals area:** Receipt of garments returned by the customers (workstation 3); Receipt of garments ordered from brands (workstation 2); Receipt of garments from laundry (workstation 1).
2. **Tagging area:** Tagging of garments ordered from brands (workstation 4).
3. **Storage area:** Storage of garments (workstation 5).
4. **Packaging area:** Packaging (workstation 7).
5. **Quality control area:** Quality check of garments before tagging them and sending them to laundry (workstation 6); Quality check of garments after they return from laundry (workstation 6).
6. **Output area:** Shipment of garments to laundry (workstation 8); Shipment of garments to customers (workstation 9).

The warehouse was therefore structured in the following formation:

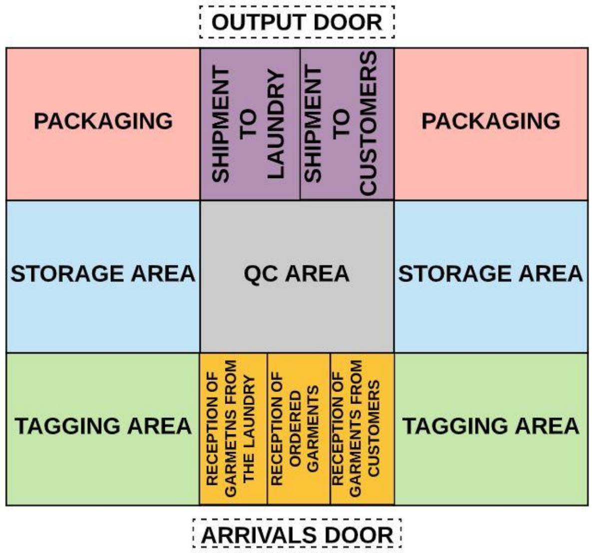

Fig. 2. Warehouse Structure

The different types of garments that arrive at the warehouse (e.g., dresses, tops, bottoms, handbags, outerwear etc.) are transported via these five main flows and go through the following workstations:

1. Brand orders: 2, 6, 4, 8.
2. Customers' garments: 3, 6, 8.
3. Garments returning from the laundry to be used the following month: 1,6,7,9.
4. Garments returning from the laundry to be stored: 1, 6, 5.
5. Change of sizes: 5, 6, 9.

It is also important to be aware of the different kinds of transport flows required and the staff responsible for each one:

- Logistics operator:
  - From fashion brands suppliers' warehouses to Pantala's warehouse.
  - From Pantala's warehouse to customers' individual address locations.
  - From customers' individual address locations to Pantala's warehouse.
- Laundry's own transport:
  - From Pantala's warehouse to the laundry contractor's premises.
  - From the laundry to Pantala's warehouse.

Figure 3 depicts the interaction between the different locations:

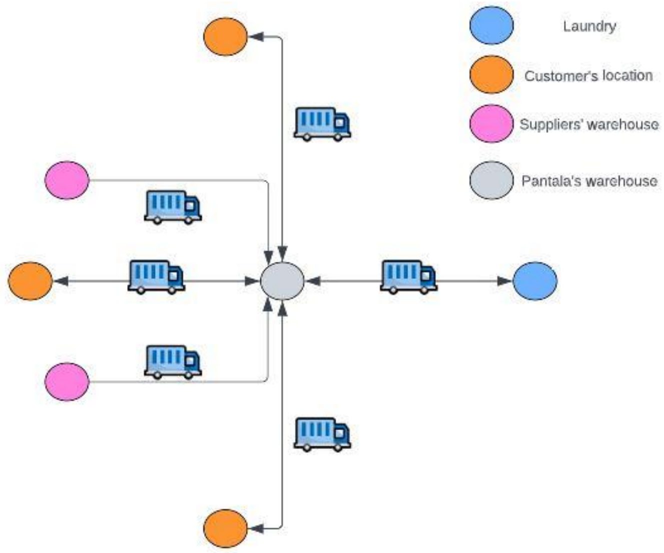

Fig. 3. Transport Flows

3. Literature Review

3.1. Fashion e-commerce

The world of fashion has experienced a radical transformation over recent years and there are currently two different types of fashion economies. As Datsko [4] explains, the first category is that of "haute couture" which consists of products for the elite sector and the other is "pret-a-porter" which consists of mass production of clothing targeting the middle and lower end of the mass-consumer market.

The term e-commerce has been used extensively over the last few years and there are currently five different types of e-commerce, depending on who the participants are. Pantala is focused on the "Business to Consumer" (B2C) e-commerce, frequently referred to as "e-tailing", which according to Datsko [4], is a type of commerce where the key players are the online stores and the individual customers with the former offering to send the latter goods and services via the internet in return for money. E-tailing differs from trading in conventional stores regarding customers' behaviour, as they are able to search for products and services, compare prices and read others' reviews. There is also another type of e-commerce, commonly known as re-commerce, which consists of the recovery and resale of a garment by the original retailer. Re-commerce has become a fully integrated part of the industry and has been growing 21 times faster than traditional retailing [1].

3.1.1. *Operations and logistics*

With regards to delivery performance, of all the key factors that have a major impact on order-processing performance, time is invariably the most significant one [4]. An inappropriate management of time can have a devastating impact on the shipping process and the relationship with customers.

It is also notable that the increasing adoption of Environmental, Social and corporate Governance (ESG) reporting, along with growing awareness of the concept of the circular economy, are creating an impetus for the fashion industry to seek more environmentally sustainable and ethically transparent supply chains [9].

Finally, in order to ensure consistency and accuracy in fast order fulfilment, according to Christopher et al. [3], a thorough understanding of the market, a successful alignment of processes and a compact operating system prove to be essential in order for a company to achieve a quick response capacity.

4. Modelling and Analysis

4.1. *Methodology choice*

As there were dynamic variables and future steps that could not be controlled, a virtual simulation was developed in order to model the early months of the company's operational activity. Therefore, the methodology chosen was a mixture of a simulation modelling along with a real case study.

4.2. *Justification of the methodology chosen*

During Pantala's pre-launch phase - like in most start-up ventures - there were more operational unknowns than certainties. Fortunately, a simulation methodology can be a powerful tool that can be used to provide support for decisions concerning the design, planning and operations of nascent and emerging supply chain systems [6][10]. The use of computational simulation in such cases can produce very useful results and it seems appropriate to quote the late Professor Patrick Henry Winston [11] on this point: "…models, using differential equations, probabilities, physical and computational simulations …are used to explain the past, predict the future, understand the subject and control the world." It is also important to bear in mind that the methodology used was a mixture of a simulation and a real case study. As Mohd Noor [8] and Johansson [5] explain, a case study methodology enables the researcher to gain a holistic view of a certain phenomenon or series of events and seems to be very helpful when the organisational activity is changing very fast within any given company.

4.3. *Software selection*

The simulation modelling was carried out using the 'AnyLogic' simulation software tool, which was selected for its ease-of-use and its versatility in presenting final results.

4.4. Data gathering

Most of the activities inside the warehouse were to be carried out exclusively by Pantala's employees. In order to carry out the simulation in AnyLogic it was important to define all the main activities and their standard times. Broadly, six core activities were identified which are as follows:

- Arrivals management (ARR).
- Output management.
- Packaging.
- Quality Check (QC).

- Storage.
- Tagging (abbreviation: TPD, which includes tagging, packaging, and product differentiation tasks).

Once all the different activities had been defined, it was important to decide how many garments were going to enter and leave the warehouse during the first six months.

Table 1 presents the demand-forecast data which highlights the variation of the number of garments during the first six months with progressive growth:

Table 1. Initial 6-months forecast of customer and garment quantities.

Subscribers	Jul 20'	Aug 20'	Sep 20'	Oct 20'	Nov 20'	Dec 20'	Jan 21'
Customers	33	63	88	144	193	237	309
Necessary garments	99	189	264	432	579	711	927
Purchase orders sent at the beginning of the month	99	135	139	237	264	267	357
Garments sold at the end of the month	7	13	18	30	41	50	65
Warehouse stock at the beginning of the month	0	92	214	335	542	765	982
Warehouse stock at the end of the month	92	214	335	542	765	982	1,274
Following month's resting garments	38	89	140	227	321	412	1,274
Previous month's reused garments	0	54	125	195	315	444	570

4.5. Data analysis

4.5.1. Model conceptualization

The simulation was going to be based on modelling product flow scenarios inside Pantala's warehouse, in which garments would be received into, and be shipped out of, after several processes have been carried out.

The correct identification of potential bottlenecks along with the process of reducing them via optimisation would be crucial for the warehouse's performance [2]. Therefore a "Discrete Event Simulation" (DES) approach has been adopted.

4.5.2. Model assumptions

In any modelling, it is essential to define the different activities involved as well as the distribution of their duration times. Cycle times were based on measures assumed and recorded in brief past trials (prior to the company's launch).

Table 2. Cycle times

Operation	Cycle time (min)
Arrivals management	Random between 1 and 5 minutes
Output management	Random between 1 and 3 minutes
Packaging	Maximum 10 minutes, most likely 5 minutes and minimum 3 minutes
Quality Checks	Maximum 7 minutes, most likely 5 minutes and minimum 2 minutes
Storage	With the most likely value of 2 minutes
Tagging	With the most likely value of 2 minutes
Separation	With the most likely value of 3 minutes

Table 3 shows the distribution types that have been selected for every single task:

Table 3. Distribution types

Operation	Cycle time (min)
Arrivals management	Uniform (1,5) (Batches of 1)
Output management	Uniform (1,5) (Batches of 1)
Packaging	Triangle (3,5,10)
Quality Checks	Triangle (2,5,7)
Storage	Poisson (2)
Tagging	Poisson (2)
Separation	Poisson (3)

4.5.3. Model development

Pantala's operational calendar was designed to be predetermined in order to make the operations and logistics easier to control and carry out. The model is clearly divided into four different flows to aid further clarity of representation. The purchase orders sent to the suppliers (brand owners) have been represented as flow 1, composed of three main activities: arrivals (receiving goods, ARR), quality checking (QC1 and QC2), and tagging. Subsequently, the garments are redirected to the shipping area in order to be transported to the laundry facility (external supplier). Flow 2 represents the garments that are returned to the warehouse by the customers. The flow is based on three different activities: arrivals, quality checking and sorting which involves dividing the garments into two different groups (resting and reused). Subsequently, the garments are transferred to the shipping area to be transported to the laundry facility. The garments that return from the laundry and are going to be used the following month, are shown in flow 3. It is composed of arrivals, quality checking (QC1 and QC2) and packaging activities. After the completion of these activities, the garments are taken to the shipping area. The last flow, number 4, shows the garments arriving from the laundry that are going to be stored. There are two main activities which are arrivals management and quality checking. Once both have finished, the garments are transported to the storage area.

In the following tables, we have the different elements and tools used in AnyLogic in order to represent the activity flows within the warehouse:

Table 4. Description of AnyLogic Tools 1

Tool	Usage
Source	Represents the arrival of garments to the warehouse. The garments come from the brands, customers, and the laundry.
Rack Store	Shows the arrivals' management by the employees. Follows the schedule of the employees in charge of the arrivals.
Delay	Represents the different workstations within the warehouse. Corresponds to the arrivals, quality check, "separation", tagging and packaging.
Queue	Enables the different flows to have some garments waiting to be processed. It must be before and after the different workstations.
Seize	Allows the entrance of workers into the workstations and put them in charge of it.
Release	Allows the exit of workers from the workstations. It has a direct connection with the previous seize.

Table 5. Description of AnyLogic Tools 2

Tool	Usage
SelectOutput	Used to represent the quality check point. It carries a specified probability and has two different outputs as the garments could pass or fail the quality check.
Sink	Corresponds to the different output areas within the warehouse. It has three main recipients: laundry, customers and storage area.
TimeMeasureStart	Consists of a tool that provides information related to every single garment that goes through. It has a direct connection with the following TimeMeasureEnd element.
TimeMeasureEnd	Consists of a tool that provides information for every single garment that goes through it. It has a direct connection with the following TimeMeasurestart.
Schedule	Represent the different shifts of the employees and their breaks.
ResourcePool	Used to represent the different employees. There are four of them in charge of arrivals, quality check, packaging, tagging and dividing the garments.

4.5.4. Simulation vs. Real-life results:

Of the total four flows, only two of them (flows 1 and 3) took place during the first month of actual operation. Simulation and the real-life case study both allowed to compare the % of utilisation per workstation and the processing time when carrying out any task within the warehouse. The processing time is segmented into its maximum (MAX), minimum (MIN) and average (AVG) values.

In the following table the results for flow 1 (f1) during the first month (M1) of actual operations and simulation scenarios are shown:

Table 6. Comparison of results M1 f1

Category	Flow	Simulation M1	Actual M1
Employee Utilisation ARR (%)	1	0%	0%
Employee Utilisation QC1 (%)	1	12%	10.3%
Employee Utilisation QC2 (%)	1	12%	10.3%
Employee Utilisation TPD (%)	1	8%	7.72%
Average PT (min)	1	239.5	240.31
MAX PT (min)	1	130.7	140.12
MIN PT (min)	1	5.72	5.88
QC Passed (Didn't Passed)	1	97 (2)	99

Utilisation was lower in real-life than in the simulation as the distributions designed for the simulation were slightly wider. The processing times (PT) proved to be quite similar, and the results of the QC completely changed as all the garments passed it.

Similarly, table 7 shows the data for flow 3 (f3) during the first month of actual operations and simulation scenarios.

Table 7. Comparison of results M1 f3

Category	Flow	Simulation M1	Actual M1
Employee Utilisation ARR (%)	3	0%	0%
Employee Utilisation QC1 (%)	3	13%	11.6%
Employee Utilisation QC2 (%)	3	13%	11.6 %
Employee Utilisation TPD (%)	3	11%	12.8 %
Average PT (min)	3	683	668.1
MAX PT (min)	3	341.8	355.7
MIN PT (min)	3	17.72	11.51
QC Passed (Didn't Passed)	3	96 (3)	99

The utilisation for arrivals management (ARR) in both flows (f1 and f3) is nearly 0% as it is of very little complexity.

The simulation and actual real-life results were highly aligned. Figure. 4 presents an overview in terms of utilisation (%) as a comparison between real-life and the simulation. The utilisation in terms of packaging was higher in the real-life scenario because packaging was more complex than originally envisaged. However, the utilisation relating to the QC department was lower as the simulation distributions were wider than those in real-life.

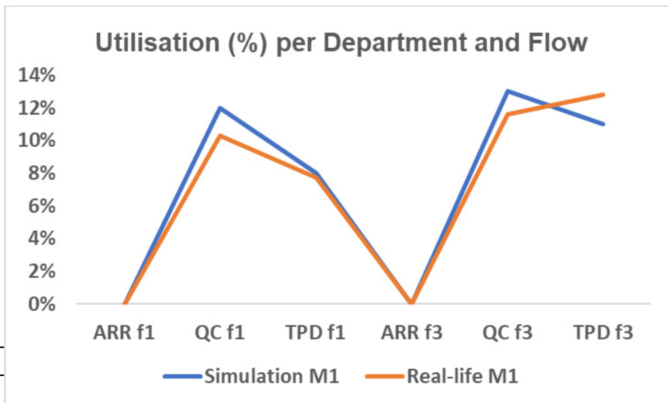

Fig. 4. Simulation vs. Actual Real-life (Utilisation, M1)

Figure 5 depicts the close-step matching comparison of processing times (in minutes) between simulated and actual scenarios.

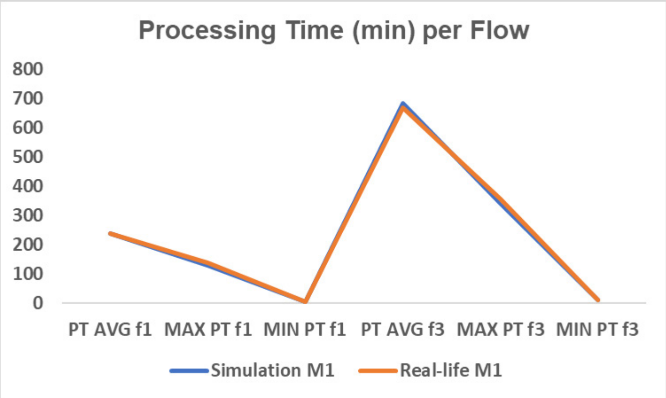

Fig. 5. Simulation vs. Actual (Processing Time, M1)

The graphical representations of results, demonstrate the reliable semblance of the simulation data with actual operations in M1 that validated assumptions and preparations in terms of resource readiness for the successful "go-live" of operations.

5. Conclusion and future work

The data obtained via the real-life case study confirmed the validity of the simulation model with an average relative error of less than 5% for most performance indicators. Actual data gathered during Pantala's first month of operations was used to further optimise operational tasks and the simulation parameters. This approach can form a useful blueprint for any product-based start-up, by enabling entrepreneurs to leverage digital tools to plan complex operations successfully and demonstrate robust risk management to potential investors.

By simulating critical start-up operations, it was possible to offer Pantala's inexperienced staff a reliable baseline for process execution, offering them a valuable future planning tool for further investments, since it only requires minor changes when modelling alternative scenarios with regards to scale and scope.

References

[1] Morrison, H., Petherick, L., and Ley, K., 2019. The future of circular fashion. Assessing the viability of circular business models. Fashion for Good, pp. 29. https://fashionforgood.com/wp-content/uploads/2019/05/The-Future-of-Circular-Fashion-Report-Fashion-for-Good.pdf

[2] Pound, E. S., Bell, J., and Spearman, M., 2014. Factory Physics for Managers: How Leaders Improve Performance in a Post-Lean Six Sigma World. 1st ed. McGraw-Hill.

[3] Christopher, M., Lowson, R. and Peck, H., 2004. Creating agile supply chains in the fashion industry. International Journal of Retail & Distribution Management, 32 (8), pp. 367-376. https://doi.org/10.1108/09590550410546188

[4] Datsko, E., 2019. Successful factors and barriers for e-commerce business within the fashion industry. Senior Thesis 2019, pp.8-28. http://hdl.handle.net/10251/124237

[5] Johansson, R, 2007. On Case Study Methodology. Open House International, 32(3), pp. 48-54 https://doi.org/10.1108/OHI-03-2007-B0006

[6] Kleijnen, J. P., 2005. Supply chain simulation tools and techniques: a survey. International journal of simulation and process modelling, 1(1-2), pp. 82-89. https://doi.org/10.1504/IJSPM.2005.007116

[7] Business Insider India. https://www.businessinsider.in/science/news/the-fashion-industry-emits-more-carbon-than-international-flights-and-maritime-shipping-combined-here-are-the-biggest-ways-it-impacts-the-planet/articleshow/71640863.cms; 2019 [accessed 3 February 2022]

[8] Noor, K. B. M., 2008. Case study: A strategic research methodology. American journal of applied sciences, 5(11), pp. 1602-1604.

[9] Shen, B., 2014. Sustainable fashion supply chain: Lessons from H&M. Sustainability, 6(9), pp. 6236-6249. https://doi.org/10.3390/su6096236

[10] Umeda, S., & Jain, S., 2004. Integrated Supply Chain Simulation System (ISSS)-Modeling Requirements and Design Issues. National Institute of Standards and Technology, US deparment of commerce. Washington, DC, pp.2. https://nvlpubs.nist.gov/nistpubs/Legacy/IR/nistir7180.pdf

[11] MITopencourseware. Fall 2010. Artificial Intelligence. Lecture Videos. Lecture 1: Introduction and Scope. https://ocw.mit.edu/courses/6-034-artificial-intelligence-fall-2010/resources/lecture-1-introduction-and-scope/ [accessed 18 August 2022]

[12] Hultberg, E. and Pal, R., 2021. Lessons on business model scalability for circular economy in the fashion retail value chain: Towards a conceptual model. Sustainable Production and Consumption, 28, pp.686-698.

[13] Kant Hvass, K. and Pedersen, E.R.G., 2019. Toward circular economy of fashion: Experiences from a brand's product take-back initiative. Journal of Fashion Marketing and Management: An International Journal, 23(3), pp.345 365.

[14] Atstja, D., Cudečka-Puriņa, N., Vesere, R., Abele, L. and Spivakovskyy, S., 2021, May. Challenges of textile industry in the framework of Circular Economy: Case from Latvia. In International Conference on Sustainable, Circular Management and Environmental Engineering (ISCMEE 2021). EDP Sciences.

[15] Albu, A.V., SOPOTA, D., CACIORA, T., HERMAN, G.V., BERDENOV, Z., ILIES, A., ILIES, D.C., KECSE, G., STURZU, B. and Ghergheles, C.G., 2021. Digitalization of garment in the context of circular economy. world, 30, p.31.

[16] Dissanayake, D.G.K. and Weerasinghe, D., 2021. Towards circular economy in fashion: Review of strategies, barriers and enablers. Circular Economy and Sustainability, pp.1-21

2024-01-12

Modelling the operations of a circular economy fashion start-up

de Olañeta, Javier

Elsevier

de Olañeta J, Patsavellas J, Salonitis K. (2024) Modelling the operations of a circular economy fashion start-up. Procedia CIRP, Volume 120, 2023, pp. 1618-1623

https://doi.org/10.1016/j.procir.2023.12.005