

Circular Economy in Global Apparel Supply Chains: Restructuring the Fashion System using Agent Based Approach (ABA)

Onilee Wilson^{a,b,c,@}

^aCornell University

^bJeb E. Brooks School of Public Policy

^cCornell Institute for Public Affairs

@ email: omw5@cornell.edu

ABSTRACT: The purpose of this paper is to use the Agent Based Approach to analyze the Global Apparel Supply Chain system. Through this paper, I will use DSRP analysis to understand the system as it is, POSIWID analysis to compare the current system to the aspirant system, and CAS analysis to define the agents of the system. With these analyses methods, I will illustrate where interventions can be made within the supply chain system to alter the system structure from a linear to circular model. Through this change in system structure, these recommendations will address the emergent behaviors of the supply chain system through circularity and sustainability initiatives.

Keywords: Circular Economy | Circularity | Responsibility | Sustainability | Fashion | Textiles | Apparel

Cite this paper: Onilee Wilson (2022) Circular Economy in Global Apparel Supply Chains: Restructuring the Fashion System using Agent Based Approach (ABA) *Journal of Systems Thinking*. (22) 5.

Introduction

CLOTHING IS ONE of the basic human needs, yet most of us humans do not typically posit where the shirt on our back came from, let alone how that shirt can affect the environment or communities across the globe. As consumers, we tend to focus on the product in front of us, rather than considering how it was made and where it is going after we are finished with it. The purpose of this paper is to look beyond what we see on the rack to instead better understand the supply chain system as it is and how we can make changes to improve its outcomes.



Figure 1: Linear (Current) Model of Global Apparel Supply Chains

The first rule of systems thinking is to “fall in love with reality¹.”

Yet, I recognize it is hard to love the acknowledgement of our consumptive culture contributing to negative environmental and social impacts globally. However, in order to implement “good” in the world, we must distinguish what is “bad” and what we can do to influence change for the better. Therefore, through this Agent Based

¹ D Cabrera, et al., The Four Waves of Systems Thinking, in *The Routledge Handbook for Systems Thinking*, edited by D Cabrera, et al., Routledge Press, London, UK, 2022; 2; 3; 4; 5; 6; 7; and 8

Approach (ABA) Analysis, we as systems thinkers can change the behaviors within a system to be more collaborative, educated, and innovative to improve outcomes for stakeholders throughout the global apparel supply chain system².

² 9

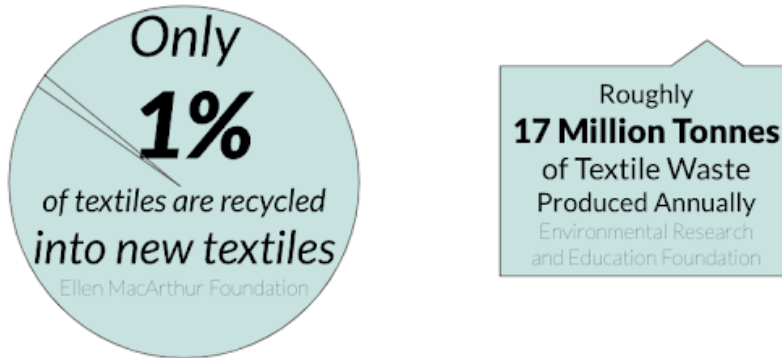


Figure 2: Infographics of Current Impacts of the Apparel and Textile Industry

The current system of global apparel supply chains is quite linear. As shown in Figure 1, the relationships between each step in the supply chain flow in one direction, with a clearly distinguished beginning and end point. As inputs of the system inevitably become outputs, along with it comes mass amounts of textile waste, roughly 17 million tons of it from the U.S. alone each year³. About 73% of textiles end up in a landfill while product life cycles continue to shorten with each year, causing the issues surrounding landfill pollution to continue to worsen⁴. Despite efforts within the supply chain to increase product life cycles and decrease waste, only 1% of textiles are recycled to make new textiles⁵.

³ 10

⁴ 11

⁵ 11

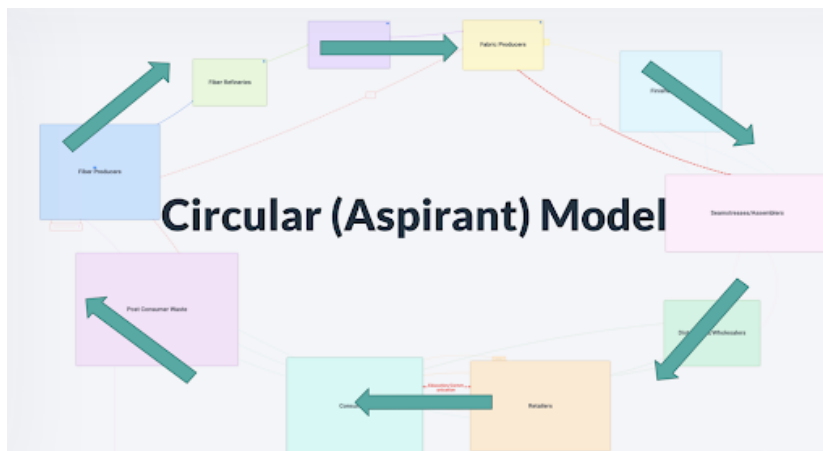


Figure 3: Circular (Aspirant) Model of Global Apparel Supply Chains

As small inputs are not enough to provide the change necessary to

stop and reverse the negative impacts caused by the fashion industry, structural change to the entire system needs to take place. Therefore, through the use of ABA Analysis, I propose that the system structure itself must be adjusted from an open to a closed-loop system to effectively address and revert the negative outcomes caused by the current linear model⁶. As Figure 3 illustrates, the circular model creates a closed-loop system through converting outputs into inputs, rather than inputs into outputs.

⁶ 9

Methods

Why an Agent Based Approach (ABA)?

THE AGENT BASED APPROACH, or ABA, is used to understand a system to recommend interventions and solutions to improve the outcomes of a system and its agents⁷. Firstly, it is important to note that mental models include a combination of two equal parts, information and thinking⁸. This means that throughout any ABA Analysis of a mental model, information and data on the topic are equally as crucial as thinking about each aspect of the topic, especially with how they relate to one another and to the real world⁹. I will go more into depth with the application and implementation of ABA and mental modeling within apparel supply chains specifically, however it is crucial to highlight why this approach is generally beneficial, as well as why it is more useful in this instance than Agent Based Modeling (ABM)¹⁰. One key advantage ABA has over ABM is its versatility and diversity in application¹¹. The Cabrera Research Lab states that “ABA is a tool anyone can use,” however ABM “require(s) specific parameters detailing specific purposes¹².” As this project requires a broader approach, ABA Analysis is the ideal choice to analyze the complexities of the global apparel supply chain system.

⁷ 9

⁸ 4; 7; and 12

⁹ 4; 7; and 12

¹⁰ 9

¹¹ 9

¹² 9

Steps to an Agent Based Approach (ABA)

NOW THAT WE HAVE recognized why ABA Analysis was chosen to analyze global apparel supply chains, it is crucial to understand the steps involved in completing this analysis method¹³. Through these analyses, recommendations on how to influence behaviors within the system can be made to improve outcomes.

¹³ 9

Step 1: DSRP Analysis of the System

FIRSTLY, THIS APPROACH requires the analyzer to understand the system as it is and to test your understanding of the system against the “real world.” This is accomplished through DSRP (Distinctions, Systems, Relationships, Perspectives) Analysis and Systems Mapping of Mental Models¹⁴. The DSRP analysis considers multiple aspects of a system simultaneously, which allows the researcher to fully understand each component of the system and how they relate to one another; see Figure 4 for basic structures of DSRP¹⁵. DSRP Analysis serves as a guide to mapping a system, because each component of DSRP is combined to create a Systems Thinking Map¹⁶. Through this DSRP Analysis and mapping the system, we can begin to understand the complexities of the system to create recommendations.

¹⁴ 1; 2; 3; 4; 5; 6; 7; 8; and 12

¹⁵ 1; 2; 3; 4; 5; 6; 7; and 8

¹⁶ 1; 2; 3; 4; 5; 6; 7; and 8

Patterns	Elements
Distinctions (<i>D</i>)	identity (<i>i</i>) ↔ other (<i>o</i>)
Systems (<i>S</i>)	part (<i>p</i>) ↔ whole (<i>w</i>)
Relationships (<i>R</i>)	action (<i>a</i>) ↔ reaction (<i>r</i>)
Perspectives (<i>P</i>)	point (<i>ρ</i>) ↔ view (<i>v</i>)

Table 1: Basic Structures of DSRP [1]

Step 2: POSIWID and CAS Analysis

NEXT, WE MUST CONSIDER the system’s purpose in regard to how the system currently operates along with the outcomes it produces. This is a crucial step, as a “purpose of a system is what it does”, or POSIWID, rather than what its intent is¹⁷. Through POSIWID Analysis, we can understand both the intended and unintended purposes of the system, as well as how we can make interventions within the system to correct where unintended outcomes are taking place. In order to determine the agents within a system, it is important to conduct a Complex Adaptive Systems (CAS) Analysis¹⁸. Through a CAS Analysis, we can determine who are those affecting and being affected by the system along with their perspective, what rules they follow, their emergent properties, and their effect on the behavior of the system¹⁹. One important note of using CAS Analysis to determine the agents of the system is recognizing that not agents have agency, but, despite this, those agents can still be an important component of that system.

¹⁷ 9; and 13

¹⁸ 4; 14; and 15

¹⁹ 4; 14; and 15

Step 3: Rubric and Recommendations

THROUGH DSRP, POSIWID, AND CAS Analysis, recommendations on how to improve outcomes of the system can be made. In order to provide guidance for the recommendations, it is useful to establish a recommendation rubric. This rubric provides specific rules and guidelines on what the recommendations should, or should not, include. Additionally, it elaborates on what specific interventions have been implemented into the system to improve its outcomes. Through establishing a rubric prior to making recommendations, it ensures that the recommendations will be uniform across all parts of the system.

Results

TO BEGIN THE RESULTS section, I would like to provide a 10,000 foot level comparing the current, linear system to the aspirant, circular system. As stated prior, the recommendations of this system will not simply occur within the DSRP of the current system structure. Instead, the recommendation for the Global Apparel Supply Chains system is to change the current, linear model's system structure into a new circular system structure or cognitive jig. Figure 5 illustrates the juxtaposition of the two key complex systems and compares the key differences between the current and aspirational systems. In order to provide an overview for the topics analyzed throughout the ABA Analysis process, I will provide a brief tour of the map and its DSRP flow²⁰.

²⁰ 9

The current, linear system, which is located at the upper portion of the map, consists of one directional flow of actions from left to right leading to the landfill distinction. This linear system has a color key, as the same distinctions of the linear system will be a part of the circular system. The aspirational and circular system at the lower portion of the map includes all of the DSRPs of the linear model, as well as additional DSRPs to aid in the shift towards a circular system structure. Additionally, it is illustrated how the emergent properties of the system and each part-whole system, or level of the supply chain, relate to those properties. Those properties are where behavioral interventions will take place to influence a transition to the circular model system.

DSRP Analysis of the System

WITHIN MY ABA ANALYSIS of the Global Apparel Supply Chain system, I began with a DSRP Analysis of each component of the

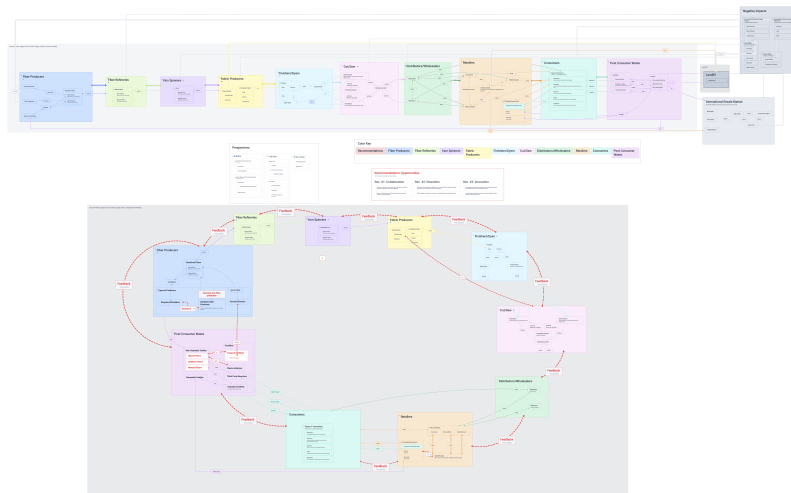


Figure 4: 10,000 ft view of Systems Thinking Map

current supply chain system²¹. As I have a bachelors in fashion, the information half of the mental model came together quite quickly. However, my new challenge was thinking further about the DSRPs of the information I knew about the supply chain and relating it back to the realities of the system. Within this system, I began with creating distinctions between each level of the supply chain, using my personal knowledge of the current supply chain. I then compared my understanding of the DSRP's of the my mental model map with other sources, as seen in Figure 5, on apparel supply chains to develop my own systems thinking map.

²¹ 9; 1; 2; 3; 4; 5; 6; 7; and 8

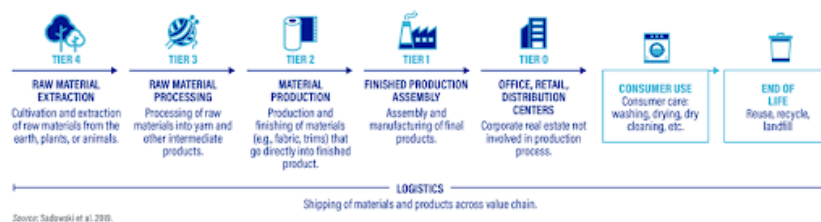


Figure 5: Basic Linear Model of Global Apparel Supply Chain [20]

As shown in Figure 4, DSRP Analysis involves understanding various elements throughout the supply chains, such as identity/other distinctions, part/whole systems, action/reaction relationships, and point/view perspectives²². The initial ten part-whole systems, systems that are part of a larger system and have their own parts, include: fiber producers, fiber refineries, yarn spinners, fabric producers, finishers/dyers, cut/sew manufacturers, distributors/wholesalers, retailers, consumers, and post consumer waste facilities. Each of

²² 9

these systems are a part of the larger Global Apparel Supply Chain System and have their own part systems within their distinction. More simply, the map illustrates that the supply chain system has multiple levels of the supply within and those levels of the supply chain each have their own operation system of receiving inputs and creating outputs. Structural predictions were made that the current system is linear in nature and action relationships flow in one direction with an open-loop system. From the perspective point of the current or traditional apparel industry on global supply chains, the relationships between each of the distinct systems flow in one direction with a beginning and end.

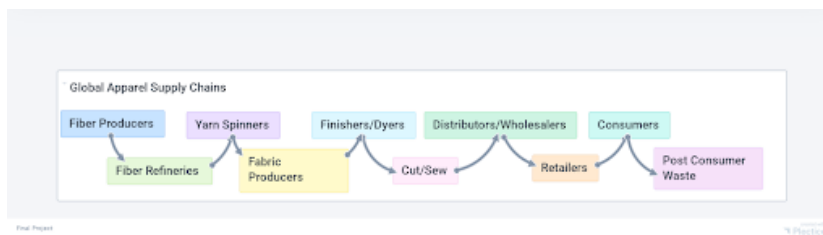


Figure 6: Mental Model Mapping of Basic Global Apparel Supply Chain System

When conducting DSRP analysis, it is imperative to set framing and stopping, or fropping, rules for what will be included in your map. Through establishing fropping rules, distinctions, systems, relationships, and/or perspectives that are not within the scope of a project are left out in order to ensure clear and concise results²³. The fropping rules for this project are represented below.

²³ 1; 2; 3; 4; 5; 6; 7; and 8

DROPPING RULES FOR GLOBAL APPAREL SUPPLY CHAIN SYSTEM

1. Each level of the supply chain's part-whole system only includes general/basic distinctions and relationships.
2. Supply chain parts include the most general agents in the supply chain.
3. Consider emergent properties only caused by textile waste.

POSIWID Analysis

AS STATED PRIOR, POSIWID Analysis states that the purpose of a system is what it does. With regard to the Global Apparel Supply Chain system, it is great at having a high and fast paced demand for low cost products, despite the detrimental impacts this consumption has on the environment and global communities. In contrast, its

future POSIWID aims to be good at positively affecting its global supply chains and actively working to improve the environmental and human rights outcomes across the globe. In order to make this shift from current to future POSIWID, the agents of the system must consider the lack of the following: US market accountability, coordination throughout the supply chain, action by global governments. Through changing these behaviors of the system, outcomes can improve to reach the future POSIWID.

Problem Statement	Current POSIWID	Future POSIWID	Root Difference
The U.S. Fashion Market and its Global Supply Chains System produce mass amounts of waste at the expense of global working communities and the environment.	The U.S. fashion market is great at having a high and fast paced demand for low cost products, despite having detrimental impacts on the environment and low income communities around the world.	The US fashion market is good at positively affecting its global supply chains through actively working to improve the environmental and human rights outcomes across the globe.	At its core, POSIWID difference is: 1. Lack of US market accountability. 2. Lack coordination throughout the supply chain. 3. Lack of action by global govts.

Table 2: POSIWID of Global Apparel Supply Chain

When comparing my current POSIWID to the real world, I came across a quote from *The True Cost*, a documentary on the realities of the fashion industry and its supply chains. It states that “people aren’t going to care until it hurts them personally,” which supports my POSIWID that the current fashion market will continue to consume despite the negative impacts affecting other communities²⁴. In order to test my future POSIWIDs against reality, I used number 12 of the UN Sustainable Development Goals, or SGDs. This goal focuses on ensuring Responsible Consumption and Production and provides insight on global impacts of natural resource depletion and guidance on how to reverse those impacts²⁵.

²⁴ 16

²⁵ 17

CAS Analysis

THROUGH CAS ANALYSIS, we as systems thinkers can understand the agents within the system. Understanding the simple rules agents follow and the system level behaviors of those agents allows us to consider what issues the system is facing and where to focus recommendations for the improvement of outputs. In order to provide context to what these agents look like in the real world, it is important to provide examples of each; these examples are provided in Table 3.

This framework for the Global Apparel Supply Chain system, reveals that in general the agents within the supply chain are simply

selling or buying products to meet the demands of the next step within the supply chain, ending with consumers driving the demand of the whole supply chain. Additionally, regulating bodies, such as international and US government and non-governmental organizations, exist to regulate the supply and demand of the system.

Rubric and Recommendations

Recommendation Rubric

No specific recommendation should violate these rules:

1. Emergent behaviors addressed will be focused specifically on waste.
2. General recommendations applicable to all agents.

Specific Recommendations

1. **Intervention/Recommendation 1:** Collaboration.
2. **Intervention/Recommendation 2:** Education.
3. **Intervention/Recommendation 3:** Innovation.

IN ORDER TO AID supply chains in becoming a closed-loop system, I have created recommendations to be implemented among the agents within the system. The three main recommendations are Collaboration between agents to achieve sustainability goals, Education of all agents on circular economy models and sustainability standards, and Innovation throughout the supply chain of circular initiatives.

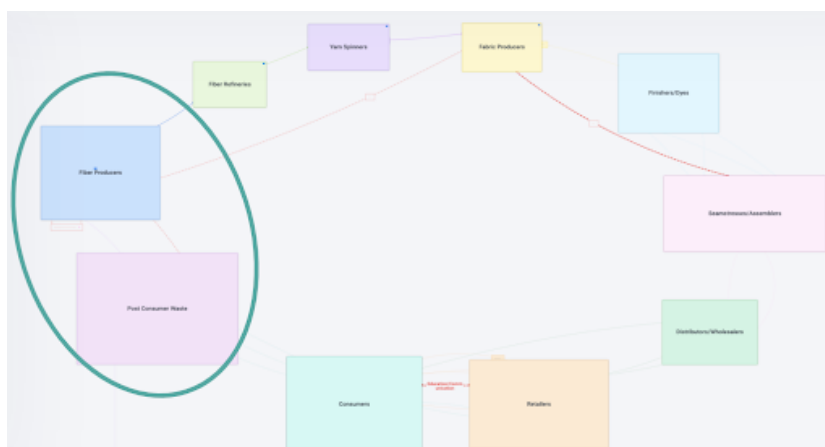


Figure 7: Area of Greatest Impact for Circularity (Part 1)

List of Salient Agents	Current Simple Rules	Current System Level Behavior
Fiber Producers/Farmers (general ex: synthetic (petroleum-based) vs natural (cotton, wool, silk)) (Industry leaders: Cotton Inc., China Petrochemical)	1. Create fibers. 2. Meet demands of Manufacturers.	1. Depletion of renewable and non-renewable resources. 2. Pollution of ground water through the use of chemicals, including pesticides. 3. Labor Rights violations, such as child and forced labor.
Manufacturers (ex: yarn spinners, fabric producers, dye/treatment facilities, cut/sew) (Industry leaders: Shenzhou International, Group Saint Gobain Tape Solutions)	1. Produce textiles and apparel products. 2. Meet demands of Seller/Distributor.	1. Pollution of land and water through dyes, chemicals, and textile waste. 2. Human Rights violations through increasing water scarcity through pollution of groundwater. 3. Labor Rights violations, such as child and forced labor.
Sellers/Distributors (Industry Leaders: DNC Wholesale, Apparel Source Inc.)	1. Order products from Manufacturers. 2. Sell products to Brands/Retailers. 3. Meet demands of Brands/Retailers.	Create GHG emissions through transit of goods.
Brands/Retails (Industry leaders: Inditex, Nike, LVMH)	1. Order products from Sellers/Distributors. 2. Meet and increase demands of consumers.	Pollution of land and water through textile waste.
Consumers	Order products from Brands/Retails.	1. Pollution of land and water through textile waste. 2. Creation of microplastic pollution in water supply through laundering.
Post Consumer Waste Facilities (ex: donation facilities, 3rd party recycling facilities, garbage collectors) (Industry Leaders: TerraCycle, Goodwill)	1. Collect textile and apparel waste. 2. Send non-reusable products to landfill. 3. Sell reusable products to second hand market.	Pollution of land and water through textile waste.
Landfill (ex: incinerators, waste collection land mass)	1. Receive waste. 2. Keep or burn waste.	1. Pollution of land and water through textile waste. 2. Pollution of air quality through GHG emissions from landfill and incineration.
US Government Agencies (ex: US Dept. of Commerce, US Environmental Protection Agency)	Regulate supply through trade agreements and tariffs.	Hindering international development through harsh trade regulation.
International Government Agencies (ex: Depts. of Environmental Protections, Depts. of Labor)	1. Regulate fiber production and manufacturing standards. 2. Regulate pollution and resource management.	1. Lack of labor standards enforcement causing unfair wages and unsafe working conditions. 2. Lack of environmental conservation causing pollution and resource scarcity.
Non-Governmental Organizations (ex: United Nations, ILO)	Investigate and regulate human rights issues.	Lack of human rights standards enforcement causing violations to take place.

Table 3: CAS Analysis of Global Apparel Supply Chain System

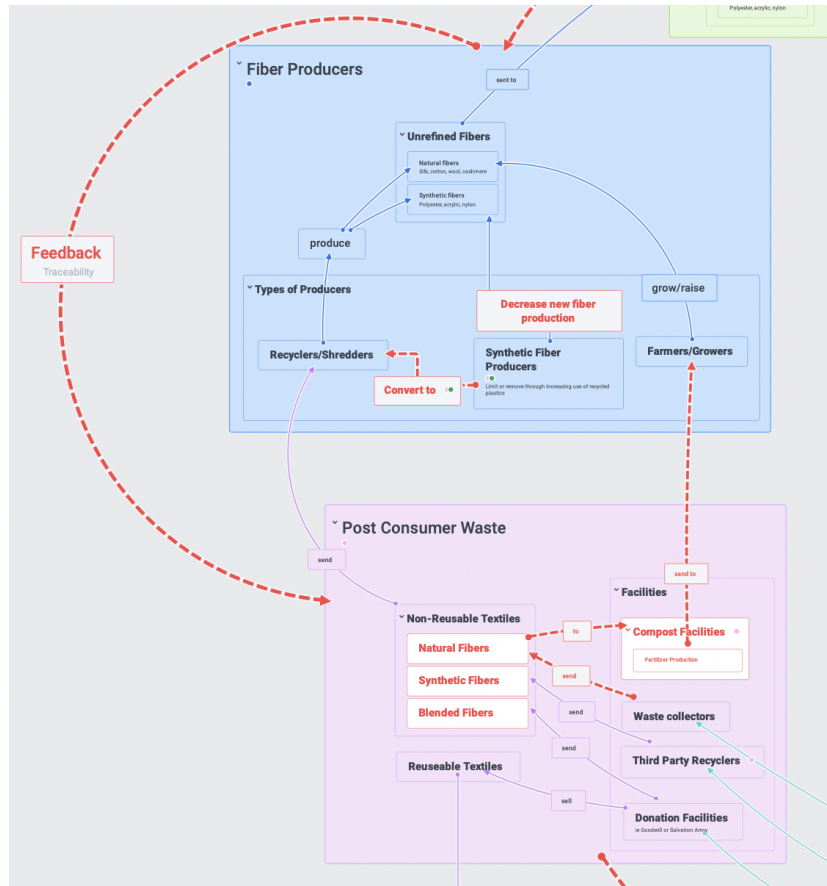


Figure 8: Area of Greatest Impact for Circularity (Part 2)

As noted in Figure 7, it is imperative to note the greatest area of impact for the implementation of the circular economy model is between the Post Consumer Waste system and the Fiber Producer system. Intervening within this area will close the loop to create a fully circular system. Within Figure 9, you can see the distinctions and relationships within the Post Consumer Waste system are represented in magenta, and the Fiber Producer system is represented in royal blue. Recommendations on how to connect these two systems and close the loop are illustrated in red.

Under the Collaboration-based recommendations within this area include creating a reaction feedback loop relationship between the two systems. As shown in Figure 9, this feedback loop is a commonality throughout the supply chain. Through collaborative action and feedback loops, the supply chain system is ensured responsibility and accountability.

With consideration for Education within the supply chain system, agents must be educated on sustainability and circularity initiatives

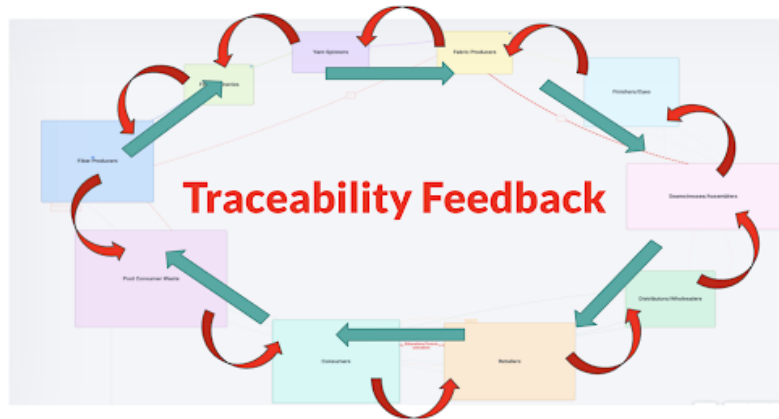


Figure 9: Traceability Feedback Loop

they can implement within their system. One example of this within Figure 8 is education on the use of composting. Through a study conducted on the efficacy of cotton textile waste composting found farmers benefited from this practice²⁶. Therefore, educating consumers, waste management facilities, and farmers on the benefits of composting can not only decrease waste, but also increase crop productivity. Additionally, through the perspective of the US government, policies should be set into place to support compost system utilization.

²⁶ 18

Lastly, with consideration for Innovation within the system, it is imperative to look for where improvements can be made to increase reuse initiatives. For example, within the Fiber Producer System (see Figure 8), innovation is required to convert traditional, synthetic fiber producers to utilize recycling technology. Through this behavioral change within the Fiber Producer system, the entire supply chain system will be able to reach a circular system structure.

The recommendations for the Global Apparel Supply Chains system are focused on affecting the emergent behaviors surrounding waste from the industry. I have based these recommendations on guidance from the US Environmental Protection Agency to regulate industrial waste, which aims to “protect human health and the environment,” as well as “foster partnerships” between stakeholders²⁷.

²⁷ 19

Discussion

DSRP Analysis of the System

WHEN COMPARING THE MAPS of the linear system to the circular system, it is interesting to consider how the DSRPs differ. Specifically with regard to what distinctions must be added to the linear model

to close the system and create a circular system. Through this analysis, I was able to consider what distinctions and relationships within the current system can remain in the aspirant model and which need to be removed to ensure the success of the new circular system. One key removal was the landfill system, as it was the largest component to the negative outcomes of the system and had no benefit towards the implementation of the circular system implementation. Through understanding the relationships each part-whole system of the supply chain system had with the landfill system, I was able to determine where behavioral interventions would need to take place.

POSIWID Analysis

WITHIN THE POSIWID ANALYSIS of the system, I was able to frame the current outputs of the system against the aspirant outcomes of the system. Through this reflection of focusing where the root differences lie between the current and future POSIWID, I was able to identify what the recommendations of my map needed to address in order to reach the future intended state.

CAS Analysis

THROUGH CAS ANALYSIS of the system, I was able to gain a clear understanding of the agents of the system. This allowed me to reflect on which agents were important within my map aligned with my goal to implement a circular model within the supply chain system. Understanding who the agents were in my system, the simple rules they follow, and the current system level behavior allowed me to recognize how each agent played a role in achieving, or not achieving, a circular system. Additionally, it permitted me to see what influence each agent had in intervening within various emergent behaviors.

Rubric and Recommendations

WITHIN RECOMMENDATIONS, I quickly learned that the recommendations for the system must be both broad and part-whole system specific. Though the supply chain system is complex in nature, it is still one system consisting of multiple smaller systems. Therefore, it was crucial to make broader recommendations for the entire system, as well as stakeholder specific recommendations to achieve smaller

strides towards circularity. As collaborative action, industry-wide education, and supply chain innovation are all pertinent to the success of the circular economy, small strides towards responsibility by each stakeholder will lead to improvements of outcomes for the entirety of the system.

References

- [1] D Cabrera, et al., "The Four Waves of Systems Thinking", in *The Routledge Handbook for Systems Thinking*, edited by D Cabrera, et al., Routledge Press, London, UK, 2022.
- [2] Derek Cabrera, et al. (eds.), *Handbook of Systems Thinking*, Routledge, 2021.
- [3] D Cabrera, et al., "A Unifying Theory of Systems Thinking with Psychosocial Applications", *Systems Research and Behavioral Science*, 2015.
- [4] D Cabrera and L Cabrera, *Systems Thinking Made Simple: New Hope for Solving Wicked Problems in a Complex World*. Odyssean Press, Odyssean Press, Ithaca, 2015.
- [5] Cabrera D, Cabrera L, Lobdell, "System Thinking", *Journal of Evaluation and Program Planning*, 2008, pp. 299–310.
- [6] D Cabrera, "Patterns of Knowledge: Knowledge as a Complex, Evolutionary System, and Educational Imperative", in *Creating Learning Communities*, edited by R Miller, Solomon Press, online edn., 2002.
- [7] D Cabrera and L Cabrera, *Thinking at Every Desk: Four Simple Skills to Transform Your Classroom*, Education Series, Norton Books, 2011.
- [8] Derek Cabrera, *Remedial genius: think and learn like a genius with the five principles of knowledge*, Project N Press, Loveland, CO, 2000.
- [9] Mulyono, Y.O., Sukhbaatar, U., and Cabrera, D., ""Hard" and "Soft" Methods in Complex Adaptive Systems (CAS): Agent Based Modeling (ABM) and the Agent Based Approach (ABA)", in *Routledge Handbook of Systems Thinking*, edited by Laura Cabrera Midgley, Derek Cabrera, Routledge, vol. 20, 2021.
- [10] U S Epa and OLEM, "Textiles: Material-specific data", EPA, 2017.
- [11] MacArthur, "Fashion and the circular economy", , 2020.
- [12] A Castellanos Canales, et al., "The Universal Cognitive Grammar of Systems Mapping: A Rubric to Evaluate the Various Tools and Techniques of Systems Mapping", in *The Routledge Handbook for Systems Thinking*, edited by L Cabrera, et al., Routledge Press, London, UK, 2021.

- [13] Stafford Beer, "What is cybernetics?", *Kybernetes*, 31(2), 2002, pp. 209–219.
- [14] Murray Gell-Mann, *The Quark and the Jaguar*, W.H. Freeman and Co., New York, 1995.
- [15] M Mitchell Waldrop, *Complexity: the emerging science at the edge of order and chaos*, Simon & Schuster, New York, 1992.
- [16] A Morgan, "The true cost", , 2015.
- [17] Martin and Titouan Chassagne, "Sustainable consumption and production", , 2015.
- [18] A Sachidhanandham and S Amsamani, "Evaluating the efficacy of compost evolved from biomanaging cotton textile waste", *Journal of Environmental Research And Development*, 2012.
- [19] Epa, "EPA's Guide for Industrial Waste Management", , 2020.