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TOWARDS INDUSTRY 5.0: CIRCULAR ECONOMY AND THE ROLE OF CONSUMER BEHAVIOUR

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Abstract
As the global economy shifts from classic industrial models to more circular frameworks, Industry 5.0 emerges as a transformative paradigm emphasizing human-centric, sustainable, and resilient systems. Central to this evolution is the circular economy, which seeks to minimize waste, maximize resource efficiency, and extend product lifecycles. This paper explores the intersection of Industry 5.0 and the circular economy, focusing particularly on the critical influence of consumer behaviour. By integrating insights from behavioural and systems thinking, the study highlights mechanisms to encourage more circular consumption pattern. Ultimately, the paper argues that aligning technological innovation with behavioural change is essential to realizing the full potential of Industry 5.0 and achieving a regenerative economic future.
Keywords: *Industry 5.0, consumer behaviour, circular economy, systems thinking, system dynamics*

JEL Classification: O33, Q56, D12, Q01, O31

1. INTRODUCTION

Industry 5.0 builds upon the technological advancements of Industry 4.0 by reintroducing human intelligence and creativity into the manufacturing process. It emphasizes collaboration between humans and machines to achieve sustainable and personalized production outcomes (Ghobakhloo *et al*., 2022). This paradigm shift aims to create value through ethical considerations, customization, and the integration of advanced technologies like artificial intelligence (AI), the Internet of Things (IoT), and digital twins (Dwivedi *et al*., 2023). The circular economy challenges the traditional linear model of "take, make, dispose" by promoting practices that extend the lifecycle of products and materials (Ellen MacArthur Foundation, 2013). The integration of circular economy principles within Industry 5.0 frameworks enables the development of closed-loop systems where products are designed for longevity, adaptability, and recyclability, thereby reducing the environmental footprint of industrial activities (Ghobakhloo *et al*., 2022).

Research indicates that consumer awareness and attitudes towards sustainability are increasing, with many expressing a willingness to support businesses that prioritize environmental and social responsibility (PWC, 2023). However, despite these positive inclinations, there exists a notable gap between consumers' intentions and their actual behaviours – a phenomenon often referred to as the "intention-action gap" (Sustainable Brands, 2022). Factors such as convenience, cost, and accessibility continue to drive consumer choices, sometimes at the expense of sustainability considerations.

Strategies such as providing clear information about the environmental impact of products, offering incentives for sustainable behaviours, and creating convenient systems for recycling and product returns can encourage consumers to make choices that support circular practices (Sustainable Brands, 2022). Moreover, leveraging digital platforms and social media can amplify the reach of sustainability messages and foster community engagement around circular economy initiatives (GHD, 2022). To combat this, it is crucial to establish clear standards and certifications for sustainable products and to promote transparency in corporate sustainability practices.

This paper will be focusing on the fashion industry, valued at over $2.5 trillion globally, is undergoing a major transformation, propelled by the need for environmental sustainability, ethical production, and a more conscious consumer base (Ellen MacArthur Foundation, 2017, and Niinimäki, 2020). Traditional models of production and consumption – especially those tied to fast fashion – have proven incompatible with ecological and social well-being. This context has paved the way for Industry 5.0, a new industrial paradigm emphasizing human-centric innovation, environmental responsibility, and long-term system resilience (Meadows, 2008). A crucial path to aligning fashion with Industry 5.0 is through the circular economy (CE), which rethinks resource use to eliminate waste and enable closed-loop systems. However, implementing CE in fashion is complex due to entrenched linear supply chains and unpredictable consumer behavior (Bocken,2016 and European Commission, 2021).

This paper explores how system dynamics (SD) modeling can be employed to design, test, and optimize circular fashion systems, particularly emphasizing the influence of consumer behavior as a dynamic and strategic variable. This paper will be divided into the following sections: sections two will review how systems thinking supports the above-mentioned challenges, section 3 will illustrate through a fashion case study which illustrates the usefulness of systems thinking in the development of industry 5.0 concepts with focus on consumer behaviour, and then conclusion for the whole paper.

2. LITERATURE REVIEW

System thinking has been utilized as an effective management tool for modelling complex real-world systems, comprehending their behavior and carrying out tactical policies. Lertpattarapong (2002) and Hihuchi and Troutt, (2004) argued that system dynamics can act as an effective technique to monitor the non-linear dynamic behavior of a system and aiding the understanding of ways in which structure and specifications of the system determines behavior patterns

The conceptual idea fueling system dynamics is the communication of all items within a particular system through casual relationships (Berry and Naim, 1996). System dynamics asserts that these relationships form the underlying structure for any system. The production of a dynamic design of a system needs the recognition of causal relationships and referral modes that make up the feedback loops of the system. The feedback system discussed here describes the circumstance where variable A impacts variable B and B in turn impacts A through a series of causes and effect (Canella *et al*., 2008 and Torres and Maltz, 2010). System dynamics differs to other methods employed to study systems that are complex. This is primarily because of its use of feedback loops extensively. The foundation of system dynamics models are Stocks and Flows, which best describes the connection formed by feedback loops (Georgiadis *et al*., 2005). Performing simulation analysis termed "what-if" are carried out to examine several policies that significantly aid the understanding of changes in the system over time (Juntunen and Juga, 2009).

System thinking proposed solving the problem would improve awareness, education and communication. The bullwhip effect was a phenomenon of demand amplification experienced by Procter and Gamble (Lee *et al*., 1997). Through simulation studies carried out in an upstream company, it was deduced that even under constrained supply, deliveries are high. In addition, it was noted that as shipment move downstream, they are decreased in the supply chain (Shukla *et al*., 2009). The backlash impact reflected bullwhip effect and can lead to inefficient scheduling and high transportation cost. Various studies have been conducted to reduce and measure the variability in demand and the impacts on the supply chain performance such as financial performance, transportation and production operations (Potter and Lalwani, 2008).

The effect of system dynamics on supply chain performance was also explored in some case studies such as automobiles, food, grocery, electronics and toys industries (Kumar and Nigmatullin, 2011). Therefore, a dynamic framework where the causal relationships and feedback of these variables in the system as they run in real world over a long period needs to be highlighted. It enables the understanding of the variables and how various policies affect the behaviour of the system. The system dynamics model helps in understanding the system through the feedback structures in the system and shows the relationship of each variables linked (Sterman, 2000).

3. RESEARCH MODEL

The aim of carrying out this step in the modelling process is to understand the structural causes that trigger the changes of system performance arising from unpredictability of customer order. The inventory model seeks to provide and extend the method of managing inventory that can investigate the issue of circular economy and the role of consumer behaviour in the multiple fashion companies in UK and China. In this research, the system dynamic model comprises all the variables involved in a downstream flow chain that represents the movement of fashions products between distributor inventory and retailer inventory storage and finally delivered to consumers as shown in Figure 1.

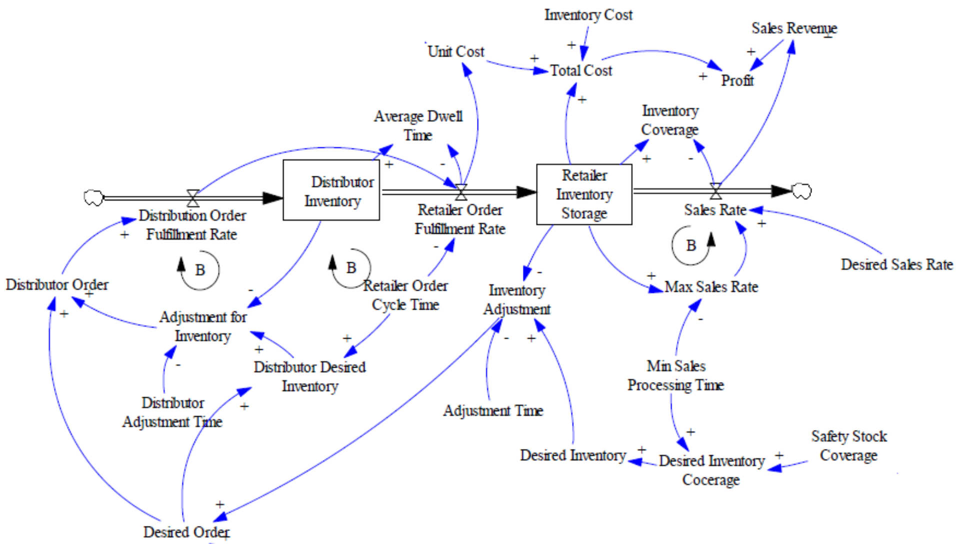

Figure 1. The suggested System dynamics model

The stock distributor inventory is increased by an inflow called distributor order fulfilment rate, and decreased by the outflow, retailer order fulfilment rate. Therefore, if the sales rate or the demand, at any given time is greater than the amount of fashion distributor inventory, the retailer can only sell the smaller one of these amounts, that is, the amount he has ready. The fashion retailer and distributor ordering process in this model include accounting for the reduction of their inventory before a decision can be made as to the level of inventory to order, they must also determine how long the inventory they have in stock will last.

Consumers purchase from the retailer which then prompts the retailers to adjust their current level of inventory to know the difference between their actual inventories from the desired. Both the fashion retailer and distributor carry fashion inventories and have in place separate policies. Similarly, the distributor and the retailer have order forecasting policies in place using exponential smoothing methods shown in the model. The feedback loops and different variables signify the dynamic and complex interrelations between customer orders, desired inventory level, order fulfilling rates, the ability for the distributor to fulfil order, distributor own desired inventory levels, and the time to fill this desired inventory levels.

The stock and flow structure of the fashion supply chain in this research includes delay between orders and fulfilling order. The structure includes the distributor inventory of unfulfilled orders, those orders that have been placed but not yet received. The order fulfilling rate is now the firm decision rule. The fulfilling rate depends on the fashion distributor or retailer inventory of barrel that have been ordered but not yet received and the average inventory fulfilling delay. The distributor and retailer still order to replace expected flow out from their stocks and try to reduce the difference between the desired inventory and actual inventory.

Under the extreme condition test, the robustness of the model is tested under extreme circumstance. The extreme condition test suggests the behaviour of the model to be realistic despite the various polices or inputs in the model. The extreme test improves the validation process of the model by examining the beyond the initial boundaries. Despite the size of model, all the concerned variables such as zero can be tested to verify whether the system behaviour matches the expected results. Inventory should never be zero no matter the size of demand.

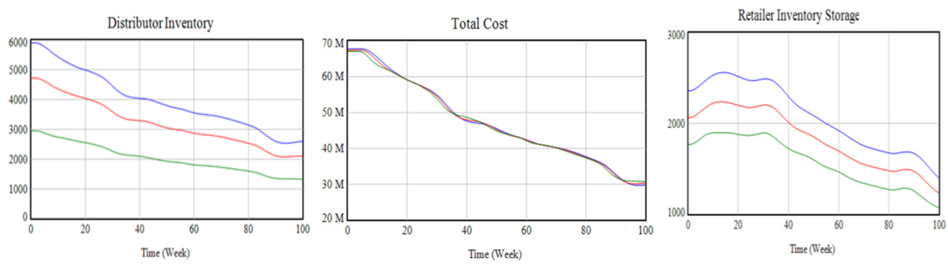

Figure 2. The tested results

As shown in Figure 2 the base case and low order pattern have the effect of increasing the inventory level and there is a significant rise in inventory level in the low order under retailer inventory storage. The model responds well to the base case and low order pattern with smaller level of fashion distributor inventory and retailer inventory storage, except under high order. Low order has the undesirable effect of increasing the level of retailer inventory storage. These results are important as they display that the test is sufficient to reveal the effect of the demand uncertainties under the different policies. The results from the sensitivity analysis of fashion distributor inventory, retailer inventory storage, total costs, and profit presents questions how managers can achieve best policy-decision in responding to the different ordering pattern. The purpose for conducting an in-depth sensitivity analysis is to search and find the best policy. The performance metrics employed in the models were based on financial and non-financial metrics.

4. CONCLUSIONS

Industry 5.0 offers a compelling framework for transforming the fashion industry into a system that prioritizes human well-being and environmental stewardship. A circular economy is central to this vision, yet it cannot succeed without actively engaging consumers. Understanding and shaping consumer behavior – through education, digital tools, incentives, and social influence – is essential. System dynamics offers a unique approach to capture the complexity of this transformation, revealing feedback loops and leverage points that traditional linear models overlook. By combining technology, ethics, and design thinking, the fashion industry can not only reduce its environmental footprint but also redefine value creation in a world that urgently needs sustainable solutions.

References

1) Berry, D. and Naim, M.M. (1996). Quantifying the Relative Improvements of Redesign Strategies in a Personal Computer Supply Chain. International Journal of Production Economics, 46-47(1), pp. 181-196: 131–153.
2) Bocken, Nancy & Pauw, Ingrid & Bakker, C.A. & van der Grinten, Bram. (2016). Product design and business model strategies for a circular economy. Journal of Industrial and Production Engineering. 33. 1-13. 10.1080/21681015.2016.1172124.
3) Cannella, S., Ciancimino, E. and M´arquez, A.C. (2008). Capacity constrained supply chains: a simulation study. International Journal of Simulation and Process Modelling, 4 (2), pp. 139–147.
4) Dwivedi, Y.K., *et al*. (2023). 'Beyond Industry 4.0: a systematic review of Industry 5.0 technologies and implications for social, environmental and economic sustainability', Asia Pacific Journal of Business Administration, 15(2), pp. 133-157.
5) Ellen MacArthur Foundation (2013). Towards The Circular Economy: Economic and Business Rationale for an Accelerated Transition. [pdf] Available at: https://www.ellenmacarthurfoundation.org/towards-the-circular-economy-volume-1 [Accessed 8 June 2025].
6) Ellen MacArthur Foundation. (2017). A New Textiles Economy: Redesigning Fashion's Future.]
7) European Commission. (2021). Industry 5.0: Towards a Sustainable, Human-centric and Resilient European Industry.
8) Georgiadis, P., Vlachos, D. and Iakovou, E. (2005). A system dynamics modeling framework for the strategic supply chain management of food chains. Journal of Food Engineering, 70 (3), pp. 351–364.
9) GHD (2022). 'Benefits of Industry 5.0 and the Circular Economy'. [online] Available at: https://www.ghd.com/en-gb/insights/five-business-benefits-of-shifting-towards-industry-5-and-its-push-for-a-circular-economy [Accessed 8 June 2025].

10) Ghobakhloo, M., *et al*. (2022). 'Beyond Industry 4.0: a systematic review of Industry 5.0 technologies and implications for social, environmental and economic sustainability', Asia Pacific Journal of Business Administration, 15(2), pp. 133-157.
11) Higuchi, T. and Troutt, M.D. (2004). Dynamic simulation of the supply chain for a short life cycle product. Computers & Operations Research, 31 (7), pp. 1097–1114.
12) Juntunen, J. and Juga, J. (2009). Controlling the bullwhip with transport capacity constraints. International Journal of Servi ces and Standards 5,pp. 160 171.
13) Kumar, S. and Nigmatullin, A. (2011). A system dynamics analysis of food supply chains Case study with non-perishable products. Simulation Modelling Practice and Theory 19 pp. 2151 2168Meadows, D. (2008). Thinking in Systems: A Primer.
14) Lee, H.L., Padmanabhan, V. and Whang, S. (1997). The bullwhip effect in supply chains. Sloan Manag ement Review 38 pp.93-102.
15) Lertpattarapong, C. (2020). Applying System Dynamics Approach to the Supply Chain Management Problems Msc. Thesis, Massachusetts Institute of Technology.
16) Niinimäki, Kirsi & Peters, Greg & Dahlbo, Helena & Perry, Patsy & Rissanen, Timo & Gwilt, Alison. (2020). The environmental price of fast fashion. Nature Reviews Earth & Environment. 1. 189-200. 10.1038/s43017-020-0039-9.
17) PWC (2023). 'Three industries where consumer behaviour is powering the circular economy'. [online] Available at: https://www.pwc.co.uk/issues/esg/three-industries-where-consumer-behaviour-is-powering-circular-economy.html [Accessed 8 June 2025].
18) Potter, A. and Lalwani, C. (2008). Investigating the impact of demand amplification on freight transport. *Transportation Research Part E* ,44(5), pp. 835–846.
19) Shukla, V., Naim, M.M. and Yaseen, E.A. (2009). Bullwhip'and'backlash' in supply pipelines. International Journal of Production Research 47, pp. 64 77 6497.
20) Sterman, J. D. (2000). Business Dynamics: System Thinking and modeling for a complex World. Irwin/McGraw Hill, Boston
21) Sustainable Brands (2022). 'How Does Consumer Behavior Challenge the Circular Economy?'. [online] Available at: https://sustainablebrands.com/read/consumer-behavior-challenge-circular-economy [Accessed 8 June 2025].
22) Torres, O.C. and Maltz, A.B. (2011). Understanding the financial consequences of the bullwhip effect in a multi echelon supply chain. Journal of Business Logistics 31 (pp. 23 41.