Development of Sustainable Supply Chain Management Games

Victor Alonso Cuesta Aguiar
(Student ID Number: 81552525)

Supervisor: Masaru Nakano

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SUMMARY OF DOCTORAL’S DISSERTATION

| Student Identification Number | 81552525 | Name | Cuesta Aguiar Victor Alonso |

Title
Development of Sustainable Supply Chain Management Games

Abstract

This research is intended to develop a Sustainable Supply Chain Management (SSCM) game capable of integrating the 3 main dimensions of sustainability and risk. Researchers have developed several games in Supply Chain Management (SCM), however, seldom do these games incorporate and integrate more than 1 dimension of sustainability, before this research there were a total 0 SSCM games publicly validated and published in journals. To address this issue, this thesis develops two SSCM games, Chain of Command (CoC) and Looper. CoC is partially successful at integrating the three dimensions of sustainability and risk, nevertheless, the level of complexity present in the representation of SCM in the game diminished its educational, enjoyment value, and resulted in a complex and difficult to understand game. Looper is then developed to address the previously mentioned problems.

The purpose of this research is reducing the complexity of SCM to properly integrate the 3 dimensions of sustainability and risk to create a SSCM game that increases the awareness of SSCM in beginners. This is achieved through the following originality: (1) Eliminating market fluctuation and communication among stakeholders in SCM (2) Simplifying the time delay in the SC by decreasing the amount of stock locations.

This dissertation consists of 8 Chapters. Chapter 1 describes the purpose, goals, and structure of this research. The chapter begins with a research background on serious games and the establishing the fact that there are no SSCM games. The literature review reveals that games in conventional studies focus only on one or at most two dimensions of sustainability. Chapter 2 describes the quantitative and qualitative methods used during the research. Chapter 3 provides insight into the game design process, the complexity reduction method,
systems engineering technical processes, the stealth serious games model, and the serious game cube. Chapter 4 regards the development and testing of the Origami SG a single dimension SC game focusing on economics, developed to gain insight into serious game design and test systems engineering technical processes in the design of serious games. Chapter 5 introduces the reader to SSCM and SSCM games. In addition to displaying the development of CoC and Looper. Chapter 6 contains detailed descriptions of the verification and validation, this includes test setups, data gathering and results for CoC and Looper. Test results show that Looper is more educational and enjoyable to play than CoC and succeeds were CoC failed. Chapter 7 contains a discussion on the validation results from CoC and Looper, along with observations and insights obtained from the games testing. Important findings for Looper include players investing in green technology as a retroactive approach to government regulations, short leads times and SC robustness is valued over the environment and corporate social responsibility is an activity players are not willing to engage in if there is no incentive to do so. Chapter 8 contains the conclusion of the study for CoC and Looper related to our research goal and the academic contribution. It additionally provides the direction for future research: (1) Develop a SSCM game that teaches solutions to current SSCM problems, (2) Develop a SSCM game for SSCM professionals.

Key Word (5 words)

Games, interactive learning, supply chain management, sustainable supply chain management, serious games development
Development of Sustainable Supply Chain Management Games

Victor Alonso Cuesta Aguiar
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Abstract

This research is intended to develop a Sustainable Supply Chain Management (SSCM) game capable of integrating the 3 main dimensions of sustainability and risk. Researchers have developed several games in Supply Chain Management (SCM), however, seldom do these games incorporate and integrate more than 1 dimension of sustainability, before this research there were a total 0 SSCM games publicly validated and published in journals. To address this issue, this thesis develops two SSCM games, Chain of Command (CoC) and Looper. CoC is partially successful at integrating the three dimensions of sustainability and risk, nevertheless, the level of complexity present in the representation of SCM in the game diminished its educational, enjoyment value, and resulted in a complex and difficult to understand game. Looper is then developed to address the previously mentioned problems. The purpose of this research is reducing the complexity of SCM to properly integrate the 3 dimensions of sustainability and risk to create a SSCM game that increases the awareness of SSCM in beginners. This is achieved through the following originality: (1) Eliminating market fluctuation and communication among stakeholders in SCM (2) Simplifying the time delay in the SC by decreasing the amount of stock locations. This dissertation consists of 8 Chapters. Chapter 1 describes the purpose, goals, and structure of this research. The chapter begins with a research background on serious games and the establishing the fact that there are no SSCM games. The literature review reveals that games in conventional studies focus only on one or at most two dimensions of sustainability. Chapter 2 describes the quantitative and qualitative methods used during the research. Chapter 3 provides insight into the game design process, the complexity reduction method, systems engineering technical processes, the stealth serious games model, and the serious game cube. Chapter 4 regards the development and testing of the Origami SG a single dimension SC game focusing on economics, developed to gain insight into serious game design and test systems engineering technical processes in the design of serious games. Chapter 5 introduces the reader to SSCM and SSCM games. In addition to displaying the development of CoC and Looper. Chapter 6 contains detailed descriptions of the verification and validation, this includes test setups, data gathering and results for CoC and Looper. Test results show that Looper is more educational and enjoyable to play than CoC and succeeds were CoC failed. Chapter 7 contains a discussion on the validation results from CoC and Looper, along with observations and insights obtained from the games testing. Important findings for Looper include players investing in green technology as a retroactive approach to government regulations, short leads times and SC robustness is valued over the environment and corporate social responsibility is an activity players are not willing to engage in if there is no incentive to do so. Chapter 8 contains the conclusion of the study for CoC and Looper related to our research goal and the academic contribution. It additionally provides the direction for future research: (1) Develop a SSCM game that teaches solutions to current SSCM problems, (2) Develop a SSCM game for SSCM professionals.
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Abbreviations

Chain of Command (CoC)

Complexity Reduction and Integration Method (CRIM)

Player Controlled Variables (PCV)

Serious Games (SG): The word serious games and games are used interchangeably; the word game shares the same meaning as serious games in this research.

Serious Games Design (SGD)/(GD)

Systems Engineering Technical Processes (SETP)

Supply Chain Management (SCM)

Sustainable Supply Chain Management (SSCM)

Stealth Serious Games Model (SSGM)

Stealth Serious Games (SSG)

Serious Game Cube (SGC)

Stealth Learning (SL)
1 INTRODUCTION

Serious games (SG) have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement, this does not mean that SG are not, or should not be, entertaining [2]. This research develops a successful Sustainable Supply Chain Management (SSCM) game. There is a lack of SSCM games, the complexity of integrating the three dimensions of sustainability (environmental, economic, social) and risk management into a SG is rarely tackled by SG developers and researchers, resulting in an underdeveloped area. Reality is highly complex and properly replicating it through a SG has significant challenges; replicating reality yields simulations. Simulations are great tools for training, however, the time and knowledge necessary to operate a simulation are substantially higher than what a SG requires, simulation instructors must also be highly trained. SG are simpler representations of reality that are used to teach specific solutions to problems or widen the user’s perspective towards a topic. A SG does not necessarily require an instructor or facilitator. In the cases where training an instructor or facilitator to administer the SG is required, the time needed is significantly shorter when compared to a simulation.

Even though SG attempt to be noncomplex, SG designers can inadvertently create complex SG. Complexity does not necessarily originate from the issue trying to be taught. Complexity can also originate from the rules of the SG, and how it is played (mechanics and dynamics). In the case of SG in Supply Chain Management (SCM) add the first layer of complexity, focusing on a single dimension and a specific issue, adds one more layer of complexity. Additional layers of complexity are added through the rules of the SG, the mechanics, and dynamics. When developing a SG in SSCM there are three dimensions and risk, this makes developing a SG four times more complicated than a SG considering only one dimension. One more level of complexity is added by the rules, mechanics, and dynamics of the SG. Developing a SSCM game is six times more complex than developing a single dimension SCM game.

Three full SG are developed. The Origami SG focuses on a single dimension (economic dimension) and very specific topics within that dimension. The Origami SG is designed to teach undergraduate students three economic concepts: marginal cost curve, market demand curve and market surplus (market flooding). The complexity of the Origami SG emerged from the rules, mechanics, and dynamics; not from the single dimension being handled by the SG. The designed SG provides engineering economics instructors an additional tool with which they can teach students using an interactive and entertaining approach. This first SG is developed using SETP. The advantages and disadvantages of SETP are highlighted. SETP has never been used for SG design based on the literature review that was carried. It is then of significance to display how SETP performs for SG development. This was an attempt to give SG development a more structured approach that did not yield the expected results.
The second SG “Chain of Command: A Sustainable Supply Chain Management Stealth Serious Game” (CoC) is developed incorporating all the lessons learned from developing the Origami SG. A new model for the development of Stealth Serious Games (SSG) serves as the basis for CoC. The stealth serious games model (SSGM) gives importance to lowering complexity of the issue or topic to be taught and provide rich visuals to the players. The main pillars of the SSGM are: gaming, stealth learning ((SL) eventuates when the player is not aware that he/she is learning), fun, replay value and visuals. SSG have a high replay value coupled with an equal ratio of fun to educational content, the player is not aware that he or she is learning when playing and can be played for amusement or education [3]. SSGM tries to usher the development of SG into a gray area where users do not know if they are playing a SG or a regular game. The problem with traditional SG experiences is that the player knows that he/she is playing a SG. Additionally, the visuals and production values of SG are nowhere near conventional games/board games. CoC successfully incorporates the three dimensions of SSCM and risk. In CoC the player can proceed to focus on a specific dimension and then expand to other dimensions. CoC, being a multiplayer competitive experience is regarded as fun yet complex. Managing the complexity of the mechanics and dynamics remained complicated as in the Origami SG. The games developed using the SSGM teaches SSCM and incorporates SCM concepts such as market fluctuation, communication dynamics among stakeholders in the SC and SC time delay. CoC is the first SSG to incorporate the triple bottom line (environment, economy, and social dimensions) and risk. Most SG in SCM incorporate at most two dimensions. The intricacy of designing a game that encompasses the triple bottom line is clearly detailed in the development of CoC Chapter 5.

The third SG developed is “Looper” a single player sustainable supply chain management SG. It is developed by performing a deeper review of existing SG in SCM, SSCM and classifying them based on playtime, number of players and complexity into 8 quadrants of the Serious Game Cube, Chapter 3. The SGC provides insight into areas that are available for SG development. Looper is influenced by CoC’s visual aesthetics, mechanics, and dynamics. Looper is more fun and less competitive than CoC. The advantages of Looper are: simpler rules, shorter play times and being easier to play and distribute than CoC. Looper also eliminates complex SC topics such as market fluctuation, communication dynamics among stakeholders in the SC and has a much more simplified SC time delay. Additionally, being a single player SG, participants can fully concentrate on planning their strategy without the pressure of other players.

Generally, we would not use SG to teach or train university students or professionals to do basic mathematical calculations, such thing can be better taught with lectures, books, tutorials, and cases. We use SG to let professionals gain more insight into social-technical complexity, and how to handle it for instance when they are put in the position of project leader [4].
The main problem, method, and result being tackled by this research is summarized in Figure 1. Secondary problems identified during the development of the SG and the SSG are presented in more detail in their respective chapter.

Figure 1 Research problem, method, and result

1.1 Background

Games in Sustainable Supply Chain Management is an under researched area. Since the inception of the term serious games up to the year 2009, a total of 2218 games have been developed [1] in all knowledge areas. After the year 2009, and only considering games around SCM, a total of 12 new games have been developed to have a grand total of 2230 games. From those 2231 games 33, that is 1.47%, are related to SCM, see Figure 2. The oldest SCM game from the ones researched is MIT’s Beer Game, developed by Jay Forrester [5] in the 1960’s. Since that year a total of 8 games in SCM were developed. More important is to state the fact that of the total of SCM games developed, 25 of 33 have been developed in the last 18 years (2000-2017). This is a roughly 300% increase in the amount of games in SCM.

Figure 2 Total Games up to 2017
Further analysis of the SCM games developed, indicates that from the 33 SG, 63.6% of the games are computer based while 36.36% are board games. This means that most of the SCM games can only be played while having a computer. There is the possibility of developing SCM board games, if a researcher wants to pursue this specific area. More importantly, there are a total of 0 SSCM computer-based games and a total of 0 SSCM board-based games.

As impressive as the 300% increase in the development of SCM games may be, which indicates the growing interest in this area, the area of SSCM games has been completely neglected. A total of 0 SSCM games have been developed, verified, and publicly validated. There are of course a few SSCM games that have been developed but these lack the scientific evidence and publications to back up their efficacy at raising awareness or teaching SSCM concepts and therefore cannot be included in this thesis.

1.2 Purpose

The purpose of this study is to increase the awareness of the topic of SSCM among people through the development and use of a game that encompasses the three dimensions of sustainability and risk management, see Figure 3. As part of the development of an effective SSCM game, a literature review consisting of games in SCM and SSCM is performed. The literature review was important to this study because it was hoped it would be possible to identify the characteristics of games in SSCM to answer the research question. The research effort included SGD models and frameworks that would allow for the creation of successful games in SSCM. The second part of the study involves the verification and validation of the SSCM game developed. The verification of the games involves testing the game’s game mechanics and dynamics. The validation involves pre and post questionnaires in SSCM dimensions (economic, environmental, social and risk).
1.3 Motivation

The researcher responsible for this study has always been a huge fan play for fun games. Ever since he was kid he has been playing games. Games are a significant part of his life and he has been exposed to several genres and game types. It was always his dream to work as a game designer, unfortunately, the economic prospects for such a profession are not good in his home country. Therefore, he studied electrical and mechanical engineering. When he decided to pursue a master’s degree, he was given the chance to do research on games, a topic he continued up to his PhD. While SG are not games meant to be played for fun, they are still games to some extent. He decided to try being a serious game developer, with his experience of conventional games he was sure he would be able to produce exciting new games that would be closer to play for fun games. While doing research on SG he realized that many of the existing SG neglect using mechanics and dynamics used in conventional games. It was this moment when he realized that his vast knowledge of conventional games would provide to be an asset for the development of exciting new SG. Developing SG in SSCM became the perfect research topic for him once it was found that no SSCM games were currently available. His work could have a positive impact on how future SSCM games are developed and inspire all SSCM games to come. Additionally, bringing awareness of the importance of SSCM to the masses and influencing their way of thinking sealed his decision to do research on SSCM games.

This study is additionally motivated by the fact, that there are no SSCM games and by the need to develop new models, frameworks and methods that can be used to develop next generation SG. These next generation SG could be non-stealth learning experiences or stealth learning experiences. SETP aim at helping the developer think in detail about the SG and all its systems, subsystems, interfaces etc. The SSG model aims to create SSG that can rival traditional non-SG board games. Additionally, SSCM management is gaining popularity, and to provide a tangible academic contribution the SSG CoC and Looper are developed to further the understanding of SSCM to a broad audience.
1.4 Literature Review & Study Objectives

There are several SG concerning SCM, a total of 32 SG (this number excludes the SG developed in this study) These SG specialize on a dimension of SSCM. The only two available SG for SSCM that are published, verified, and validated concern to this study; those SG are CoC and Looper. Table 1 shows the number of SG by sustainability dimension and Table 3 provides the name of the SG with additional information regarding the use of the game.

Table 1 Number of SC SG by main sustainability dimension

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<th>Economy</th>
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<th>Environmental</th>
<th>Risk</th>
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<tr>
<td>Number of Games</td>
<td>18</td>
<td>2</td>
<td>5</td>
<td>8</td>
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A brief explanation of each game will now be presented:

The Beer Game [5] is a SCM game developed by Jay Forrester from MIT to introduce students of management to the concepts of economic dynamics. This SG was initially developed as a board game. Computer versions of this game do exist. The Beer Game is an 8-player game, in addition to the players the game requires a facilitator. In the game players oversee a company in four company supply chain. The average length of a session of the Beer Game is 2 hours. The beer game teaches the concept of the bullwhip effect in supply chains. The debriefing of this game includes the explanation of the bullwhip effect. In the dimensions of SSCM, this game falls into the risk and economic dimensions of SSCM. The beer game has a onetime market fluctuation, time delay through several stocks in the SC and communication dynamics in the SC.

![Figure 4 Beer Game board](image)

Brass [6] is developed by Tree Frog games. It is a board game; no computer versions are sold by the publisher. Brass is a 2 to 4 player game. The game does not require a facilitator and its playtime is estimated at 2 to 3 hours. Brass teaches players the basics of supply chain management. In the game, players oversee a supply chain of three individual products, iron, coal, and cotton. Players must meet the supply and demand of the market. There is no debriefing at the end of the game. This game located
in the economic dimension of SSCM. Brass includes market fluctuation, time delay, and communication dynamics among the SC stakeholders.

CODEPRO [7] is a board game with no computer versions available. It is an 11 to 15 player game and requires a facilitator to be played. The play time for this game is limited to the amount of discussion that the players do during the game session. In the CODEPRO game the participants act different roles in a supply chain of a manufacturing firm. The supply chain consists of one focal company, its customer, a subcontractor, and a materials supplier. The aim of the game is not to study any specific, single phenomenon in a SC, but to demonstrate the holistic and dynamic nature of multiple interrelations of several factors such as information transparency, personnel roles, cooperation and communication in a company. CODEPRO is primarily located in the social dimension of sustainability although it does contain some elements that belong to the economic dimension of SSCM such as production efficiency. CODEPRO includes market fluctuation, time delay, and communication dynamics among SC stakeholders.

![Figure 5 Layout and roles of the game CODEPRO [7]](image)

CRAC Metal Box Business Game [8] is a computer game designed to teach problem-solving skills and effective communication by allowing teams of to simulate the running of a company manufacturing and selling goods in a competitive market. It is a 5-player game that requires a facilitator. The playtime for this game is not specified. It appears that the length is highly dependent on the players. CRAC teaches operations management concepts. Players oversee a company and must become the most profitable company at the end of the game. CRAC includes market fluctuation and communication dynamics.

Global Supply Chain Management Simulation [9] is a computer game. The learning focus is to create a cost effective and flexible supply chain, evaluating forecasting methods, building a production plan based on probabilistic demand forecast, distinguish between a forecast and production plan, weigh the importance of results and process performance measures. The topics it covers are market fluctuation,
forecasting, operations management, product management, and SCM (time delay and communication dynamics). It is a single player game that requires no facilitator. It appears that the play time for this game varies significantly based on the player. This game teaches the player how to manage a cost-effective supply chain, how to manage production planning and how to implement forecasting. This game is in the economic dimension of SSCM.

HEC Montreal ERP Simulation Game [10] is a computer game. It is a 4-player game that requires facilitation. A typical play session for HEC Montreal ERP Simulation Game has a duration of 1 day. This game provides a simulation of a make-to-order manufacturing supply chain, where the buyers and sellers’ market responds and behaves just as it would in the real world. Participants plan, produce, procure, and sell to experience the value of up and downstream information flows. The most essential function of the game is simulating the passing of time. This game is primarily located in the economic dimension of SSCM. It includes market fluctuation, time delay and communication dynamics.

HECOP sim [11] is a computer game. It is a 4 to 5 player game that requires a facilitator. HECOP teaches players how to manage materials purchase, production, inventory management, and production capacity. The game is played over a series of linked excel spreadsheets that contain randomized information. The game is played over a span of 10 periods where the team decides the amount of raw materials to purchase and the number of subassemblies and finished products to assemble. Every other period the team must submit a hiring and layoff plan. This game is primarily located in the economic dimension of SSCM. HECOP sim includes market fluctuation, time delay and communication dynamic topics in the SC.

Figure 6 Spreadsheet used in HECOP sim [11]
Internet Supply Chain Simulation [12] is a computer game. It is a 7-player game that requires facilitation. A typical play session of this game requires 1 to 3 days. In this game players learn forecasting, warehouse management, transport planning, inventory production planning, order fulfillment and purchasing, supply network design, the value of information sharing, collaboration, innovation, and leadership skills. The game contains 5 modules, customer purchasing and fulfillment, production planning and production, regional distribution center, local distribution center and two third party logistics. The game has 5 types of products. The primary focus of this game is the economic dimension of SSCM. It includes market fluctuation, time delay and communication dynamics in the SC.

Lean Leap Logistics Game [13] is a computer game. It is a 6 to 12 player game that does not require a facilitator. This game focuses on supply chain core processes and problems. A typical game session has a duration of 3.5 to 6 hours. A session comprises several rounds subdivided into periods. The stations in the game are the final customer, dispatch, final assembly, press shop, blanking operations, service center, and steel mill. Stations are subject to chance events. Players are encouraged to change stations during certain occasions in the game. The primary focus of this game is the economic dimension of SSCM. The game includes market fluctuation.

![Image](image.png)

**Figure 7 Lean Leap Logistics Game sheet example [13]**

Littlefield Technologies [14] is a computer game. It is a 4-player game that requires a facilitator. In a typical session of this game players will learn process analysis, forecasting, capacity management, production control, inventory control queueing and lead time management. In a typical setting, students are divided into teams, and compete to maximize their cash position through decisions: buying and selling capacity, adjusting lead time quotes, changing lot sizes and inventory ordering parameters, and selecting scheduling rules. This game is primarily located in the economic dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.
LOGA logistics game [15] is a computer game. It is a 4-player game that requires a facilitator. The length of a typical LOGA session is not specified, this could be due to playtime varying significantly according to the players. The main concern of the LOGA logistics game is teaching players regarding logistics in a supply chain. The focus of this game is the economic dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

Logistics Game [16] is a computer game. It is a game that is meant to be played by 1 or more players without the need of a facilitator. The playtime required for a session of the Logistics Game is not specified. This could mean that the time varies significantly based on the players. The main concepts being taught to the players are supply chain planning operations and cross chain control center. In the game, the player is a planner for an LSP. In his player role he provides a planning for the LSP based on their own transportation resources, trucks, and collaboration contracts with partners: A player first links orders to a truck, and secondly designs a route for pick-up and delivery. Collecting and delivering multiple packages is possible if the capacity of the truck is not exceeded. The planning horizon is one week, whereas simulation time for one week is 5 minutes. The focus of this game is the economic dimension of SSCM. The game includes time delay, and communication dynamics in the SC.

![Figure 8 Logistics Game gameplay overview](image)

Figure 8 Logistics Game gameplay overview [16]

Logistics Game [17] is a computer game. It is a 1 player game that requires a facilitator. Playtime for the game is not specified and indicates variability according to the player. The learning objective of the Logistics Game is conveying SC, material disposition, and quality management techniques. The focus of this game is the economic dimension of SSCM. The game includes market fluctuation and time delay in the SC.
Mango Chain Game [18] is a board game. It is a 7 to 11 player game that requires 2 to 3 facilitators. A typical session of this game takes 2.5 to 3 hours. The Mango Chain Game [18] is played on a game board placed on a large table surrounded by enough space to allow participants to walk around it. Players in the game can be producers, multinationals, independent exporters, and retailers. The game involves producing, trading, transporting, fulfilling contracts, and the consumer market. The goal of the game is to maximize company revenue. The primary focus of this game is the economic dimension of SSCM. The game includes market fluctuation, and communication dynamics in the SC.

Figure 10 Game boards for Mango Chain Game during a game session[18]
Milk Supply Chain Game for Waste Management [19] is a computer game. It is a 4 to 8 player game that requires 1 facilitator. In this game, the player is part of a milk supply chain as either a producer or a super market. In either role, players strive to reduce milk waste by properly managing their inventory. Player are encouraged to negotiate to achieve reasonable milk prices between super markets and producers. The Milk Supply Chain Game [19], teaches players the rule of thirds applied to food in Japan. The goal of the game is to reduce milk waste and be the most profitable company by the end of the game. The game includes market fluctuation, time delay, and communication dynamics in the SC.

Poker Chips [20] is a board game. The playtime or number of players of this game are not specified by the creator. It is known that it requires a facilitator. The purpose of the Poker Chips game is to demonstrate the detrimental impact of using single-item, single firm inventory theory in a multi-item, multi-echelon production/distribution system for a multi-item, multi-echelon production/distribution environment using theory of constraints and just in time to avoid risk. The focus of this game is the risk dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

SBELP: Supply Chain Simulator [21] is a computer game. It is a 1 player game that requires no facilitator. A typical play session of SBELP: Supply Chain Simulator has a duration of 1 hour. Players are taught the importance of inventory holding, back order cost, upstream, downstream and the bullwhip effect. SBELP tries to emulate an international supply chain network. The supply chain is used to deliver goods such as electronic equipment. The performance of the supply chains is judged by the parameters such as inventory holding cost, backorder cost and transportation cost. The primary focus of this game
is the economic dimension of SSCM. The game includes market fluctuation, time delays and communication dynamics in the SC.

![Figure 12 SBELP interface [21]](image1)

SCMDesign Game [22] is a board game. It is a 7-player game that requires a facilitator. A typical session of the SCMDesign Game has a duration of 1 hour. While playing this game, players are taught design thinking, logistics, and supply chain management. The main concern of this game is the economic dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

![Figure 13 SCMDesign game system [22]](image2)

Seconds [23] is a computer game. It is a 24-player game that requires a facilitator. The playtime of a session of Seconds is not specified. Seconds intends to teach the players strategic decision making.
The game aims at supporting the user in making strategic decisions within the scope of a collaborative manufacturing. The game is based on a generic process model and a simulation engine providing a complex virtual business environment. Each player takes over a role in an organization designed in the game, establishes sites, buys buildings defines departments, and controls processes. Players must find business partners, communicate, and negotiate with them. Analyzing risks and opportunities is emphasized. The main concern of this game is the economic dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

Shortfall computer game and board game [24]. It is a 6 to 12 player game that requires a facilitator. A typical session of Shortfall has a duration of 2 hours for the board game and is not specified for the computer game. In the game players are taught SCM and environmental benign manufacturing also known as green manufacturing, it is the renewal of production processes and the establishment of environmentally-friendly operations within manufacturing. The game allows for competition among three teams or companies in an automobile supply chain. Tier 2 suppliers, Tier 1 materials and OEM car manufacturers. The game offers students’ opportunities to assess many weighted decisions, to indicate that business decisions that include environmental factors are not cut and dry. The main concern of Shortfall [24] is the environmental and economic dimensions of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

Figure 14 Shortfall automobile manufacturer team board [24]

Siemens Brief Case Game Supply Chain Simulator [25] is a board game. It is a 9 to 18 player game that does not require a facilitator. A typical session of Siemens Brief Case Game Supply Chain Simulator has a duration of 2.5 to 10 hours. The game teaches players the importance of delivery capability, customer delivery, reliability, quality, and profit. The supply chain consists of a customer, a supplier, sales order processing, sales traffic and warehousing, plant procurement, subassembly, final assembly, plant order processing and plant traffic and warehousing. Player in the simulation play the roles of employees in these activities and carry out the task needed to transform an order issued by the customer into a delivered product. The primary focus of this game is the economic dimension of SSCM. The game included market fluctuation, time delay and communication dynamics in the SC.
Sim Green [26] is a board game. The purpose is to present a new conception to the learner that at the planning stage a systemic view of the potential solutions and the summary of related required resources could optimize the decisional process about the integration of the environmental activities. The number of players for this game is not specified, however it does require a facilitator. The playtime is also not specified. In Sim Green players are taught the importance of carbon footprints, environmental management systems, utilization of recycled materials, product life cycle and the WEEE directive. The primary focus of this game is the environmental dimension of SSCM. The game includes communication dynamics in the SC.

Stock Control [27] is a board game. It is a 1 player game that does not require a facilitator. A typical play session of stock control has a duration of 1 hour. Stock Control is an online game that is played within a web browser. The player is tasked with making the “when” and “how many” decisions of ordering independent demand inventory items while simulated time is running. In each of the nine levels of play, the student must manipulate one or more inventory decision variables to find their optimal values. The levels lead the student through a sequence of inventory concepts in an order that is similar to what is often used in introductory operations management textbooks. The focus of this game is the economic dimension of SSCM. The game includes market fluctuation and time delay in the SC.

![Figure 15 Stock Control user interface](image)

The Dice Game [28] board game and computer game. It is a 12-player game that requires a facilitator. The typical duration of a session of this game is not specified by the developers. In the Dice Game players learn about production processes, lead times, and pull vs push in SCM. The Dice Game is a virtual environment in which people can simulate the production process of a hypothetical factory. The scenario for a real implementation of the game used to involve simultaneously 12 people from plant personnel around a table, each one simulating the operation of a manufacturing cell in the production line. Each station was simulated with objects representing raw material colored chips), machines (the dice), finished product, etc. The game includes market fluctuation, time delay and communication dynamics in the SC.
The Distribution Game [29] is a computer game. It is a single player game that does not require a facilitator. The length of a play session is from 10 to 15 minutes. While playing the Distribution Game players learn the importance of inventory and safety stock. The focus of this game is the economic dimension of SSCM. The game includes market fluctuation and time delay.

The Supply Chain Game [30], it is not specified whether The Supply Chain Game is a computer game or a board game. It is a 1 player game that requires no facilitator. The duration of a session of this game is 3 or more hours. The Game teaches the concept of risk management in SCM. In “The Supply Chain Game” [30], players at first will only deal with risks within an organization. In a second step they will operate in an inter-organizational collaboration and face inter-organizational risks. The main concern of this game is the risk dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

The Global Supply Chain Game-The Distributor Game [31] is a computer game. It is a game that can be played from 1 to 36 players and requires a facilitator. The game teaches players the complexities of global supply chains and exogenous events. The GSCG differs from many existing business learning games in that, as opposed to being turned-based and locked in on demonstrating a single phenomenon (i.e., the bullwhip effect), it simulates a real-world experience by operating on a continuous clock with ongoing events and responses to individual decisions. The focus of this game is the risk dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

The Green Beer Game [32] is a board game. It is a game that can be played by 4 or more players and requires a facilitator. A typical game session has a duration of 1.5 hours. The green beer game is

![Figure 16 Distributor Game user interface for the player [31]](image-url)

The Green Beer Game [32] is a board game. It is a game that can be played by 4 or more players and requires a facilitator. A typical game session has a duration of 1.5 hours. The green beer game is
inspired by the Beer Game. This game teaches players the importance of green supply chain management. This game is in the environmental dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

The Supply Chain Disruption Game [33] is a board game. It is a 5-player game that requires a facilitator. A typical session of this game has a duration of 3.5 hours. The Supply Chain Disruption Game teaches players risk management and Shared Situational Awareness (SSA) through three different scenarios. This game is in the risk dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

![Figure 17 Sheet from the Supply Chain Disruption Game [33]](image)

The Supply Chain Game [34] is a computer game. It is a 2 to 6 player game that requires a facilitator. The developers do not specify the typical session length of The Supply Chain Game. It is an online supply network simulator, students are divided into teams and compete against each other in one or two assignments lasting a week each. To meet the different demand patterns in five regions, student teams set production and inventory control parameters, transportation choices, and add new factories and warehouses. The objective of the game is to maximize the cash position at the end of the game while avoiding demand risk. While playing this game players will learn forecasting, inventory management, production control, supply network design, and logistics. This game is located on the risk dimension of SSCM. The game includes market fluctuation, time delay and communication dynamics in the SC.

![Figure 18 The Supply Chain Game user interface [34]](image)
Trust and Tracing [35] is a board game. It is a 4-player game that requires a facilitator. The playtime for Trust and Tracing is 3 hours. In this game players learn the concept of trust among different stakeholders in the supply chain. Trust and Tracing models a generic food supply network. The product traded has a hidden quality attribute that can be either ‘high’ or ‘low’. This could symbolize the invisibility of quality, freshness, harmful chemicals, or pollutants, etc., appearing in food. There are four roles for participants: producer, middleman, retailer, and consumer. The game leader acts as the tracing agency for uncovering the hidden quality at the demand of any participant who has purchased an untraced envelope of pretended high quality. The tracing agency provides a means for anybody except producers to check the hidden quality of a product. Due to the labels that traders put on the envelopes when selling, he can see which trader sold the product for what stated quality. Thus, he can reveal cheats about the quality, the game also tries to teach supply chain optimization among stakeholders. The game includes market fluctuation, time delay and communication dynamics in SC.

Table 2 Summary of SCM games and their purpose/content

<table>
<thead>
<tr>
<th>Game Name</th>
<th>Purpose of the SCM game</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beer Game [5]</td>
<td>Bullwhip effect</td>
</tr>
<tr>
<td>Littlefield Technologies [14]</td>
<td>Supply chain management</td>
</tr>
<tr>
<td>CODEPR [7]</td>
<td>Communication, cooperation</td>
</tr>
<tr>
<td>CRAC Metal Box Business Game [8]</td>
<td>Operations Management</td>
</tr>
<tr>
<td>LOGA Logistics Game [15]</td>
<td>Logistics</td>
</tr>
<tr>
<td>Coke It Game [16]</td>
<td>Forecasts, inventory, production control, production optimization</td>
</tr>
<tr>
<td>Logistics Game [17]</td>
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</tr>
<tr>
<td>Mango Game [18]</td>
<td>inventory management, material handling, inventory planning, production planning,</td>
</tr>
<tr>
<td>Milk Supply Chain Management Game [19]</td>
<td>demand planning</td>
</tr>
<tr>
<td>Sim Green [26]</td>
<td>Design thinking, logistics, supply chain management</td>
</tr>
<tr>
<td>SHORTFALL [24]</td>
<td>Strategic decision making</td>
</tr>
<tr>
<td>Trust and Tracing [35]</td>
<td>Trust among different stakeholders in supply chain, business ethics, SC optimization</td>
</tr>
</tbody>
</table>

…

34
## Table 3 Games in Conventional Studies

<table>
<thead>
<tr>
<th>SG Name</th>
<th>Dimensions Integrated</th>
<th>Provides General Understanding of SSCM</th>
<th>Teach Solutions to Problems in SCM or SSCM</th>
<th>Diversify player’s approach to SCM or SSCM</th>
<th>Shortest additional playtime required to experience other dimensions not included in game</th>
<th>Target Audience</th>
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<td>Beer Game [5]</td>
<td>2 &amp; 4</td>
<td>×</td>
<td>○</td>
<td>×</td>
<td>4.5 h</td>
<td>A &amp; B</td>
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<td>Brass [6]</td>
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<td>×</td>
<td>○</td>
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<td>×</td>
<td>○</td>
<td>5.5 h</td>
<td>A &amp; B</td>
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<td>○</td>
<td>×</td>
<td>7.5 h</td>
<td>A &amp; B</td>
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</tr>
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<td>A &amp; B</td>
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<td>Shortfall [24]</td>
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<td>B</td>
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<td>Sun Green [26]</td>
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<td>○</td>
<td>×</td>
<td>5.5 h</td>
<td>A &amp; B</td>
</tr>
<tr>
<td>Game</td>
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<td>○</td>
<td>×</td>
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<td>The Distribution Game [29]</td>
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<td>×</td>
<td>5.5 h</td>
<td>B</td>
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<td>5.5 h</td>
<td>A &amp; B</td>
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</tr>
<tr>
<td>The Supply Chain Disruption</td>
<td>4</td>
<td>×</td>
<td>○</td>
<td>×</td>
<td>5.5 h</td>
<td>A &amp; B</td>
</tr>
<tr>
<td>Game [33]</td>
<td>4</td>
<td>×</td>
<td>○</td>
<td>×</td>
<td>5.5 h</td>
<td>B</td>
</tr>
<tr>
<td>The Supply Chain Game [34]</td>
<td>4</td>
<td>×</td>
<td>○</td>
<td>×</td>
<td>5.5 h</td>
<td>A &amp; B</td>
</tr>
<tr>
<td>Trust and Tracing [35]</td>
<td>2 &amp; 3</td>
<td>×</td>
<td>○</td>
<td>×</td>
<td>4.5 h</td>
<td>A &amp; B</td>
</tr>
</tbody>
</table>

**This Research Games**

| Chain of Command: A                         | 1, 2, 3 & 4          | ×                                      | ○                                        | 3 h                                                                              | B               |
| Sustainable Supply Chain Management Serious Game [36] | 1, 2, 3 & 4 | ×                                      | ○                                        | 3 h                                                                              | B               |
| Looper (Single player)                      | 1, 2, 3 & 4          | ×                                      | ○                                        | 1 h                                                                              | B               |

1=Environment, 2=Economy, 3=Social, 4=Risk; ○=Yes, ×=No; A=Companies & SCM/SSCM Professionals, B=Students & Non SCM/SSCM Professionals
Difference with conventional studies. There are two main cases, see Figure 19, when designing and using games in research. In the first case, the game is used as a tool to test a theory or gain new insights into human behavior. The second case is using games as an educational tool to teach people about a topic or concept.

Within the second option, there are two paths to game development. The first option has researchers develop SG gathering requirements from companies to design and build games that can focus on specific issues. The games provide practical knowledge to professionals regarding the topic of the game, whether it be SSCM or any other topic. In this case, researchers tend to isolate, or at most, combine 2 dimensions to provide a deeper understanding of the topic to companies and professionals. The games only focus on very specific issues in the chosen dimensions. For example, CODEPRO [7] focuses on the social dimension and teaches communication and cooperation. Shortfall [24] focuses on the environment/economic dimensions and teaches environmental benign manufacturing and supply chain management. Lean Leap Logistics Game [13] focuses on the economic dimension and teaches supply chain core processes and problems. It is clear then, that games in SCM focus primarily on a single dimension.

In the second option, the reasoning behind developing the game is not to provide concrete practical knowledge to company professionals but to give an understanding of a topic to students and non-professionals in a short time. This approach does not require the developer to gather requirements from a company to later develop a game that suits the company’s needs, it only requires the developer to understand the topic enough to be able to develop a game. That is why researchers in SSCM had yet to develop a game in this area, the focus in conventional studies is to provide concrete solutions to problems for professionals. Chain of Command and Looper have a purely academic reason to exist.

Figure 19 Game use in research, development type & game purpose.
It appears that the complexity of having more than one dimension in a SCM game to convert it into a SSCM game is an additional issue that researchers are not tackling. To tackle this issue several frameworks and models for SG design were also reviewed.

There are plenty of frameworks and models for the development of SG. Table 4 shows 17 frameworks and models and compares them to SETP and the SSG model.

### Table 4 Models and Frameworks for SG Development

<table>
<thead>
<tr>
<th>Model/Framework Name</th>
<th>Considers Fun</th>
<th>Considers Replay Value</th>
<th>Considers Stealth Learning</th>
<th>Standard SG Learning</th>
</tr>
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<tbody>
<tr>
<td>4 Dimensional Framework [37]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARCS [38]</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>CMX Design Framework [39]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Play Experience (DPE) [40]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital Game Based Training Systems [41]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DODDEL [42]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational Games</td>
<td>○</td>
<td>○</td>
<td></td>
<td>○</td>
</tr>
<tr>
<td>HABS+ISIS [44]</td>
<td>○</td>
<td>○</td>
<td></td>
<td>○</td>
</tr>
<tr>
<td>Key Criteria for Game</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model Driven Design Framework to Support Development of SG [47]</td>
<td>○</td>
<td></td>
<td></td>
<td>○</td>
</tr>
<tr>
<td>P-III Framework [48]</td>
<td>○</td>
<td>○</td>
<td></td>
<td>○</td>
</tr>
<tr>
<td>Robert L. Appelman Model [49]</td>
<td>○</td>
<td>○</td>
<td></td>
<td>○</td>
</tr>
<tr>
<td>Serious Game Constructivist Framework for Children [50]</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SGameFlow Framework [51]</td>
<td>○</td>
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<td>○</td>
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<tr>
<td>SGGD [52]</td>
<td>○</td>
<td></td>
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<td>○</td>
</tr>
<tr>
<td>Six Facets of Serious Game Design [53]</td>
<td></td>
<td></td>
<td></td>
<td>○</td>
</tr>
<tr>
<td><strong>This Research SETP</strong></td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★</td>
</tr>
<tr>
<td><strong>This Research SSG</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Model</strong></td>
<td>○</td>
<td>○</td>
<td></td>
<td>○</td>
</tr>
</tbody>
</table>

○ → Complies with the category.

★ → Requires changes to comply with the category.

A brief explanation of each SG framework or model will now be given.

4 Dimensional Framework [37] has 4 main dimensions. The first-dimension “context” refers to whether the SG is classroom based, outdoors, requires access to equipment, technical support etc. The “learner” is the next dimension, which focuses on the learner profile, pathways, learning background, group profile etc. The third dimension focuses on the internal representational world of the SG or
simulation, in other words, the mode of presentation, the interactivity, the levels of immersion, and fidelity used in the game or simulation. This dimension allows for the focus and analysis of the format and mode of the game or simulation. The fourth dimension focuses on the process of learning both during formal curricula-based learning time and during informal learning. This dimension promotes the practitioners’ reflection upon methods, theories, models, and frameworks used to support learning practice.

ARCS (Attention, Relevance, Confidence, and Satisfaction) [38] model consists of four elements for promoting and sustaining motivation in the learning process. These four processes are: attention, relevance, confidence, satisfaction, and instructional content. Relevance has two main components; perceptual arousal aims to surprise the user and gain his interest, while inquiry arousal aims to stimulate the curiosity by posing challenging questions or problems to be solved. Relevance makes it clear to the learner why playing the game is important. Confidence, it is important that the players have the feeling of confidence in the possibility of success regardless of external factor or innate ability of the learner. Finally, in Satisfaction the learner must get satisfaction after a learning period.

CMX Design Framework [39] has the following components: infrastructure, learning objectives, pedagogy, learning outcomes, user, scenario, and activities. In infrastructure, the infrastructure architecture, technical requirements specification and user interface concepts visualization design are established. In learning objectives, the designer defines generic goals for the game. In pedagogy, the number of units of learning educational material to be taught, etc. is used to determine the game’s layout. In learning outcomes, the target outcomes include the comprehension of the taught material. In user, the specific characteristics of users are determined. In scenario, the game’s setting should be thoroughly researched and planned out to produce an attractive and immersive virtual world. Finally, in activities, the design and development of things to do is essential and will result in the interest and participation of the students.

Design Play Experience (DPE) [40] framework aims to demonstrate and analyze the phases that correspond to each design layer. During the design phase the learning objectives that will guide the activities design are identified. In the play phase, the interaction of the players with the game’s features are represented; it is during this phase, that designers must consider the target audience that will use the educational game. Finally, the experience phase relates to the different understandings that the players will obtain.

Digital Game Based Training Systems [41] has three main components. The authoring component addresses the teacher and includes playing the back-story, accessing, and integrating external data and creating tasks. The training component addresses the student, this component adheres to traditional SG and implements in-game training; it also includes the logging of specified data and data changes such as those caused by user interaction, the evaluation of the logged data in terms of
training session assessment and the visualization of the assessment in a comprehensible visual review log. The final component is data representation, this component is essential when presenting learning content in a game-based user interface. Data access can be granted via data interfaces of the respective components.

DODDEL [42] offers an articulation from broad design approach to detailed specifications, multiple iterations within each stage incorporating dependent elements specific to the learning outcomes, user needs, characteristics, and the learning strategy developed. Heuristics guide the content within each element and specified document outputs are created at each stage of the process. The model addresses the complete development lifecycle.

Educational Games Design Framework [43] has three main components: Game design, pedagogy and learning content modelling. Game design contains three components, usability (satisfaction efficiency and effectiveness) multimodal (multimedia and interaction) and fun (challenge, clear goals, uncertain outcome, and self-esteem). The pedagogy component contains learning outcomes, motivation theory, self-learning and problem solving. The learning content modelling component contains syllabus matching and scaffolding.

HABS+ISIS [44]; HABS has three main components: operations, actions, and activity. The “operations” component contains conditions that need to be met, such as, keyboard and mouse linked to virtual operations. In “actions”, the designer sets up goals, sub-goals, and sub-sub goals for the player. The final component “activity” contains the motive and the objective of the game. ISIS is a graphical user interface that indexes the results and queries generated by the game. It helps in the understanding of players behavior and experience.

Key Criteria for Game Design [45] provides a list of criteria that must be considered when developing a SG. The key criteria are: Motivation-competence, motivation-autonomy, motivation-relatedness, content, freedom rules and feedback, mistakes, failure and emotional aspects, game integration, acceptability, usability, and utility. By taking these key criteria into consideration the SG designer should be able to create a SG that provides a compelling experience to the player.

Mechanics Dynamics Aesthetics (MDA) [46] In MDA the mechanics give rise to dynamic system behavior, which in turn leads to aesthetic experiences. Aesthetics deals with the description of the SG, words such as sensation, fantasy, narrative, challenge, fellowship, discovery, expression, and submission can be used. Dynamic models work to create aesthetics experiences. Dynamics should remain as concrete as possible. Mechanics are the various actions, behavior and control mechanism afforded to the player within a game context and support the overall gameplay dynamics.

Model Driven Framework to Support Development of SG [47] consists of nine modules: user interface, models, mde tools, components library, code templates, artefacts, technology platform,
operating platform, and software. The “user interface” module supports input mechanisms such as natural language, script, or visual language. The “models” module contains the game content model, the game technology model, and the game software model. The MDE tools module performs the transformation between models. The “component library” module contains art assets and game functionalities. The “code templates” contains predefined code that can be mapped. The artefacts contain source codes, settings, and documentation. The technology platform can be XNA, Java, Unreal or Flash to name some examples. The operating platform can be console, smart phone, pc, or web. Software refers to SG.

P-III Framework [48] has four pillars. The first pillar is player centered design, P-III process incorporates specific methods to involve the player throughout the design process from ethnographical inquiries at the start of the project and participatory design phase to user test during the development. The second pillar is iterative development; an iterative and incremental approach to game design and development. The third pillar is interdisciplinary teamwork; SG development requires a broad range of expertise. To develop a SG that is fun to play and effective in reaching its serious goals, instructional and game designers need to collaborate. The final pillar is the integration of play and learning, play and learning needs to be integrated as close as possible, a successful SG according to the P-III framework provides a seamless blend between the game fantasy, core mechanics and the learning principles.

Robert L. Appelman Model [49] this model involves the quantification of key operant categories. These categories are the player experience and the game structure. The player experience contains: cognition (changes in cognitive and affective domains), meta cognition (vision, audio, olfactory, kinesthetic, and haptic senses, plus the awareness of time), choice (perception of degree of control and access to variables and information during game play) and action (perception that the player can do things such as interact with objects and elements within the game. The game structure contains: content (the story, the context, the amount of information available), environment (the virtual spaces and boundaries, the objects within these spaces and their functional capabilities) and affordances (the abilities made for the player to change, manipulate, the objects, information, environment, their identity & capabilities.)

Serious Game Constructivist Framework for Children [50] has 6 main components: Modeling (modeling is a form of demonstration followed by imitation, frequently used as a way of helping the learner progress), reflection (involves enabling the children to compare their own problem solving processes with those of an expert or another child), strategy formation (the child tries to form appropriate playing strategies in order to solve the problems that the game provides), scaffolded exploration (involves guiding the students to a mode of problem-solving on their own), debriefing (it helps learners explore what went on, talk about their experiences, develop insights, and connect the
activities to their real-life situations), and articulation (children can share their game experiences and acquired knowledge).

SGameFlow Framework [51] contains 8 dimensions: player skill (must support the player skill development and mastery), challenge (should be sufficiently challenging and match the player’s skill level), concentration (the game must require concentration and the player must be able to concentrate on the game), feedback (must provide frequent information for players to determine the distance and progress towards objectives), immersion (players should experience immersion in a game, immersive games draw players into the game and affect their senses through elements such as audio and narrative), learning opportunities (the learning process has to be taken into consideration in the SG design), accessibility (the SG must be easy to use for people with special needs), adaptivity (the SG must adapt to the player’s cognitive load).

SGISD [52] is a model that has several components: Analysis (instructional theory, needs analysis, target audience, and external data), concept (learning methodology, and game features), design (character design, design lessons, design media, storyboards, and assessment design), quality assurance (bug testing, usability testing, play/fun testing, and learning testing), technical design specifications, prototype implementation (media construction, write lesson plans, and produce material), interactive lesson plan, learner material/game, modding (new scenario, new learning objectives, and new evaluation) and summative evaluation. The model develops SG in an iterative process.

Six Facets of Serious Game Design [53] contains six elements for SG design. These elements are: Pedagogical objectives (defines the pedagogical content), domain simulation (raises the problem of how to respond consistently and coherently to the correct or erroneous actions of the game players within a specific ambiguous context), interactions with the simulation (specifies how to engage the players by allowing them to interact with the simulator), problems and progression (concerns which problems to give the players to solve and in which order), decorum (specifies which type of multimedia or fun elements, unrelated to the domain simulation will foster the motivation of the players) and conditions of use (specifies how, where, when, and with whom the game is played).

The analysis of conventional studies shows that there is no SG model/framework that considers fun, replay value and stealth learning as the main pillars for SGD. Fun is the most common aspect for the different models/frameworks available; next is stealth learning and finally there is replay value with only one explicit mention. SG, SSG should have replay value as a core design pillar. A SG or SSG that can only be played once is missing the opportunity to provide further learning to the player. A prime example of a game that is very successful at teaching but also not fun is the Beer Game [5] developed by MIT. This game excels at education and at the same time fails at being highly entertaining. Many of the models/frameworks focus on standard style of learning in games. What is meant by “standard style of learning”? The traditional structure of SG play session followed by a debriefing session. Debriefing
is a powerful tool to enhance SG learning, nonetheless, it should not be the main activity in driving learning in players. The author believes that debriefing is occasionally used as a crutch for subpar SGD.

In this study the following research questions are investigated:

Question 1: Why are there few SSCM games?

Question 2: What are the contents and characteristics (session length, number of players, pc use and competitive/non-competitive) of SCM and SSCM games?

Question 3: Are SETP suitable for SGD and development?

Question 4: Are the SSCM games developed successful at teaching and bringing awareness to SSCM?

Additional research questions stemming from the development of the Origami SG, CoC, and Looper are formulated and answered in their respective chapters.

The objective of this study is to develop a game that successfully integrates the three dimensions of sustainability and risk management. This thesis contributes with insights from interdisciplinary research on SSCM games and SGD. The games developed can be used to bring awareness of SSCM to a broader audience and the SSGM can be used to develop next generation SG.

1.5 Originality

The challenge lies in creating a game that is not too complex as to not overburden the player but have just enough options to allow for the interaction of the different dimensions of SSCM. Existing games in SCM primarily focus on one or two dimensions of sustainability and on very specific concepts within that dimension. Integrating the three dimensions of SSCM in a single game and achieving an appropriate balance between them poses a challenge. The complexity of developing a SSCM game stems from the core difficulty of SCM topics such as market fluctuation, time delay and communication among stakeholders. The initial game developed CoC contained the formerly mentioned topics of SCM and proved to be significantly complex for players to play and learn from the game. Market fluctuation, time delay and communication among stakeholders are not relevant topics for the player to understand the core integration of the four dimensions of SSCM (environment, economy, social and risk).

The originality of this study is tackling the complexity of developing a SSCM game by eliminating or simplifying the following complex topics in SCM: market fluctuation, time delay and communication dynamics in the SC. Simplifying the previously mentioned topics allows non SCM professionals to focus and learn the core of SSCM through an easy to play game (Looper).

The educational advantage of simplifying a complex concept/topic is that the players, in particular beginners, can focus on the main core of the concept/topic and can better understand it. The demerit of simplifying is that such an approach is not useful to teach people with more advanced
knowledge on the concept/topic, simplification is not recommended when trying to teach people with intermediate to advance knowledge. Simplifying SCM concepts allows for an easier integration of SSCM concepts/topics and allows the designer to more easily transform concepts into game mechanics to be implemented in the game.

The topic of market fluctuation in SC is eliminated from the game as is the topic of communication dynamics. The elimination of communication dynamics results in a single player game were the player has a complete overview of the whole SC, hence, the communication that is usually required among SC stakeholders is eliminated. The elimination of a fluctuating market means that the demand for products is unlimited. Time delay in SC is minimized by not having several stocks in the game and having the most simplified time delay behavior between suppliers. The simplified time delay only requires goods to be delivered to the SC company and then transported to the next company in the SC; there are no stock time delays inside the companies of the SC in Looper.

The two games developed are: CoC and Looper. CoC is more complex than Looper but still manages to merge all the dimensions of SSCM into a single game, unfortunately it has extended play sessions, it is complicated to understand and complex to play due to incorporating market fluctuation, a non-simplified time delay and communication among SC stakeholders; there was a need to further simplify the game. Looper is the simplification that is needed, it is a single player game that allows for better understanding of SSCM. It is aimed at beginners and eliminates the topic of market fluctuation and communication among stakeholders in the SC, additionally, it simplifies the time delay.

Figure 20 Research originality

Figure 20 The left side displays the topics in SCM that must be eliminated or simplified to reduce SCM complexity as the main focus of the game is not professionals but students/non SCM professionals (beginners) and showing player options as cards to the player. These requirements are used as inputs to develop Looper. The right side displays the core topics in SSCM and the concepts being taught by
Looper in each of them. Table 5 displays the concept, simplified concept behavior, game mechanics, implementation in Looper and the interaction of the concept with other SSCM and risk dimensions. See Table 5.

Table 5 Looper summary of concepts simplification, game mechanics and SSCM Integration

<table>
<thead>
<tr>
<th>Concept</th>
<th>Simplified concept behavior</th>
<th>Game Mechanics</th>
<th>Integrates SSCM dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product Life Cycle</td>
<td>From creation to disposal</td>
<td>Raw material/products manufacturing: Physically represented by a black cube see Figure 44. Customer: Represented by a zone in game board see appendix section 11.3.4 Landfill: Represented by a zone in game board see appendix section 11.3.4</td>
<td></td>
</tr>
<tr>
<td>Closed Loop SC</td>
<td>Generate <code>value</code> from trashed/disposed products</td>
<td>Raw material/products manufacturing: <code>Physically</code> represented by a black cube see Figure 44. Customer: Represented by a zone in game board see appendix section 11.3.4 Landfill: Represented by a zone in game board see appendix section 11.3.4 Recycling: Represented by a zone in game board available at 4 different locations, see appendix section 11.3.4</td>
<td></td>
</tr>
<tr>
<td>Carbon Footprint</td>
<td>All activities produce CO₂</td>
<td>Technology levels: Represented by 3 technology levels, see appendix section 11.3.3 Raw material/products manufacturing: Physically represented by a black cube see Figure 44. Raw material/products transportation: Represented by streets in the game board, see appendix section 11.3.4 Carbon footprint meter: Represented by six multipliers ranging from 1.01 to 1.06, see appendix section 11.3.4</td>
<td></td>
</tr>
<tr>
<td>Government Environmental Regulations</td>
<td>Enforce behavior by an entity</td>
<td>Government environmental regulations: Represented by 3 cards that raise an environmental regulation level meter, see appendix section 11.3.4 game board lower part. Audits &amp; Government penalties: Represented by an event card, see appendix section 11.3.3 Environmental certification: Represented by 3 environmental certification levels, see appendix section 11.3.3 Carbon footprint meter: Represented by six multipliers ranging from 1.01 to 1.06, see appendix section 11.3.4 game board lower part</td>
<td></td>
</tr>
<tr>
<td>Green Technology</td>
<td>Reduce environmental impact</td>
<td>Technology levels: Represented by 3 technology levels, see appendix section 11.3.3 Raw material/products manufacturing: Physically represented by a black cube see Figure 44. Raw material/products transportation: Represented by streets in the game board, see appendix section 11.3.4 Recycling: Represented by a zone in game board available at 4 different locations, see appendix section 11.3.4 Customer: Represented by zone in game board, see appendix section 11.3.4</td>
<td></td>
</tr>
<tr>
<td><strong>Legend:</strong> Environment ● Economy ● Risk ● Social ●</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

44
Customer: Represented by a zone in game board see appendix section 11.3.4

<table>
<thead>
<tr>
<th>Concept</th>
<th>Simplified concept behavior</th>
<th>Integrates with SSCM dimensions</th>
<th>Integrates SSCM dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Disruption</td>
<td>Cripple a node in the SC</td>
<td>Event card/natural disasters: Represented by several cards, see appendix section 11.3.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supplier Failure: Represented by three types of suppliers and the roll of a die, see lower right corner of game board appendix section 11.3.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raw material/products transportation: Represented by streets in the game board, see appendix section 11.3.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sales: Represented by a zone in game board see appendix section 11.3.4</td>
<td></td>
</tr>
<tr>
<td>Inventory Control</td>
<td>Complete view of all raw materials/products in the SC</td>
<td>Factory, wholesaler, retailer, supplier: Represented by locations in each of the 4 zones in the game, see Figure 44.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Retrieving: Represented by a zone in game board available at 4 different locations, see appendix section 11.3.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recycling: Represented by a zone in game board available at 4 different locations, see appendix section 11.3.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raw material/products manufacturing: Physically represented by a black cube see Figure 44.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Raw material/products transportation: Represented by streets in the game board, see appendix section 11.3.4</td>
<td></td>
</tr>
</tbody>
</table>

Social

<table>
<thead>
<tr>
<th>Concept</th>
<th>Simplified concept behavior</th>
<th>Game Mechanics</th>
<th>Integrates SSCM dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate Social Responsibility</td>
<td>Perform good actions expect nothing back</td>
<td>Corporate Social Responsibility Card: Represented by a card in game, see appendix section 11.3.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Event card/Natural disasters: Represented by several cards, see appendix section 11.3.3</td>
<td></td>
</tr>
</tbody>
</table>

Legend: Environment ●, Economy ●, Risk ●, Social ●

1.6 Research Goal

The goal of this research is to overcome the challenge of integrating the three dimensions of SSCM and risk management into a game that can be used to raise the awareness of SSCM in the public. To achieve this, an extensive literature review on SCM and SSCM games is performed. A literature review on SG models and frameworks is also performed to help in the design of the SSCM game. A method is devised to overcome the complexity of SSCM and to properly integrate the triple bottom line and risk management.

1.7 Research Structure

This dissertation consists of 8 Chapters. Chapter 1 describes the purpose, goals, and structure of this research. The chapter begins with a research background on serious games and the establishing the fact that there are no SSCM games. The literature review reveals that games in conventional studies focus only on one or at most two dimensions of sustainability. Chapter 2 describes the quantitative and qualitative methods used during the research. Chapter 3 provides insight into the game design process, the complexity reduction method, systems engineering technical processes, the stealth serious games model, and the serious game cube. Chapter 4 regards the development and testing of the Origami SG a single dimension SC game focusing on economics, developed to gain insight into serious game design and test systems engineering technical processes in the design of serious games. Chapter 5 introduces the reader to SSCM and SSCM games. In addition to displaying the development of CoC and Looper. Chapter 6 contains detailed descriptions of the verification and validation, this includes test setups, data gathering and results for CoC and Looper. Test results show that Looper is more educational and
enjoyable to play than CoC and succeeds where CoC failed. Chapter 7 contains a discussion on the validation results from CoC and Looper, along with observations and insights obtained from the games testing. Important findings for Looper include players investing in green technology as a retroactive approach to government regulations, short lead times and SC robustness is valued over the environment and corporate social responsibility is an activity players are not willing to engage in if there is no incentive to do so. Chapter 8 contains the conclusion of the study for CoC and Looper related to our research goal and the academic contribution. It additionally provides the direction for future research: (1) Use Looper as a research tool to assess the behavior of players towards SSCM initiatives, (2) Develop a SSCM game that teaches solutions to current SSCM problems, (3) Develop a SSCM game for SSCM professionals. A comprehensive view of the thesis structure can be seen in Figure 21.

Figure 21 Research Structure
2 METHODS

An integral part of any research performed is the method by which the problem is attempted to be solved. In this study, after identifying the problem of a lack of games that teach and bring awareness to SSCM an approach was devised. The formulated approach contains several steps, that in conjunction make the method.

Figure 22 Holistic view of the method used for this research

The complexity of developing SSCM games stems from the combination of the 3 dimensions of sustainability (environmental, economic and social). In addition, to these 3 dimensions, risk is also being added as an additional dimension. Developing a SSCM game that only encompasses 1 dimension is the equivalent of developing a traditional SCM game. To achieve a SSCM the balance of the 3 dimensions of sustainability must be achieved. This study starts with a survey of SSCM games and SG frameworks and models. Having identified the under researched area of SSCM games three important steps are taken to start the development of SSCM games. The first step is the development of the Origami SG. The Origami SG focuses on a single dimension and teaches very specific concepts. The development of the Origami served two purposes. The first purpose is the evaluation of SETP as a framework to develop SG. The second purpose is obtaining experience for the development of SG. After the development of the Origami SG, a new model for the development of SSG emerged, together with a SG categorization model. The categorization model can be used for any SG topic. The SSGM is then used for the development of the SG. The testing and evaluation of the SG uses SE verification and validation. After the SSCM game is tested and evaluated, potential areas for improvement are detected. Should the SSCM game fail it is scraped and we return to either modifying the model or the scenario. If the SSCM game does not fail the testing and evaluation phase, then it is improved. Depending on the level of improvement required by the SSCM game, the SSCM game may undergo a lesser change or notable change. A meaningful change in the game requires the game to be moved back into the development section of the method in Figure 22. For the game Development section, the game is developed following the method shown in Error! Reference source not found.
This study utilizes qualitative and quantitative methods. The beginning of the study involves a systematic review and a thematic analysis. Additional qualitative and quantitative methods are later applied. A more detailed explanation regarding the qualitative quantitative and literature review methods used can be found in the sections below.

2.1 Qualitative Analysis

Qualitative research is broad methodological approach that encompasses several research methods. The understanding of a situation or a phenomenon comes from exploring the totality of the situation usually with access to significant amounts of data. It may start as a grounded theory approach with the researcher having no understanding of the phenomenon. The study may also commence with propositions and proceed in a scientific and empirical way throughout the research process [54]. The qualitative method used for this research is thematic analysis. Additional processes such as experiential learning debriefing and discussion are performed at the end of the Origami SG. Experiential learning debriefing is a semi-structured process by which the facilitator, once a certain activity is accomplished, makes a series of progressive questions in this session, with an adequate sequence that let the participants reflect what happened, giving important insights with the aim of that project towards the future, linking the challenge with the actions and the future (Yturralde as cited in [55]).

2.1.1 Systematic Review

For the literature review a systematic review is performed. Systematic review has its origins in the medical field [56] but has also been adopted to education [57]. A systematic review is a type of literature review that collects and scrutinizes several research studies. It is used to provide a complete and exhaustive summary of current literature relevant to the research question.

Steps of a systematic review:

1. Defining a question: Choose an objective method.
2. Search for relevant data: Only include research that matches the criteria.
3. Extraction of relevant data: Excerpt appropriate data.
4. Assess the quality of data: Data must comply to the criteria chosen during earlier stages
5. Review Analyze and combine the data: Visualize the data.

Extensive searches using a meta search engine (google scholar) are performed. Words are combined into search strings and a date limitation is often set to encompass the latest research on the field.

In this research, systematic review was used for the following:

1. Review of SG development frameworks and models.
2. Review of existing games in SCM for the development of CoC and Looper.

2.1.2 Thematic Analysis

A thematic analysis emphasizes pinpointing, examining, and recording patterns (or “Themes”) within data [58]. Themes are patterns across the data sets that are important to the description of a phenomenon and are associated to a specific research question [59]. The themes become the categories for analysis [60]. A thematic analysis categorizes and summarizes what is known and established already [61]. This method is used for the analysis of current SG development frameworks and games in SCM.

2.2 Survey Quantitative Analysis

2.2.1 Survey

During the development of the SG Origami, CoC, and Looper, surveys are used to gather information at specific stages of the SG session. In the case of the Origami SG, a questionnaire is administered at the end of the SG session. For CoC and Looper identical pre and post surveys are used. The information gathered by the surveys is later analyzed using statistical methods. The development of the surveys followed the best practices as outlined by Qualtrics®

The surveys may contain open ended, Likert scale or multiple-choice questions. For the Origami SG, a post survey with open ended questions and graph drafting is given. For CoC Likert scale and multiple-choice questions are used. Finally, the survey used for Looper similarly uses Likert scale and multiple-choice questions. The results of the surveys are later aggregated, statistical data is extracted, and observations are performed.

2.2.2 Statistics

Statistics is the systematic empirical investigation of observable phenomena via statistical, mathematical, or computational techniques [62]. The process of measurement is significant to quantitative research as it provides the essential connection among empirical observation and mathematical expression of quantitative relationships. Quantitative data is any data that is in numerical form such as statistics, percentages, etc. [62].

The Origami SG and CoC use traditional statistics such as: mean and standard deviation.

Looper’s hypothesis test is performed using Wilcoxon signed-ranked test. It is a non-parametrical statistical hypothesis test used when comparing two matched samples to assess whether their population mean rank differs.
2.2.3 SE V&V

Systems engineering verification and validation processes are used for CoC and Looper. According to the INCOSE handbook, the purpose of the verification process is to provide objective evidence that a system or system element fulfills its specified requirements and characteristics [63]. The purpose of the validation process is to provide objective evidence that the system, when in use, fulfills its business or mission objectives and stakeholder requirements, achieving its intended use in its intended operational environment [63]. The verification process for games mainly concerns checking that the game is in condition to be played; that is, the mechanics and dynamics of the game are working. The validation of the game is performed using the statistical methods explained in section 2.2.1 and 2.2.2.

Figure 23 shows a visual representation of the relationship of the methods used in the research and how they impact the development and results of the Origami SG, CoC, Looper, the SSG model and SETP assessment.

![Figure 23 Methods used in this research and the topics they were applied to](image)

Both qualitative and quantitative research methods are used in this research. The combination of this methods allows for Looper and CoC to be effectively developed, verified, and validated. In Figure 23, thematic analysis and systematic review are used for the literature review of SSCM and SCM games,
SG development models and frameworks. For the Origami SG statistic and survey quantitative methods are used to verify and validate the design of the Origami SG. The result of the thematic analysis and the systematic review of SG development models and frameworks in conjunction with the Origami SG give the first result of this study. That first result is the evaluation of SETP in the development of SG. The result of SETP is not favorable and future endeavors on this area are ceased. The thematic analysis yields the SGC classification model, that is later used to categorize the SSCM games developed in this study. SG Development Models and Frameworks together with SETP Assessment result produce the SSG model. SSCM & SCM games thematic analysis result is used with the SSG model to produce CoC. Survey and statistic methods are used to verify and validate the design of CoC. The game looper, is the result of the research done in SSCM and SCM games, the SSG model, and CoC. Statistic and survey methods are used for the validation and verification of Looper. In Figure 23 pink rectangles represent intermediate steps that enabled the obtention of research results denoted by blue rectangles. Yellow rectangles are methods used and the green rectangles represent qualitative or quantitative methods.
3 GAME DESIGN

3.1 Design Process

Any game starts with an idea, how the idea of the specific serious game is further developed is the responsibility of the SG designer. Serious game designers have several tools at their disposal to help them along the creative process, such as models. In this research a model, is a simplified version of a system to facilitate understanding by eliminating unnecessary components and presenting only the most important features that should be considered when developing SG. The use of models helps ensure quality work.

The conventional problem with games and the models the games are designed with tends to be a heavy focus on active learning. This study presents an alternative model for SG development and a definition for stealth serious games (SSG).

A novel model for SG design is presented in this study, the SSG model (SSG). The purpose of the SSG model is to bridge the gap between game design and serious game design, to create experiences that are educational, nevertheless, the player is not fully aware he or she is learning, known as “stealth learning” [64] and that possess a high replay value.

SSG have a high replay value coupled with an equal ratio of fun to educational content, the player is not aware that he or she is learning when playing and can be played for amusement or education. SSG are primarily designed with education as a goal, thus, SSG differ from conventional games acquired at toy shops. Games acquired at toy shops have not been designed with any educational purpose into consideration.

A systematic review of models available for SG development is performed to identify what current models may lack. Systematic review has its origins in the medical field [56] but has also been adopted to education [57]. This study’s approach entailed extensive searches using a meta search engine (google scholar). Words used for performing the search were: Serious, Game, Model, Framework, Education. The previous keywords are later combined into several strings. The strings used in the search are:

Serious Game Model

Serious Game Framework

Serious Game Model Education

Serious Game Framework Education
The intention is to create a search that will yield the most relevant examples. A 12-year limitation is set as to encompass all possible modern SG models. The results of the search categorized are as follow:

Fun is defined as an activity that is intended purely for amusement and should not be interpreted as having a serious purpose. Models taking into consideration Fun: Educational Games Design Framework [43], MDA [46], Design Play Experience (DPE) [40], P-III Framework [48], SGISD [52], Robert L. Appelman Model [49], Six Facets of Serious Game Design [53], Serious Game Constructivist Framework for Children [50], SGameFlow Framework [51].

Replay value is the property of the SG to be played repeatedly, providing new experiences, and learning to the player every time the SG is played. Additional to presenting a model to develop SG a definition of what SSG should be is presented. Models taking into consideration replay value: Key Criteria for Game Design [45].

Stealth learning: Eventuates when “players are focused not on learning but on playing” [65]Models taking into consideration stealth learning: Design Play Experience (DPE) [40], Serious Game Constructivist Framework for Children [50].

Models not including fun, replay value or stealth learning: HABS+ISIS [44], Model Driven Framework to Support Development of SG [47], DODDEL [42], 4 Dimensional Framework [37], CMX Design Framework [39], Digital Game Based Training Systems [41], ARCS [38].

17 models were analyzed and categorized based on the limitations that these models possessed SSG model was developed. Stealth learning and replay value were 2 important concepts that the previous models do not address in conjunction. Table 6 contains an easier to understand visual representation of the categorization above for quick reference.
### Table 6 Elements considered in the Models/Frameworks

<table>
<thead>
<tr>
<th>Model/Framework Name</th>
<th>Components Considered in the Framework (Fun, Replay Value and Stealth Learning)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-Dimensional Framework [37]</td>
<td>Does not consider any of the three components</td>
</tr>
<tr>
<td>ARCS [38]</td>
<td>Does not consider any of the three components</td>
</tr>
<tr>
<td>CMX Design Framework [39]</td>
<td>Does not consider any of the three components</td>
</tr>
<tr>
<td>Design Play Experience (DPE) [40]</td>
<td>Fun and Stealth Learning</td>
</tr>
<tr>
<td>Digital Game Based Training Systems [41]</td>
<td>Does not consider any of the three components</td>
</tr>
<tr>
<td>DODDEL [42]</td>
<td>Does not consider any of the three components</td>
</tr>
<tr>
<td>Educational Games Design Framework [43]</td>
<td>Fun</td>
</tr>
<tr>
<td>HABS+ISIS [44]</td>
<td>Does not consider any of the three components</td>
</tr>
<tr>
<td>Key Criteria for Game Design [45]</td>
<td>Fun and Replay Value</td>
</tr>
<tr>
<td>Mechanics Dynamics Aesthetics (MDA) [46]</td>
<td>Fun</td>
</tr>
<tr>
<td>Model Driven Framework to Support Development of SG [47]</td>
<td>Does not consider any of the three components</td>
</tr>
<tr>
<td>P.III Framework [48]</td>
<td>Fun</td>
</tr>
<tr>
<td>Robert L. Appelman Model [49]</td>
<td>Fun</td>
</tr>
<tr>
<td>Serious Game Constructivist Framework for Children [50]</td>
<td>Fun and Stealth Learning</td>
</tr>
<tr>
<td>SGGameFlow Framework [51]</td>
<td>Fun</td>
</tr>
<tr>
<td>SGISD [52]</td>
<td>Fun</td>
</tr>
<tr>
<td>Six Facets of Serious Game Design [53]</td>
<td>Fun</td>
</tr>
<tr>
<td>This research SETP</td>
<td>Fun, Replay Value and Stealth Learning by modifying the framework</td>
</tr>
<tr>
<td>This Research SSG Model</td>
<td>Fun, Replay Value and Stealth Learning</td>
</tr>
</tbody>
</table>

In addition to researching frameworks and models used to develop SG, special attention was placed on the characteristics of games such as playtime, complexity, and number of players. 33 games in SCM and SSCM were researched. The characteristics these games exhibited were taken into consideration to approximate upper and lower limits of the Serious Game Cube (SGC).

### Table 7 SCM and SC G No. of Players and Playtime characteristics

<table>
<thead>
<tr>
<th>Game sample</th>
<th>Game</th>
<th>Average No. of Players</th>
<th>Average Playtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=34</td>
<td>SSCM=2</td>
<td>Min=6 Players</td>
<td>Min=2.8 hours</td>
</tr>
<tr>
<td></td>
<td>SC=32</td>
<td>Max=8 Players</td>
<td>Max=5 hours</td>
</tr>
</tbody>
</table>

More importantly, the specific method used to integrate the triple bottom line and risk management dimensions into a single game is displayed. This method can be used to properly map concepts to game mechanics and see their interrelationships.
3.2 Systems Engineering Technical Processes

It is significant to explain what SE engineering is to have a better understanding and delve deeper into Systems Engineering Technical Processes. SE is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem. SE integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. SE considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs [66], [67]. Life cycle is the evolution of a system, product, service, project, or other human-made entity from conception through retirement [68]. Product life cycle model (PLCM) is a framework of processes and activities concerned with the life cycle that may be organized into stages, which also acts as a common reference for communication and understanding [68]. The aim of this research is to give an assessment of SETP and PLC in the development of a serious game whose aim is to teach the concepts of market demand, marginal cost curve and market flooding. The research question is: Is SE, specifically SETP suitable for analogue/digital SG development?

SETP are the following:

Stakeholder requirement definition: Defines the requirements of a system that can provide the services needed by users and other stakeholders in a defined environment.

1. Requirement analysis: Transforms stakeholders, requirement-driven view of desired services into a technical view of a required product that could deliver those services.
2. Architectural design: Synthesize a solution that satisfies system requirements.
3. Implementation: Realizes a system element that satisfies specified design requirements through verification and stakeholder requirements.
4. Integration: Assemble a system that is consistent with the architectural design, verification and validation is also carried.
5. Verification: Confirm that the system fulfills the specified design requirements.
6. Transition: Establish a capability to provide services specified by stakeholder requirements in the operational environment. It is the installation of a verified system in the operational environment, along relevant enabling systems, such as operator training systems.
7. Validation: Provide objective evidence that the services provided by a system when in use, comply with stakeholder requirements, achieving its intended use in its intended operational environment.
8. Operation: Use of the system to deliver its services
9. Maintenance: Sustain the capability of the system to provide a service.
10. Disposal: End the existence of a system entity.

Additionally, SE requires the use of a PLCM, there is no specific PLCM for the development of SG, ISO 15288:2015 does not prescribe a specific system LC model, development methodology, method model or technique; the users of this international standard are responsible for selecting a LC.
A modified PLC model based on ISO 15288:2015 [68] is used, Figure 24.

Figure 24 Generic life cycle compared to serious game life cycle used in this research

3.3 Stealth Serious Games Model

The Stealth Serious Game Model (SSGM) is developed to address the area of opportunity present within current models and frameworks. SETP have the capability to include into the framework the components of fun, replay value and stealth learning, however, as explained in Chapter 4 SETP has several limitations and the high expertise required to apply the framework substantially diminishes its applicability by non-systems engineers. The SSGM tries to provide a simpler approach to SGD that can be applied regardless of experience in SGD. This is performed by lowering the amount of knowledge required to use and understand the model. SSG do not require the user to perform complicated calculations to advance the game.

The SSGM includes 5 main components: replay value, gaming, stealth learning, fun and visuals. These easy to understand components provide a solid foundation for the development of SSG. The components and the interaction among components are visually represented in Figure 25.

3.3.1 Replay Value

Replay value is the property of the SG to be played repeatedly, providing a new experience, and learning to the player every time the SG is played. Replay value has a direct interaction with the Gaming aspect of the model and is profoundly dependent on mechanics and dynamics. SG often make the mistake of not emphasizing replay value. After playing the SG once, there is no need to replay the SG again, as all learning has already been achieved. Replay value is cornerstone of the model and all SG should contain this component.

Replay value has three main aspects:

No game is the same: The SG should have several mechanics and dynamics that can generate multiple scenarios and situations.

Allow for different approaches: The SG should permit the player the freedom to approach any situation the game simulates in any way he/she wants.

New learning happens every time the game is played: Not all learning should be achieved if the game is played once.
3.3.2 Gaming

Low Rule Complexity: This aspect is extremely important, if the rules are too complex the barrier to play the game becomes too high and some players might lose motivation to learn how to play. Rules directly affect mechanics and dynamics; simple rules that allow for deep mechanics and dynamics are necessary.

Mechanics: Describe the components of the SG, at the level of data representation and algorithms [46].

Dynamics: Describes the run-time behavior of the mechanics acting on player inputs and each other’s outputs over time [46].

3.3.3 Stealth Learning

Stealth learning: Eventuates when “players are focused not on learning but on playing” [65]

Educational topics feed mechanics: The mechanics in the SG must be generated using the topics the designer wants the player to learn. It is important to state that the topics must be presented in such a way that the player does not fully realize he/she is learning.

3.3.4 Fun

Fun is a combination of simulation, simplicity, and the gaming and stealth facet.

Not a simulation: If the game is a simulation the SG becomes too complex for non-professionals and can potentially lead to boredom for those who are not professionals. Complexity in this case is defined as giving the player several variables and interdependencies to control when playing the SG, the ability to control every aspect of the game is not always met with joy by players.

Not overly simple: If the game is too simple professionals will not take the game seriously.

3.3.5 Visuals

Visuals encompass how the SG looks and must emerge from the Gaming aspect of the SSG model.

Appealing: SG usually lack enthralling visuals; good visual representations allow for more player immersion and make the player feel excited about playing the SG.

Provide support to play the SG: The player does not need to remember everything in the game. It is the game’s responsibility to remind players about important rules, mechanics, and dynamics.

Free Mental resources from the player: Well implemented visuals free mental resources in the player allowing him/her to focus on the strategic layer of playing the SG.
Figure 25 SSG Model components.
3.4 Complexity Reduction and Integration Method for Serious Games

This section provides an in depth look at the Complexity Reduction and Integration Method (CRIM) used to interweave the 3 dimensions of sustainability and risk management to create CoC and Looper.

The method used to integrate all dimensions into a seamless experience is as follows:

1. Dimension: A dimension from sustainability is picked, Environmental, Economic, Social or Risk. Research is performed to obtain a general understanding regarding the concepts it includes.
2. Concept: A concept to be included in the SG is chosen by the developer.
3. Concept Definition and Variables: The definition of the chosen concept is consulted along with variables that contribute to the concept.
4. Simplification: The concept is stripped to its minimum to understand the underlying behavior and facilitate the creation of mechanics for the SG
5. Mechanic(s): Emerge from the simplification and concept definition and variables. Mechanics: Describe the components of the SG, at the level of data representation and algorithms [46].
6. PCV (Player Controlled Variable) affecting mechanic(s) if available: Establish PCV that will directly influence the mechanics established earlier.
7. PCV/Mechanic(s) interactions (Dynamics Map): Visual representation of the interactions among the PCV’s and mechanics. These interactions generate the SG dynamic behavior.
8. Holistic Dynamics Map Overview: Created to provide a visual representation of the interaction among all the PCV’s, Mechanics and Dynamic Maps. The developer can check the interactions among all PCV’s and mechanics. Additional mechanics can be created to link unlinked mechanics. Dynamics: Describes the run-time behavior of the mechanics acting on player inputs and each other’s outputs over time [46].

Figure 26 The Complexity Reduction and Integration Method for SGD
The following diagrams using the method described in Figure 26 belong to Looper. It is easier to see how the method is used for reducing the complexity and integrating several dimensions into a single SG.

Figure 27 Environmental Dimension-Carbon footprint

Figure 28 Environmental Dimension-Green technology
Figure 29 Environmental Dimension-Closed loop SC

Figure 30 Environmental Dimension-Product Life Cycle
Figure 31 Environmental Dimension-Government environmental regulations

Figure 32 Economic Dimension-Lead time
Figure 33 Economic Dimension-Production Efficiency

Figure 34 Risk Dimension-Supply disruption
Figure 35 Risk Dimension-Inventory control

- **Dimension**: Risk
- **Concept**: Inventory Control
- **Concept Definition and Variables**: Defined as coordination and supervision of the supply, storage, distribution, and recording of materials to maintain quantities adequate for current needs without excessive oversupply or loss. Product Stock
- **Simplification**: Complete view of all raw materials/products in the supply chain

Figure 36 Social Dimension-Corporate Social Responsibility

- **Dimension**: Social
- **Concept**: Corporate Social Responsibility
- **Concept Definition and Variables**: Defined as actions that appear to further some social good, beyond the interests of the firm and that which is required by law. Positive impact on stakeholders including consumers, employees, investors, communities, and others.
- **Simplification**: Perform good actions, expect nothing back
- **Mechanic(s)**: 1. CSR Card, 2. Event card deck/Natural disasters

PCV affecting mechanic(s) if available

PCV/Mechanic(s) Interactions (Dynamics Map)
In Figure 37, the colored areas represent different dimensions of sustainability. The mechanics inside the colored areas represent concepts and the red arrows show the interrelationship between the mechanic’s which result in dynamics.
3.5 Serious Game Cube

Three important characteristics of SG are complexity, playtime, and number of players. These three parameters combined create the Serious Games Cube and its 8 quadrants.

Figure 38 Serious Game Cube

Complexity: High complexity SG are considerably detailed (maximalist) regarding the concepts they teach and have 7 or more variables that the player can control in the SG. Low complexity SG take a holistic approach (minimalist) to the concepts they teach and have 6 or less variables that can be controlled by the player in the SG.

Player controlled variables are the player’s input to the SG, the SG then uses those inputs to calculate output variables in the SG that are displayed to the player as feedback for his actions.

Playtime: This is the time required to play the SG to completion. Equal to or less than two hours playtime is considered short. The average length of a SCM game is 2.8 hours, hence defining short as equal to or less than 2 hours. Number of Players: Divided into single player and multiplayer SG.

The Serious Game Cube is divided into 8 quadrants having the following names:

(1) Quadrant I: Unprolonged minimalist single player SG
(2) Quadrant II: Unprolonged maximalist single player SG
(3) Quadrant III: Prolonged maximalist single player SG
(4) Quadrant IV: Prolonged minimalist single player SG
(5) Quadrant V: Unprolonged minimalist multiplayer SG
(6) Quadrant VI: Unprolonged maximalist multiplayer SG
(7) Quadrant VII: Prolonged maximalist multiplayer SG
(8) Quadrant VIII: Prolonged minimalist multiplayer SG
Categorizing the SSCM games available using the Serious Game Cube Figure 38, “Chain of Command” [36] is in quadrant VII (prolonged maximalist multiplayer SG) and Looper in quadrant I (unprolonged minimalist single player SG). The two SSCM games are complete opposites.

3.6 Stealth Serious Game Application in Chain of Command

Chain of Command: A Sustainable Supply Chain Management Stealth Serious Game (CoC) Figure 57 is the SSG developed to test the SSG model. CoC is a board game (2 to 4 players) where players need to optimize their supply chain to meet environmental needs, achieve economic success, uphold ethical behavior in dealings with other players and manage risk as they try to outperform rival supply chains to be the only player left in the game. Players must make decisions to go green, invest in technology, establish partnerships with other players, build close loop supply chains, optimize their supply chain to meet their needs and choose which products to manufacture to have an edge over the competition. The game incorporates. The game uses event cards to introduce penalties and bonuses as well as a dice mechanic for the strategic combat mechanic in the SG.

CoC manages each of the SSG model dimensions in the following way:

Replay Value: Adversarial multiplayer SSG with a strategic layer giving players control over where they produce, deploy units, and how to invest his/her cash. Depending on how the players chooses to invest cash and interact with other players he/she will learn different aspects of sustainability in supply chains.

Gaming: In CoC the game manual is designed to have many visuals and short descriptions. Rules are simple to understand yet the mechanics and dynamics allow for multiple scenarios to develop.

Stealth Learning: Focus is not placed on definitions of supply chains or sustainability. It is not desired to portray CoC as a SG in the mind of the player. The player acquires knowledge by exercising the mechanics and dynamics of CoC.

Fun: The player is given just enough controllable parameters to not overburden his/her decision process. Relevant parameters for sustainability and supply chains are chosen, such parameters include lead time, investment in newer technologies, human relationships etc.

Visuals: CoC is made to be visually appealing and present the player with relevant information that helps the player focus on controlling the parameters that are important for sustainability and supply chain management.
3.7  **Stealth Serious Game Application in Looper**

Looper manages each of the SSG model dimensions in the following way:

Replay Value: The replay value of the SG is heavily dependent on the event card deck and how the player chooses to invest his/her capital in the different certifications, technologies, or CSR.

Gaming: In Looper the game manual is kept short and to the point. Rules are simple to understand.

Stealth Learning: The player acquires knowledge by exercising the mechanics and dynamics of Looper. This is perhaps the weak point of Looper. Looper requires the user to perform calculations with the need of a calculator, pulling the player away from the gaming experience.

Fun: The player is given just enough controllable parameters to not overburden his/her decision process. Relevant parameters for sustainability and supply chains are chosen, such parameters include lead time, investment in newer technologies, CSR etc.

Visuals: As with CoC, Looper is made to be visually appealing and present the player with relevant information that helps the player focus on controlling the parameters that are important for sustainability and supply chain management.

3.8  **Cards Development**

The cards for Looper and CoC were developed in the following way:

1. Select concepts in each dimension of sustainability and risk to be included in the game.
2. Select concepts that will not require a probability mechanic and assign them a different type of mechanic such as: opt-in/opt-out or step progression (the player requires the previous card to be able to obtain the next card).
3. Choose concepts that will require a probability mechanic e.g. die roll or controlled probability via number of cards.
4. For the cards whose probability is controlled by their number on the deck, create a card drawing probability table, see Opt-in/ Opt-out means the player can take the decision of participating in CSR and also stop participating in CSR at the end of every year in the game. To read Looper game rules please see section 11.3
5. Table 9.
6. For cards that contain a die roll mechanic, calculate the probability of the card activating, see Table 10.
Opt-in/Opt-out means the player can take the decision of participating in CSR and also stop participating in CSR at the end of every year in the game. To read Looper game rules please see section 11.3

The probabilities of the cards and their effects on the player operations were refined through testing by the developer in the case of Looper. The probabilities of disasters are loosely related to reality. A tsunami will happen less likely, followed by floods and earthquakes, and finally fires with the highest probability of occurrence. The probabilities of this disasters are not taken from reality, the reason behind this is so the player can experience risk at a higher rate than in real life. It is important to remind the reader that Looper is intended for beginners and they can benefit from the unrealistic approach to the amount of disasters in the game to learn risk management.

Table 9 Event card deck probabilities

<table>
<thead>
<tr>
<th>Card</th>
<th>Number of Cards in Deck</th>
<th>Event Card Deck Probabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental regulations</td>
<td>3</td>
<td>10.00%</td>
</tr>
<tr>
<td>Government audits</td>
<td>2</td>
<td>6.67%</td>
</tr>
<tr>
<td>External risk: Tsunami</td>
<td>2</td>
<td>6.67%</td>
</tr>
<tr>
<td>External risk: Earthquake</td>
<td>3</td>
<td>10.00%</td>
</tr>
<tr>
<td>External risk: Flood</td>
<td>3</td>
<td>10.00%</td>
</tr>
<tr>
<td>External risk: Fire</td>
<td>4</td>
<td>13.33%</td>
</tr>
<tr>
<td>Economic stimulus</td>
<td>3</td>
<td>10.00%</td>
</tr>
<tr>
<td>No event</td>
<td>10</td>
<td>33.33%</td>
</tr>
</tbody>
</table>

Total number of cards 30

The die roll mechanic for external risks allows the player to not be struck by a disaster even if he/she draws an external risk card. For example, the probability of having a tsunami is 0.0667 if the player only has his/her companies in zone I of the game board (see appendix 11.3.4) then the probability of having the tsunami disaster is 0.0667*0.25=0.0166. For two zones it is 0.0667*0.5=0.0333, for three zones it is 0.0667*0.75=0.0500 and for 4 zones it is 0.0667*1=0.0667.
4 ORIGAMI ECONOMIC SERIOUS GAME

4.1 Introduction to Problem Area

It is important to research better models and frameworks to develop SG due to the increase in SG being developed. Data shows that since the year 2000 a total of 1265 SG have been developed with a total of 953 ancestors Figure 39 [1].

![Figure 39 Number of SG released each year 2218 games: Source "Djaouti, Álvarez, Jessel & Rampoux (2011)"

The great increase in the number of SG being designed and the technology’s complexity brings in the way of multiple platforms (Windows, iOS, Linux) to develop for, asks for a framework that can deal with the complexity of SG and the life cycle of SG. Whether the SG being developed is analogue, digital, or analogue-digital (hybrid), a framework that can deal with the current and emerging complexity of SG is required. Systems Engineering (SE) can be used to cope with the current and emerging complexity. Some of the current SG frameworks’ design features are briefly explained below:

General Framework for Digital Game Based Training Systems (GFDGBTS): Has three main components. An authoring component addressed to teachers, a training component addressed to
students and a component that supports communication and interaction between teachers and students [41].

P-III framework: Characterized by four conceptual pillars; Player Centered Design, Iterative Development, Interdisciplinary Teamwork and Integration of Play and Learning [48].

The Six Facets of Serious Game Design (6 FoSGD): Is a framework that highlights the following phases in game design: pedagogical objectives, domain simulation, interactions with the simulation, problems and progression, decorum, and conditions of use. Uses a design pattern library to enhance communication between experts [53].

Mechanics, Dynamics, and Aesthetics (MDA): Clarifies and strengthens the iterative process of developers, scholars, and researchers alike, making it easier for all parties to decompose, study and design a broad class of game designs and artifacts. Mechanics: describes the components of the game, at the level of data representation and algorithms. Dynamics: describes the run-time behavior of the mechanics acting on player inputs and each other’s outputs over time. Aesthetics: Describes the desirable emotional responses evoked in the player, when she interacts with the game system [46].

Design, Play, and Experience (DPE): Created as an expansion of the MDA framework, it depicts the relationship between the designer and the player. The framework considers learning, storytelling, gameplay, and user experience in an iterative design process [40].

Simulation-Games Instructional Systems Design Model (SG-ISD): The main components are: analysis, concept, design, quality assurance, technical design specifications, prototype implementation, modding, learner material/game, interactive lesson plan and summative evaluation [52]. The framework can be best described as a merge between the Instructional System Development ADDIE SAT Model [69] and Waterfall Game Development [52] where game design is embedded within an instructional design process.

The six I’s: Considers identity (through an avatar), immersion that leads to flow “The state in which people are so involved in an activity that nothing else seems to matter; the experience is so enjoyable that people will do it even at a great cost, for the sheer sake of doing it” [70], interactivity, increased complexity, informed teaching and instructional. Table 11 provides a table with a comparison of the frameworks earlier introduced along with SE.
There are several frameworks used to develop SG, however, none of the frameworks earlier presented, consider the lifecycle of SG, it is in this area that SE provides an alternative to current frameworks. Additionally, traceability is an inherent quality of SE, each component of the SG can be tracked to stakeholder requirements; the SG designer does not have to guess why a specific SG component is implemented. SE relies on documenting every change, a characteristic that is optional in most of the frameworks presented above.

### 4.1.1 Engineering Economy

Why should we learn economy as an engineer? That is a question often asked by engineering students, a question that the author of this thesis also asked when he was Bachelor of Science student. The above question will be answered but first it is important to define what engineering is and what economy is. The classic definition of engineering by Tredgold’s “Engineering is the art of directing the great sources of power in nature for the use and convenience of man” in other words it is physical science applied to helping groups of men to make a better living; Economy can be defined as the social science of earning a living [71]. Returning to our initial question, studying economy will broaden the engineer’s view by showing the relation engineering has to other activities, it will develop the habit of thinking in terms of groups rather than individuals [71].

The definitions stated above are from an article written by John F. Hayford, published in 1917 in the Journal of Political Economy almost a 100 years ago. Even back then the importance of teaching economy to engineers was comprehended. The specific way in which this is to be carried, has of course changed over the years, yet still the consensus is that teaching engineering economy has fallen behind times and that new teaching and learning techniques must be applied to bring it to the 21st century. Engineering economics was chosen as the target area since SG are not often used when teaching this subject, as exposed in the study “An empirical Analysis of Engineering Economy Pedagogy” [72]. SG are not often used when teaching engineering economics.
Problems with current teaching practices are:

a) Engineering economy instruction puts more emphasis on routine and trivial calculations and less emphasis on the analysis and decision-making process [73].
b) The curriculum of the class has failed to move forward and has become stagnant [73].
c) New technology has not been incorporated into teaching engineering economy [73].
d) Focus has turned to financial mathematics and away from decision analysis [74].

Current suggestions to enhance learning range from selecting which concepts should be taught, a method to assist the student the students in gaining a better understanding of the lecture material to a spreadsheet-based learning portal [73].

In the current state, engineering economy courses are mainly taught by the industrial Engineering department in US universities [72].

Based on a survey carried by Kim LaScola and Heather Nachtmann, SG only account for 5% of the teaching methodologies in engineering economy courses Figure 40.

![Bar chart showing teaching methods used](image)

*Figure 40 Teaching methods being used. Source “An empirical Analysis of Engineering Economy Pedagogy” Kim LaScola Needy, Heather Nachtmann, The Engineering Economist 2000, Volume 45, Number 1*

Based on the survey carried by LaScola and Nachtmann, an opportunity to develop and original serious game that teaches engineering economics concepts to engineers was developed. The game makes use of origami and teaches the following economic concepts: Marginal cost curve, market demand curve and market flooding. The above-mentioned concepts can be learned by reading books but having other options in which specific concepts can be learnt is a good alternative.
**Active Learning**

Active signifies that students do not simply listen and watch but participate through discussing, questioning, arguing, brainstorming, or reflecting [75].

**Gamification**

The use of game design elements in non-game contexts [76].

**Playing**

Playing is the voluntary attempt to confront ourselves with unnecessary challenges in a satisfying way [77].

**Marginal Cost Curve**

The marginal variable cost, or simply marginal cost is, roughly, the increase in variable cost incurred when output is increased by one unit; i.e. Average costs are high for very low levels of output relative to the size of the plant, largely because there is not enough work to keep a well-balanced work force fully occupied. People are either idle much of the time or shifting, expensively, from job to job. As output increases from a low level, average costs decline to a low plateau. But as the capacity of the plant is approached, the inefficiencies incident on plant congestion force average costs up quite rapidly. Overtime may be incurred, outmoded equipment and inexperienced hands may be called into use, there may not be time to take machinery off the line for routine maintenance; or minor breakdowns and delays may disrupt schedules seriously because of inadequate slack and reserves. [78]

**Demand Curve**

A graphic representation of the relationship between product price and the quantity of the product demanded. It is drawn with price on the vertical axis of the graph and quantity demanded on the horizontal axis. With few exceptions, the demand curve is delineated as sloping downward from left to right because price and quantity demanded are inversely related (i.e., the lower the price of a product, the higher the demand or number of sales). This relationship is contingent on conditions remaining constant. Such conditions include the number of consumers in the market, consumer tastes or preferences, prices of substitute goods, consumer price expectations, and personal income. A change in one or more of these conditions causes a change in demand, which is reflected by a shift in the location of the demand curve. A shift to the left indicates a decrease in demand, while a movement to the right an increase [79].
Market Flooding

Market surplus (Market flooding): Refers to when an excess amount of inventory for sale causes an undesired drop in price for the product, and in extreme cases, making the products impossible to sell at any price [80]
4.2 Brief History of Origami and Use in Serious Games

A very simple definition of origami is: the art of folding paper into shapes. The origin of origami is contested between China and Japan; in China the use of coins made from paper covered with foil, paper houses, et al. to be burned in funeral rites is noted as one of the earliest examples of paper folding [81]. In Japan, the use of origami dates to the Heian period (794-1185), during this period there was ceremonial folding and recreational folding. During the Kamakura period (1185-1333) origami was still used for ceremonial purposes [82]. Modern origami is believed to have developed during the Muromachi period (1333-1573) Yakkosan (an origami figure) was folded during this period. By the Edo period (1603-1867) origami had become a popular pastime in Japan, during this era several origami books were published “Chusingura Orikata” (1797), “How to fold 1000 cranes” (1797) and Kan no Mado (1850) among others [83]. During the Meiji period (1868-1912) origami became included in school and kindergarten programs as a means of educating children in the art and skill of using fingers [84], this could very well be the first educational use of origami. The Taisho period (1912-1926) marks the beginning of 15 cm x 15 cm origami paper, helping establish origami as an educational and leisure activity whose influence reaches the present day [84].

Origami as a tool and inspiration has been used in the fields of engineering and mathematics. In mathematics, it has been used in the teaching of geometry. In “The use of origami in the teaching of geometry”, paper folding is used as a means to introduce a range of geometrical concepts (angles, symmetry, properties of shapes, properties of angles within parallel lines, angle sum of a triangle and angle sum of a polygon) and further develop understanding while also developing problem solving and communication skills [85]. Other researches focus on the impact origami has on spatial visualization [86] and on using origami as a tool to engage students in the learning of mathematics through the use of a story [87]. The use of origami in the previous cases is primarily aimed towards elementary school students. In the case of engineering, origami shapes have been used as inspiration in the design of shock absorbing devices and packing materials [88]; other uses include folded texture sheets [89].

In SG, origami is not usually used; games such as “The Federal-Mogul Business Game” [90] make use of Lego blocks as a building material for their products. The game “Production of Maple Leaf Souvenir” [91] makes use of strings, paper, and tape among other materials. One such serious game making use of origami is “The software development game” [92]. In this SG, players must build origami boxes with one of the following four groups of letters, SO, FT, WA, or RE. Every box represents a software module, one group of four modules forms one software piece (a complete word, SOFTWARE, made of four modules). In the game the players compete in groups to gain profits from an imaginary software company that makes software modules. The game teaches the players the particularities of software development: communication breakdown, isolated work, and lack of planning.
The use of origami ranges in complexity, from non-complicated such as teaching geometry to complex, for instance, inspiring the design of crash boxes [88]. It is interesting to note that in the many applications origami has been used, its use in SG has not yet been fully exploited.

4.2.1 Building Materials Assessment

It is relevant to assess how origami paper compares to other building materials that could be used in SG requiring a product to be created; the purpose being to show the benefits and drawbacks it has. The specific reason for choosing the materials being evaluated is that it is possible to build complex shapes and allow the player to perform mechanical actions when building an item making the SG less tedious and more enjoyable. A comparison using the following indicators is carried in section 5:

Transportability: Refers to the quality of carrying something from one place to another. In this case, the highest concern is the volume and weight of the different building materials and how easy it is to transfer the materials from point A to point B.

Scalability: The ability to adapt to increased demands.

Complexity: Refers to the quality of being intricate. Focus is placed on how elaborate the products built with the different materials can be.

Reusability: Refers to the quality of being used again repeatedly. Emphasis is placed on the quality of reusing the building items several times without losing performance.

Disassemblability: Refers to the quality of taking apart something. How easy is it for the users to take apart the product they just built and how long does it take?

Comfortability: Refers to the quality of not causing any physical unpleasant feelings. Attention is placed on the amount of pain the building materials can cause while being used along with cleanliness.

Obtainability: Refers to the quality of being easy to procure. How easy is it to obtain the materials?

Cost: How expensive is the building material and how easy is it to obtain? The cost evaluation done only considers when first obtaining the building materials. Subsequent uses are not considered, in the case of Lego blocks and Erector the investment cost would go down as there is no need to re buy the materials as opposed to clay and origami paper were the investment cost goes up as the materials need to be re acquired.
Figure 41. Different types of building materials (top left Erector [93], upper middle Lego blocks [94], top right clay [95], lower left TinkerToy [96], lower right Origami [97]).

Now that the reader understands what each indicator is evaluating, it is now possible to assess the different building materials. A 5 points scale is used: 1 significantly poor, 2 poor, 3 satisfactory, 4 superior, 5 significantly superior. $ Inexpensive, $$ Expensive, $$$ Significantly Expensive.

Table 12. Assessment of building materials.

<table>
<thead>
<tr>
<th></th>
<th>Lego Blocks™</th>
<th>Erector™</th>
<th>TinkerToy™</th>
<th>Origami Paper</th>
<th>Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scalability</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Complexity</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Reusability</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Disassemblability</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Comfortability</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Obtainability</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cost</td>
<td>$$</td>
<td>$$$$</td>
<td>$$</td>
<td>$</td>
<td>$</td>
</tr>
</tbody>
</table>

When comparing origami to other building materials, it was rated the highest for comfortability, physical pain is not an issue when repeatedly creating products; Lego blocks, Erector and Tinker Toys have this problem. In the case of clay, cleanliness becomes an important problem, clay tends to color your fingers and leave residue in your finger nails. Transportability, origami paper is compact, easily stackable and does not require the use of plastic containers to carry from place to place. It is slightly better than clay just because it is lighter. For disassemblability, it is very easy to unfold an origami if one desires to do so. If the designer of a serious game does not require the product to be disassembled it can easily be disposed of. Lego blocks, Erector and TinkerToy take more time and effort to take apart.
All materials are easily scalable for larger groups, it is important to mention that the bigger the group, the higher the cost of getting materials and the more difficult it is to transport the materials.

The Origami paper scored the lowest in reusability, it is easy to understand why; once an origami paper has been folded it is not advisable to use it again as it makes folding new shapes substantially difficult. The visual appeal of the final product is also noticeably diminished. Regarding complexity, the shapes that can be created using origami can be complex but will never achieve the complexity Lego blocks, Erector and TinkerToy can achieve. Origami paper is easily obtainable at any stationary store or can be manufactured from regular colored copy paper. Finally, if cost is an important requirement when selecting the building materials for the serious game being designed, clay and origami paper are the most inexpensive in the short term.

Origami has been used in the field of mathematics to help children understand geometry concepts and develop solving and communication skills. In engineering, it has inspired the design of mechanical elements. Origami as an element in SG however, has not been fully exploited. “The Origami Game” to teach economy concepts makes use of different shapes and colors in origami figures to facilitate the counting of items required to update the information the player sees and to provide comfort while building the different products. The Origami game keeps a standard building material with the same dimensions (15 cm x15 cm) to create completely different products, highlighting the versatility of origami. Easy to obtain and inexpensive are what make origami a significantly attractive choice when considering the use of a building material in the design of a serious game. When using origami, only the serious game designer poses a limit to the uses it has.
4.3 Development of Origami Serious Game using SETP and PLC

Using the SETP and PLC stated earlier a serious game is developed. The parameters under which the testing of SETP and PLCM are performed are as follows:

1.1 Testing Parameters for SETP and PLCM

1.2 No use of SE specialized software as to replicate the conditions other SG developers might encounter when trying to use SETP. Microsoft Office Suite® is used for creating and updating documentation regarding the SG.

1.3 The designer of the SG possesses SETP and PLC knowledge.

1.4 The designer has an engineering background with no prior experience developing SG.

1.5 The development of the SG lasts 6 months.

1.6 Challenges and problems are documented while the SG is developed.

A summarized version of the development process using SETP to develop the Origami SG is presented below. Additional information regarding the use of origami in SG and the Origami SG can be found in [98].

1.7 Stakeholder requirement definition

Stakeholders:

1. Game players: Undergraduate university students taking economy courses.
2. Game instructors: Faculty teaching economy courses.
3. Game developers: Personnel creating the SG.
4. Universities: Universities that have economy courses.

1.8 Stakeholder needs

1. Need of an easy and interesting way of teaching and learning the marginal cost and market demand curves. This is to ensure engagement and improve learning motivation.
2. The game users must be undergraduate students.
3. The game must be easy to understand.
4. The game must involve fast thinking and problem solving.
5. The game must be developed within 6 months. Rapid development cycle of learning-based games allows for increased variation of games produced. However, we propose the games are developed in sequential sections to ensure continuity and promote participation.
6. The gameplay session must be short.
7. Previous knowledge of the topics and skills of the game is not a prerequisite. Player base will
be mostly undergraduates with no previous exposure to the topics involved.

8. Realistic nature of the game; the game must be a simplified representation of a real-world scenario. The use of a simulation provides a training ground for players to practice their skills.

9. The game must make use of technology (computers) and not be fully analogue.

10. The game must be easy to set up and must be able to run on multiple OS. Games available on multiple OS create a larger player base.

11. It must make the participants build something.

12. It must give players the option to create different products. Variation in game outcomes promote creativity and innovation.

13. It must make players compete against each other. Competition promotes engagement

14. Game information must be displayed to each player privately.

15. The game must allow the game master to quickly perform and display game calculations to the players and to him/herself.

16. Playing the games does not require a high level of English knowledge.

1.9 Measure of Effectiveness Needs (MoE)

Measure of Effectiveness Needs (MoE): Results from the test administered at the end of the game: Subjective evaluation carried by the game instructor and assigned a numerical value from 1 to 5 based on how close the answers were to the expected answer.

Discussion after test: Subjective assessment by the game’s instructor on whether the discussion with the students covered the relevant points being taught by the game.

Data to measure MoE: Test answers, voice recording of discussion taking place after the test is applied, player production data, number of times player changed product based on market demand.

Validation Criteria: The validation of the game will be carried by using measurements of effectiveness needs, which include: End game results, posttest discussion rating, comparative data of player production trend with the game’s marginal cost curve and changes in production.

1.10 Requirement Analysis

1. The game shall be interesting and must teach the marginal cost curve, market demand curve and market flooding concepts to engineering students.

2. The game users shall be faculty and undergraduate engineering students.

3. Understanding how to play the game shall take no longer than 10 minutes.

4. The game shall challenge players to constantly adapt their game strategy.

5. The game shall exit development in 6 months.

6. Gameplay sessions shall be limited to 30 minutes plus 30-minute post-test and
7. No previous knowledge shall be required to play the game.
8. The game shall be an over simplified representation of a real-world scenario.
9. The game shall make use of technology to help process player information faster.
10. The game shall run on Microsoft Windows® and Mac OS X®.
11. It shall make the participants build something.
12. It shall give players the option to build different products.
13. The game shall force players to try and beat their counterparts.
14. The game shall use independent displays to inform players regarding their in-game performance.
15. The game shall make use of a PC or Mac to calculate operations and display the relevant information to the game master and players.
16. Users with a score of 500 on the TOEFL ITP or band 6 IELTS shall be able to play the game, answer the post-test and participate in the discussion/debriefing.

1.11 System Functions

Game setup, game setup test, game instruction briefing, game start, data update, collect player data, record data, hand data to game master, input data into game, game calculations, display data to players, repeat “X” times, post evaluation, discussion and clean up.

System Functional Interfaces: Physical input interface (input player data into SG system for post processing). Visual data output interface (output processed data by the SG system and makes it visible to players).

Verification Criteria: Verification activities are to be carried out by the developer of the SG system and must be recorded in the requirements traceability matrix document. Shall the specific sub-system, function or component not pass testing, the developer must make modifications to make the specific entity comply with requirements.

1.12 Architectural Design

The 3 traditional views on architecture are used, operational, physical, and functional to generate a solution that satisfies the requirements analysis.

1.12.1 Operational View

Origami SG Mission: To help teach undergraduate students the following economic concepts: market demand curve, marginal cost curve and market flooding in an interactive and entertaining way

Origami Operation
(1) Setup game according to the physical layout.
(2) Two persons are required to operate the game.
   (2.1) Game master: Must update origami production in Excel file and update PowerPoint presentations based on the Origami Control Sheet. The game master also applies, grades, and handles the discussion following game completion.
   (2.2) Helper: Must collect origami and record the origami manufactured per person on the Origami Control Sheet.
(3) Make sure the game is correctly operating and that each player is being displayed the correct information.
(4) The following three steps (4, 5 & 6) should take no longer than 10 minutes.
(5) Explain game rules and have players sign a consent form.
(6) Demonstrate origami folding to the players at least once to ensure the players know how to fold them correctly.
(7) Explain how to read the graphs being displayed.
   (7.1) “X” axis numbers in the graphs represent turns.
   (7.2) “Y” axis numbers in the graphs represent number of origami or a monetary currency.
(8) Start the game, the game should be played for 20 rounds and should finish in approximately 30 minutes.
   (8.1) Each round has a duration of 1 minute 30 seconds.
(9) Finish the game.
(10) Apply test (give 15 minutes to finish test).
(11) Gather the tests and discuss with the players the answers and the concepts the game has taught them (Maximum time for discussion is 15 minutes).
   (11.1) For the marginal cost curve graph ask: Why do you think this behavior happens?
   (11.2) For the market demand curve ask: What do you think is happening in the market? How would you avoid this phenomenon? How would you maximize your profit?
(12) Thank everyone for participating.

Save data from the game and appropriately label it with location and date.

Figure 42 displays the use cases of the Origami SG.

![Figure 42 Origami Serious Game Use Cases.](image-url)

1.12.2 Functional View
Below it is possible to see the functional flow block diagram for the Origami SG Figure 43 and Table 13 containing all the parameters calculated in the game with their respective calculation formula.

Figure 43 Origami SG General Functional Flow Block Diagram (FFBD)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Product Units Manufactured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>Number of units manufactured by a single company by type and per game round.</td>
</tr>
<tr>
<td>Reason for measuring</td>
<td>Used to help calculate manufacturing cost.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Total Amount of Product “x” in Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>(Company A Product “x”) + (Company B Product “x”) + (Company C Product “x”) + (Company D Product “x”)</td>
</tr>
<tr>
<td>Reason for measuring</td>
<td>Used to help calculate market price for a product.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Manufacturing Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>Manufacturing cost of a product in a specific round.</td>
</tr>
<tr>
<td>Reason for measuring</td>
<td>Used to help calculate unit profit and total profit.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Market Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>Sale price of a product in the market for a specific round; determined by the total amount of product “x” in the Market.</td>
</tr>
<tr>
<td>Reason for measuring</td>
<td>Used to help calculate unit profit, total profit, and revenue.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>(Market Price of a product) - (Manufacturing Cost)</td>
</tr>
<tr>
<td>Reason for measuring</td>
<td>Indicate money turnover for a product on a specific round.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Product Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>(Market Price) * (Product Units Manufactured)</td>
</tr>
<tr>
<td>Reason for measuring</td>
<td>Calculate product revenue per product per round per company and total revenue. Helps calculate market share.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>(Revenue) / (Total Market Revenue)</td>
</tr>
<tr>
<td>Reason for measuring</td>
<td>Calculate product revenue per product per round per company and total revenue. Helps calculate market share.</td>
</tr>
</tbody>
</table>
1.12.3 Physical View

Allocating functions to hardware, software, paper, and human resources is shown in Figure 44.

![Diagram of function allocation]

The diagram displayed above in Figure 44 is an oversimplified version, the best practice of allocating individual elements to functions is carried, however, due to space constraints, it cannot be fully displayed in this paper.

1.13 Implementation

To simplify this section only one system element is realized. System display element: Monitor, satisfies requirement 15 from the requirement analysis. Verification method: Visual inspection of the system to ensure monitors display the intended elements (Pass/Fail test).

1.14 Integration

Origami Serious Game System:
1. Human Resource subsystem: Developer, game master (1 person), helper (1 person) and players (4 persons).
2. Waste subsystem: Disposal box (4 boxes) and bag (1 bag).
3. PC subsystem: 1 PC/Mac
4. Software subsystem: PowerPoint and Excel
5. Paper subsystem: Test, origami sheets 15x15 (100 red, 100 green, 100 blue and 100 yellow), origami instructions (red heart Figure 48, green Mount Fuji Figure 49, blue flower Figure 50 and yellow cat Figure 51), game layout, origami control sheet for 20 rounds.
6. Display subsystem: VGA to USB 3.0 adapters, USB 3.0 Hub Extender and displays.
The physical layout of the Origami SG can be seen in

![Origami Serious Game physical layout](Image)

**Figure 45 Origami Serious Game physical layout**

### 1.15 Verification

All components and subsystems address stakeholder requirements. Shall a specific sub-system, function or component not pass testing, the developer must make modifications to make the specific entity comply with requirements. Verification is carried through visual tests, mathematical tests, palette testing, software interoperability tests etc.

#### Software Subsystem Verification

All calculation modules, logical operators, macro codes and information displayed in graphs are tested and verified by the developer.

Testing the calculation modules and logical operators in the Origami Game Excel Sheet:

1. Dummy data is inserted in the sheet labeled “Manufacturing”.
2. Data output is compared to manual calculations performed by the developer; should miscalculations be found; the developer must trace down and correct the mistake.

#### Macro codes:

1. Open all files related to the game and run the macro code in each file to verify that the code is performing as expected.

#### Information displayed

1. Verify that the correct information is being displayed to the correct PowerPoint file.

#### Hardware Subsystem verification
1. Verify that all hardware is performing adequately (PC/Mac, keyboard, mouse, printer, chairs, tables, staplers).
   1.1. Testing is done by visual inspection and using the equipment.

Display subsystem verification:

1. Connect the multi display system to the PC/Mac being used in the game and verify that the displays are fully operational though a visual inspection.

   The following subsystems are verified through palette testing with players

Paper Subsystem verification

1. Origami Instructions
   1.1. Have players fold the different origami shapes and obtain feedback on how easy or difficult it is to follow the instructions.

2. Post evaluation test
   2.1. Have players take the test and verify whether they understand what they must answer.

3. Origami

Human Resources Subsystem

   It is not possible to test humans, therefore, to test whether this subsystem can perform adequately the developer of the game must detect and log how easy it is for players playing the game to follow the instructions and play the game appropriately.

Verification Enabling System Requirements

1. Scientific calculator for testing Excel sheet calculations.
2. Person with no eye sight, walking, hearing or other physical impairments.

Verification Report

   Actions taken to address the problems found during the verification of subsystems:

1. Major function redesign to avoid penalizing players too much for flooding the market.
2. Added Unit Profit Calculation.
3. Renamed calculation sheets to properly reflect what the sheet is calculating.
4. Added additional logic to the sheet to properly use the new functions for market demand and marginal cost curve.
5. Tested the sheet for calculation errors.
6. Post evaluation redesign.
7. Game script creation.
1.16 Transition

Origami Operational instructions. Architectural design-operational view-Origami operation for instructions on how to setup and play the game.

1.17 Validation

Validation Strategy

Validation of the Origami Game system will be performed by testing the fully assembled system with master students belonging to Keio SDM and KMD. At least 70% of the players testing the game must come from an engineering background; the reason behind this being that the game is aimed at teaching students in engineering economic concepts. A total of 5 tests will be executed, each test requires 4 players (total sample size of 20 subjects) and 1 helper in addition to the Game Master. Origami Game testers are required to sign a consent form. The main aim of testing the final version of the game is to validate to what extent the players of the game are learning the concepts the game is teaching (marginal cost curve, market demand curve and market surplus).
The validation of the game will be carried by using the measurements of effectiveness needs which include:

1. Statistical analysis of the results from the test administered at the end of the game.
   1.1. Average score for each section of the test.
      1.1.1. Section I belongs to the marginal cost curve.
      1.1.2. Section II belongs to the market demand curve.
   1.2. Average score achieved in each question.
2. After test discussion rating.
3. Total player production trends.

The game passes validation if the average score of the two post activities combined is higher than 70. On the post evaluation test section, I and II must also achieve an average score higher than 70. Finally, during the discussions the players must provide the expected answers and all members should participate. Players not participating in the discussion lower the score of the discussion.

The player production trend shows us if players were concerned with achieving a low manufacturing cost or not. Changes in production tells us if the players put priority in dominating a specific market or if they were concerned about selling products in non-contested markets. The last two measurements together with the test results are used to assess which concept (marginal cost curve or market demand curve) are players learning more often from the Origami Game. It is important to state, that whether the game passes validation or not is mainly dependent on the average test and after game discussion scores.

As evidence that the validation was performed pictures will be taken during each test, the subject’s faces will be blurred to maintain anonymity.

Validation Enabling System Requirements

1. Statistical analysis shall be performed using Microsoft Excel.
2. Camera to obtain photographic evidence that testing was performed.
3. Sound recording device to document Origami Game discussion rated on a 0 to 100 scale.
4. The grading system for the posttest evaluation shall be 0 to 100 based on a 4-point scale per question (1/4, 1/2, 3/4, 1).

Validation Constraints on Design: There are no validation constraints on the design.

Validation Procedure

To perform validation of the system the following steps need to be performed:
1. Recruit test subjects from mainly an engineering background.
   1.1. Test subjects must sign a consent form before taking part in the experiment.
2. Perform Origami Game test.
3. Grade tests and input information into an excel spreadsheet.
4. Copy information from individual Origami Game test files into different sheets in the excel file being used for validation.
5. Perform data analysis.

Validated System

The approved system is the final origami game version.

Validation Report

Origami testing sample
N=20 for a total of 5 tests
Test 1 (2 Indian students, 1 Chinese and 1 Japanese)
Quality of discussion: 70
Test 2 (2 Thai, 1 Malaysian, 2 Canadian)
Quality of discussion: 68
Test 3 (2 Vietnamese, 1 Japanese and 1 German)
Quality of discussion: 75
Test 4 (3 Japanese, 1 Saudi Arabian)
Quality of discussion: 65
Test 5 (2 Japanese, 1 Vietnamese and 1 Nepalese)
Quality of discussion: 65
The average score for the quality of the discussion held after the game was 68.6
Table 14 Post Questionnaire Results for all participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Background</th>
<th>Test Score</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>Number of Product Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Player 1</td>
<td>Engineering</td>
<td>100.00</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2.00</td>
</tr>
<tr>
<td>Player 2</td>
<td>Engineering</td>
<td>100.00</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7.00</td>
</tr>
<tr>
<td>Player 3</td>
<td>Engineering</td>
<td>100.00</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8.00</td>
</tr>
<tr>
<td>Player 4</td>
<td>Engineering</td>
<td>100.00</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9.00</td>
</tr>
<tr>
<td>Player 5</td>
<td>Engineering</td>
<td>100.00</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>12.00</td>
</tr>
<tr>
<td>Player 6</td>
<td>Engineering</td>
<td>91.67</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.00</td>
</tr>
<tr>
<td>Player 7</td>
<td>Engineering</td>
<td>91.67</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>10.00</td>
</tr>
<tr>
<td>Player 8</td>
<td>Engineering</td>
<td>87.50</td>
<td>1</td>
<td>1</td>
<td>0.25</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4.00</td>
</tr>
<tr>
<td>Player 9</td>
<td>Engineering</td>
<td>87.50</td>
<td>0.25</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10.00</td>
</tr>
<tr>
<td>Player 10</td>
<td>Accounting</td>
<td>87.50</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.00</td>
</tr>
<tr>
<td>Player 11</td>
<td>Politics</td>
<td>83.33</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>14.00</td>
</tr>
<tr>
<td>Player 12</td>
<td>Engineering</td>
<td>83.33</td>
<td>0.75</td>
<td>0.75</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>17.00</td>
</tr>
<tr>
<td>Player 13</td>
<td>Engineering</td>
<td>83.33</td>
<td>0.75</td>
<td>1</td>
<td>0.75</td>
<td>1</td>
<td>0.75</td>
<td>0.75</td>
<td>0.00</td>
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<tr>
<td>Player 14</td>
<td>Business</td>
<td>83.33</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>9.00</td>
</tr>
<tr>
<td>Player 15</td>
<td>Nutrition</td>
<td>75.00</td>
<td>1</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>13.00</td>
</tr>
<tr>
<td>Player 16</td>
<td>Sociology</td>
<td>70.83</td>
<td>1</td>
<td>1</td>
<td>0.25</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>13.00</td>
</tr>
<tr>
<td>Player 17</td>
<td>Engineering</td>
<td>66.67</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>11.00</td>
</tr>
<tr>
<td>Player 18</td>
<td>Engineering</td>
<td>62.50</td>
<td>0.75</td>
<td>0.5</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>8.00</td>
</tr>
<tr>
<td>Player 19</td>
<td>Sociology</td>
<td>58.33</td>
<td>0.25</td>
<td>0</td>
<td>0.25</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>10.00</td>
</tr>
<tr>
<td>Player 20</td>
<td>Engineering</td>
<td>45.83</td>
<td>0.25</td>
<td>0.5</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>10.00</td>
</tr>
<tr>
<td><strong>Average Score</strong></td>
<td></td>
<td><strong>82.92</strong></td>
<td><strong>83.75</strong></td>
<td><strong>83.75</strong></td>
<td><strong>60</strong></td>
<td><strong>97.5</strong></td>
<td><strong>93.75</strong></td>
<td><strong>78.75</strong></td>
<td><strong>8.35</strong></td>
</tr>
</tbody>
</table>
Post Evaluation Statistical Observations

From the 20 participants taking the test, 80% (16 out of 20) scored above the minimum passing grade that validates the game. Top performers in the post evaluation came from an engineering background. A significantly important statistic is the fact that 95% percent (19 out of 20) of the test subjects were not native English speakers, yet, they managed to understand the game, the post evaluation and discussion section; fully complying with requirement 17 which required the game to be easy to understand for players with a TOEFL score of at least 550 (some of the test subjects had scores of less than 550).

The average score for the test was **82.92** with a standard deviation of 15.467, 12.92 points above the minimum game validation requirement. If the results are analyzed by sections, section I obtained an average score of 75.83 and section II an average score of 90.00. In both cases the minimum validation requirement of 70 points was passed. Going deeper into the results analysis by questions, question 1 has an average score of 83.7, question 2 of 83.75, question 3 of 60, question 4 of 97.5, question 5 of 93.75 and question 6 of 78.75. It becomes clear that players struggled the most when answering the third question of both sections, the standard deviation for these questions is .417 and .374, clearly highlighting the non-uniformity of the scores the players obtained in these questions.

The third question in both sections asked players to explain how they would achieve a low manufacturing cost or why they decided to change the product they were manufacturing. The answers obtained from the tests show that it was difficult to make the connection between the game and what was being asked; redesigning the question could help alleviate this problem but is not necessary. It is not necessary since the discussion section of the game deals with this topic in case players disregarded it. Of the six questions present on the test, only one obtained an average score lower than 70 (question 3). Based on the results, it can be said that the game passes validation even if one of the questions has an average score of 60 the score for that section is above 70.

The total score for the origami game activity is: **75.76** successfully passing the validation criteria of **70** that was selected.

**1.18 Operation**

Operation of the system is to be performed by faculty with sufficient knowledge on economy. The faculty is responsible for operating the game and receive the title of Game Master. The helper position can be filled by any person, student, or faculty. The game requires 4 players, players should be undergraduate students. Changes to the game and overall game performance measurements across tests are performed by the developer.
1.19 Maintenance

Maintenance for the monitors, VGA to USB 3.0 adapters, USB 3.0 hub is the responsibility of the manufacturer. PC/Mac maintenance is a user and manufacturer responsibility. PowerPoint patches and updates are Microsoft’s responsibility. The Designer of the game is responsible for updating the PowerPoint display file to be compatible with the newest versions of PowerPoint.

1.20 Disposal

The display subsystem, PC/Mac subsystem, origami disposal box/bag subsystem and paper subsystems are discarded according to local waste management regulations. The disposal of the Origami SG software is the developer’s responsibility (to dispose of the game software no further updates will be done, and the files will be deleted from the cloud storage).

This concludes the use of SE technical processes in SG development. The Origami SG is a specific architectural design solution to the requirements given by the stakeholders. The Origami SG teaches undergraduate engineering students the following concepts:

- Marginal cost curve: Is the addition to the unit’s total cost resulting from the production of an additional unit of output [99].
- Market demand curve: Relationship between product price and the quantity of the product demanded [79].
- Market surplus (Market flooding): Refers to when an excess amount of inventory for sale causes an undesired drop in price for the product, and in extreme cases, making the products impossible to sell at any price [80].

Origami is a 4-player serious game, each player is the owner of a company whose purpose is to have the highest market share and profit in the origami market. To achieve this, the players can manufacture any of the following origami: red heart, green Mount Fuji, blue flower, and yellow cat, see Figure 47. The origami chosen for the game are all 4-step origami that are easy to learn and fold, players are given a set of instructions to help them fold the different origami and are taught how to fold the shapes before the game starts. Each player is given 400 origami sheets (100 red, 100 green, 100 blue and 100 yellow, size 15x15cm) The players can switch the products they are manufacturing at any time, provided that the production is continuous and that all produced origami must be sold (pre-stocking for future trade is prohibited).

The game requires 1 game master and 1 helper, the game master updates the information the players see on their individual displays and the helper is responsible for recording the amount of each origami type that each player is manufacturing in the Origami Control Sheet. The game is played for 20 rounds, each round being 1 minute 30 seconds long. At the end of each round the information displayed to the players is updated.
On the information display Figure 46, players can indirectly see what the other players are doing and obtain the following information: number of total products in the market by type, the players manufactured products, market price and manufacturing cost by product type, unit profit by product type, market share by revenue, total profit, and revenue by product. The graphs were designed to be intuitive and with the help of player feedback.

The market price for the manufactured products is calculated based on the total number of products by type in the market. The market price from the previous round is not carried over to the next round; a new market price is set each new round. The cost for manufacturing origami is specific to each player and depends on the amount of origami manufactured, considering type (red heart, green Mount Fuji, blue flower, or yellow cat). The most important calculations performed by the game are the following: manufacturing cost and market price, the rest of the parameters calculated are derived from these two factors. After 20 rounds have elapsed, the players are given a test requiring them to plot the marginal cost and market demand curve for a single product and answer questions regarding the marginal cost and market demand curves; questions are open ended. Once the test is finished, the next activity is a 15-minute discussion to help the players further understand why exactly the price of manufacturing goes down and later up as more products are manufactured (marginal cost curve). Discuss the concept of market flooding and finally discuss with the players how they would be able maximize in-game profits.
Figure 46 Origami serious game player display with data from a game session (The horizontal axes represent game rounds)

<table>
<thead>
<tr>
<th>Your Total Profit by Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Heart</td>
</tr>
<tr>
<td>Green Mt. Fuji</td>
</tr>
<tr>
<td>Blue Flower</td>
</tr>
<tr>
<td>Yellow Cat</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td>$1,265.00</td>
</tr>
<tr>
<td>$0.00</td>
</tr>
<tr>
<td>$686.00</td>
</tr>
<tr>
<td>$590.00</td>
</tr>
<tr>
<td>$2,541.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Your Total Revenue by Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Heart</td>
</tr>
<tr>
<td>Green Mt. Fuji</td>
</tr>
<tr>
<td>Blue Flower</td>
</tr>
<tr>
<td>Yellow Cat</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>-------------------------------</td>
</tr>
<tr>
<td>$3,035.00</td>
</tr>
<tr>
<td>$0.00</td>
</tr>
<tr>
<td>$1,946.00</td>
</tr>
<tr>
<td>$1,405.00</td>
</tr>
<tr>
<td>$6,886.00</td>
</tr>
</tbody>
</table>

Figure 47. Origami game products, red heart, green Mount Fuji, blue flower, and yellow cat.
Figure 48 Origami Instructions Red Heart
Figure 49 Origami Instructions Green Mt. Fuji
Figure 50 Origami Instructions Blue Flower

Step 1

Step 2

Step 3

Step 4
Figure 51 Origami Instructions Yellow Cat
4.4 Discussion

After developing the Origami SG, the following problems are found while using SETP:

1. SE engineering requires the use of a PLC, a PLC for developing SG is not available. To develop the game a modified version of a generic PLC had to be used see Figure 24

   A hypothetical PLC based on the experience gained after developing the Origami SG can be seen in Figure 52

   ![Figure 52 Revised digital and SG life cycle](image)

   **Figure 52 Revised digital and SG life cycle**

   In the proposed serious game PLC, the concept stage, development stage and utilization stage remain the same as in ISO 15288:2002 [100]. The main difference comes from the post utilization stage, in this life cycle stage, the game should aim to internalize the knowledge the players obtained from playing the SG.

2. Enabling traceability through stakeholder needs, requirement analysis, functions, subsystems, physical elements among others, is a non-complicated task but significantly time consuming.

3. SE added unneeded complexity such as displaying step by step the origami trashimg process. Specifying player control on the interface between the waste subsystem and the player subsystem is unnecessary.

4. Using SE without any SE software is a process that requires the user to manage and update multiple files from multiple different software’s; during the process of designing the Origami SG no SE software was used. All files (word, Excel, PowerPoint, pictures, and diagram files) had to be manually updated resulting in a highly time-consuming activity. SE software can greatly alleviate this problem but at a high production cost that might discourage serious game developers from using SE.

5. SE engineering requires a person with enough SE experience to successfully apply the framework. This was the first time the developer applied SE in a real project and as such reviewing and internalizing SE knowledge had to be carried throughout the development of the SG. SG developers need to devote themselves to learning the basics of SE before venturing into using the framework.

   Table 15 compares in more detail several SG development frameworks introduced earlier to SETP.

   **Level of expertise required:** Can the user start using the framework without having to learn many new concepts? Low: Significant knowledge not required; High: Significant knowledge is required.

   **Use of specialized software:** Does the framework require the use of dedicated computer software?
**Level of Detail:** How detail does the framework provide during the development of the SG.

**Verification:** Does the framework explicitly performs a verification step?

**Validation:** Does the framework explicitly performs a validation step?

SE Technical processes provide the highest level of detail but at the cost of requiring a high level of expertise. SE does not require the use of specialized software, but it is highly recommended. Based on the results from Table 15, the feasible methods point toward incorporating the use of verification and validation are P-III, MDA and DPE. These frameworks do not require the use of specialized software and provide an intermediate level of detail. For those wanting to develop a serious board game without having to learn SE, a combination of MDA/DPE would work very well or alternatively the P-III framework.

**Table 15 Comparison of SETP to other frameworks**

<table>
<thead>
<tr>
<th>Design Frameworks</th>
<th>Level of Expertise Required</th>
<th>Use of Specialized Software</th>
<th>Level of Detail</th>
<th>Verification</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFDGBTS</td>
<td>Intermediate</td>
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<td>Intermediate</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>P-III</td>
<td>Low</td>
<td>No</td>
<td>Intermediate</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6 FoSGD</td>
<td>High</td>
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<td>High</td>
<td>No</td>
<td>No</td>
</tr>
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<td>Intermediate</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>DPE</td>
<td>Low</td>
<td>No</td>
<td>Intermediate</td>
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<td>Yes</td>
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<td>No</td>
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</tr>
<tr>
<td>SETP</td>
<td>High</td>
<td>Highly Recommended</td>
<td>Very high</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Figure 53** SETP most useful to digital and hybrid SG’s development

Instead of using all the SETP, a better approach would be to only select some of SETP and then within those processes select the most relevant sub processes. The most relevant processes based on the experience the designer obtained from developing the Origami SG are as seen in Figure 53.
1. Stakeholder requirements definition: Specifically, stakeholder needs.
2. Requirement analysis: Stakeholder requirements and functional requirements.
3. Architectural design process: Operational view, functional view, and physical view. These sub processes should only be done at a high level of abstraction to avoid over documentation when developing a board game.
4. Verification process: Verification strategy, verification procedure and verification report.
5. Validation process: Validation strategy, validation procedure and validation report.

   Operation process: SG operation.

   Are SETP suitable for SGD and development? The answer is no, unless modifications are made to the framework. The complexity of SETP prompted this research to generate a model that is easy to understand and to consult when developing SG. The next chapter will introduce the SSGM.
5 SUSTAINABLE SUPPLY CHAIN MANAGEMENT GAMES

5.1 Sustainable Supply Chain Management Background

SSCM is formerly defined as “the strategic, transparent integration and achievement of an organization’s social, environmental, and economic goals in the systemic coordination of key interorganizational business process for improving the long-term economic performance of an individual company and its SC’s” [101]. The traditional concept of sustainability does not contain the concept of risk, the authors recommend risk [36] as an added concept to the basic triple bottom line encompassing environmental, economic, and social dimensions. This idea is adopted from Gladwin, who argued that sustainable development must incorporate the concept of security, which “demands safety from chronic threats and protection from harmful disruptions” [102]. To achieve a sustainable supply chain (SSC), it is important to address these issues holistically by bringing together stakeholders and implementing measures throughout the supply chains [103].

Currently, consumers and stakeholders have higher expectations of how companies should manage their business operations. Considerable importance is placed on ethical and environmental behavior; furthermore, today’s global market competition is based on “supply chain vs supply chain” [104], and the more efficient supply chain (SC) economically outperforms the less efficient SC. Present day business demands that, the accountability of a company extends to its suppliers, products, processes, ethical practices, and corporate relationships. According to Fawcett, economic sustainability has been the leading driver of the swift development of supply chain management (SCM), which was founded on the principle that an integrated and efficient SC helps minimize monetary risks and increase profits [105]. SCM has gradually introduced social, environmental (green), and economic dimensions, known as the triple bottom line [106], which are the drivers for SCM, thereby, generating what is known as sustainable supply chain management (SSCM). SSCM is defined as “the strategic, transparent integration, and achievement of an organization’s social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of an individual company and its SC’s” [101]. The concept of risk management is not a part of the operational definitions of sustainability; it is, however, a recurring theme in sustainability literature [101]. Gladwin states that sustainable development must incorporate the concept of security, which “demands safety from chronic threats and protection from harmful disruptions” [102].

Global businesses face economic, social, and environmental challenges requiring to be addressed to appeal to a more demanding consumerism market. The inclusion of social and environmental concerns into supply chain management (SCM), which is mainly focused on economic aspects according to Fawcett [105], generates what is known as SSCM and ushers SCM into what is known as
the triple bottom line [106]. A brief explanation of the three dimensions of the triple bottom line and risk is provided below.

The facets of the triple bottom line (environmental (green), economic, and social) and risk management are closely intertwined. When addressing one of the dimensions and the actions that can be taken to improve it, it is possible that one of the other dimensions will either prove to be beneficial or unviable. A clear example of a measure that benefits the environment and may or may not benefit the economic aspect of the triple bottom line is the installation of solar panels. While solar panels can partially provide for the energy requirements of a company and decrease its carbon-di-oxide (CO2) footprint, their economic viability depends on the company’s geographical location [107].

![Triple bottom line and risk diagram](image)

**Figure 54** Triple bottom line and risk

### 5.1.1 Sustainable Supply Chain Management Dimensions

#### 5.1.1.1 Environmental Dimension

Prior research states four main drivers for a corporate’s concern for the environment: legislation, stakeholder pressures, economic opportunities, and ethical motives [108]. Moreover, government legislation can lead to penalties, fines, and legal costs, and therefore, it is important for companies to comply with these legislations or keep abreast of them [109]. In addition, companies should impose higher and greener standards on suppliers and develop closer ties with them [110]. Although stakeholder pressure is mentioned as a driver for a corporate’s environmental response, it does not appear to have a significant effect [111]. Firms are responsive to stakeholders to circumvent negative public attention
and build stakeholder support [112]. Economically, companies can intensify their production processes to reduce their environmental impact and concurrently lower the costs of inputs and waste disposal [113].

Environmental or green supply chain management describe the set of SCM actions performed, policies thought of, and relationships formed to answer concerns related to the natural environment [114]. Environmental strategies adopted by organizations have a direct impact on the supply chain and competitiveness of the organization [115]. Investment in carbon reduction technology, improving energy efficiency, eco-friendly processes, design for ecology, product life cycle, and recycling are examples of measures that can drive an SSC. Additionally, treaties such as the Paris agreement, regulate the responsibilities companies have towards environmental and social standards [116]. The environmental dimension of a SSC incorporates energy efficiency, a reverse SC/closed loop SC, waste reduction, recycling, remanufacturing/refurbishing, controlling pollution [103], and product upgrades [117]. Companies can comply with stakeholders and government regulations by focusing on the environmental dimension of SSC.

Energy efficiency in a SC is measured using renewable energy sources, direct and indirect energy use, and the emission of greenhouse gasses such as CO$_2$ [118].

A reverse/closed loop SC is the process of planning, implementing, and controlling the efficient and effective inbound flow and storage of secondary goods and related information as opposed to the traditional SC direction of recovering value or proper disposal [119]. A reverse SC is initiated when the user of a product desires to replace or dispose of a product. The first step is, therefore, recovery followed by refurbishing/remanufacturing. If the product is not remanufactured/refurbished, it is recycled to produce raw materials that can be used in the manufacture of other products. Reverse/closed loop SCs should make use of existing forward SC facilities and transportations systems to facilitate the return of products at the end of their life cycle [120].

There are indubitably other ways in which an SC can take into consideration the environment, such as life cycle assessment or via the proper disposal of hazardous materials. However, in this section, only the concepts that were included in the game have been discussed.

5.1.1.2 Economic Dimension

When solely observing the economic aspect of a SC, managers can focus on the following to increase economic performance: SSCM practices shorten the supply pipeline, build an agile supply channel, lower cost in supplier management, react to market changes rapidly and have less wastes in inventory [121].

1. Shorten lead times: Allow for customer demand to be successfully met [122], and lead to a more competitive SC and to surpass the competition.
2. Increase production efficiency: Buying more efficient machinery to produce more in less time and with less energy.

3. Control stock inventory: Understand and track uncertainties; use that information to drive inventory stocking policies [123].

Additional actions that can be implemented and that are a combination of social and economic aspects include lowering labor costs, reducing health and safety costs [124], and saving costs by reducing packaging waste.

5.1.1.3 Social Dimension

The social aspect consists of a company’s organizational culture, values, and ethics. Firms are concerned about maintaining a socially responsible image [125]. As reported by Joyner and Payne, beyond maintaining a socially responsible image, good ethics is good business. Not only are customers more likely to buy from a “good” company, but employees are more strongly committed to their organization if they feel their firm’s ethics are positive [126]. Ethical motives are an important driver for increased environmental performance and corporate social responsibility. Strong business ethics is an essential factor for the success of sustainability initiatives in an organization [127].

5.1.1.4 Risk Dimension

As SCs become more complex, a disruption event affecting an entity in the SC can have a direct effect on a firm’s ability to continue operations, deliver products to the market, or provide services to customers. Christopher and Peck separate risk into external and internal [128]. External risks can hardly be influenced and include earthquakes, tsunamis, fires, terrorist attacks, political instabilities, and strikes and war, to name a few. Internal risks are those that occur within an organization and include transportation failure, changes in customer demand, machine breakdowns, increases in raw material prices, supplier quality problems, supplier failure and malfunctions of IT systems, and financial flow risks. Demand disruptions have relatively short impact periods; however, the recovery periods are significantly longer. Supply disruptions have shorter impact and recovery periods [129]. Strategies to mitigate risk can be divided into four categories: avoidance, control, cooperation, and flexibility [130].

Avoidance: Drop specific products, geographical markets, suppliers, or customer organizations.

Control: Vertical integration, buffer inventory and stockpiling, maintaining excess capacity in production, storage handling and transport, imposing contractual obligations on suppliers, or maintaining a low inventory to accelerate the efficiency of recovery activities [131].

Cooperation: Joint efforts to improve SC visibility, share risk related information, and efforts to prepare SC continuity plans.
Flexibility: Postponement (delay the decision to make, configure, label, or ship a product to a destination), multiple sourcing, and localized sourcing.
5.2 Games in Supply Chain Management & Sustainable Supply Chain Management

Sustainable Supply Chain Management (SSCM) is a complex and dynamic structure where games could provide a holistic approach to raise awareness and comprehension of SSCM. Games have pauses naturally built in; where pauses are temporary stops observed in game play, which can significantly increase comprehension [132]. This makes games excellent tools for systematic and hands on learning. Important information can be easily mastered and assimilated to reduce the time needed to learn, remember, apply new information, promote, discuss, collaborate, and build communication [133].

Why is there a need for a SSCM game? Games enable non-professionals and hopefully professionals, gain more insight into social-technical complexity and how to handle it, i.e., when they are assigned project leader positions [4]. A sustainable SC G is needed since it is not easy to identify the preferences of people towards the different aspects of SSCM. By using a SG, it is possible to reveal these preferences and create further awareness about SSCM. When dealing with SSCM, game players must prioritize what is important and, in the process, realize the importance of achieving sustainability. SGs are used due to their high motivation factor and the possibility to let the participants play an active role and engage in experiential learning [134]. Active learning has reported considerably higher attention and memory, than passive; recall feasibility reported about 20% of what was heard (passive), 70% of what was said (active), and 90% of what was said and done (active) [135].

Conventional studies in SCM focus on a single dimension; “CODEPRO” [7] is a game that is used exclusively to increase the cross-functional understanding in a SC, and hence, focuses on the social dimension of SCs. Another study, using the game “SimGreen” [136], focuses entirely on the green aspect of companies, but ignores the economic and social dimensions. The problem of not incorporating more than one dimension in games was solved by “Shortfall” [137], which incorporates environmental and economic dimensions and “Trust and Tracing” [35], which integrates economic and social dimensions. However, the problem of incorporating three or more dimensions persists.

This study develops two games that increase awareness about SSCM and integrates the triple bottom line and risk management. Managing an SSC is complex. Further, there is no single method to deal with all the different scenarios that may arise, thereby, making games an excellent tool to increase the understanding and awareness about SSCM. A similar approach is used in the game “In the Loop,” whose main purpose is to raise awareness about material criticality and circular product design [138].

Currently, the tools available to teach and bring awareness of sustainability and SSCM are mostly lectures, projects, case studies etc. [139]-[141]. Games are not significantly used as a tool to teach and bring awareness to the topic of SSCM, after a systematic review (Table 16) including SCM and SSCM games only one multiplayer and validated SSCM game was found. SCM has a substantial amount of
games that teach specific problems and solutions, the lower complexity and limited scope of SCM when compared to SSCM allows this. SSCM is highly complex and teaching the player how to solve the problems present in SSCM through a game is not a realistic approach; a more complex tool would stop being a SG and be more akin to a simulation. Teaching the different dimensions of SSCM and selective topics in each dimension to increase awareness is a feasible approach that is under developed (see section 2.2.9). Looper is the only single player SSCM game board game available that accomplishes this objective.

The author’s previous attempt at a SSCM game is “Chain of Command: A Sustainable Supply Chain Management Serious Game” [36] it is a commendable attempt at a game that raises awareness of SSCM. However, it has the same shortcomings present in other SCM games, where play sessions are considerably long and experiencing SSCM issues is not immediate. By design, the SSCM issues are hidden under a gaming layer, which over complicated the learning experience for players. The game requires two or more players to be played and has several player-controlled variables, adding to the overall complexity of the game. In addition, its distribution is complicated by the need of special tokens and elements for gameplay, severely limiting the audience that can play it. The important advantage that “Chain of Command” [36] has over Looper is the social interaction in SCM among players, only possible in a multiplayer game.

Solving the problems of the only currently existing and publicly validated SSCM game “Chain of Command” [36] and providing a holistic approach to SSCM, serves as the motivation behind the development of Looper. Looper is a single player game easy to play, with short play times and no facilitator. It allows the player to carefully think and reflect, without external pressure from other players, making learning and awareness gain a personal experience; this is not possible in multiplayer SG. Looper solves all the problems present in “Chain of Command” [36] and is the only publicly validated single player SSCM game board game currently available.

In the SGC Looper and CoC occupy different quadrants as shown in Figure 55

Figure 55 Looper and CoC position in the SGC
To investigate the research questions one, two, and three, a systematic literature review concerning SCM and SSCM games is performed. A meta search engine, Google Scholar, is used with the following strings “Supply Chain Management” OR “Serious Games” OR “Sustainable Supply Chain Management”. The searches returned a total of 354 results containing the keywords, no restriction is placed on the publication year and only English language articles containing the description of games are selected.

5.2.1 Playtime

How long does a play session last? 16 out of 34 games do not advertise their playtime. The playing time varied noticeably for those games that reported their playtime. The shortest playtime is 10 min “The Distribution Game”[29] and the longest playtime is 3 days “Internet Supply Chain Simulation Game” [12]. For the 16 games that reported their playtime, the average minimum playtime is: 2.8 hours and the maximum average playtime is 5 hours. There is an opportunity to develop SCM games whose playtime is around 1 hour. Longer playtime sessions are partially related to games being played in educational settings, where a game might be required to be played during an entire semester and where participation can be made compulsory.

5.2.2 Average Number of Players Required

The average number of players required to play a SCM or SSCM game is 6 players, this number was calculated by taking the minimum number of players required to be able to execute the game. The data also displays that the average number of facilitators required in SCM games and SSCM games is 1. The only game that required more than one facilitator by design is The Mango Chain Game [18]. Approximately 70% of all the games displayed require a facilitator to be present when the game is being played. The strong bias towards requiring a facilitator while playing games seems to reflect the dominant logic behind current SCM game design. It is important to question the true value of having complex SCM games. Additionally, the large number of players required to play SCM games might be related to the educational or company setting in which they are typically played.

5.2.3 PC Use

Indicates if the SC BG uses a computer to perform calculations in the game, this could be to either speed up the flow of the game or to perform more complex and time-consuming calculations that would require significant effort from the players. Computer based games are counted in the “PC Use” (PC: Personal computer) category. A total of 21 games use PC’s, 11 do not use PC’s and 2 games did not provide enough information to determine if they made use of a PC.

5.2.4 Competitive vs Non-Competitive

There appears to be an almost 53% ratio between competitive and non-competitive games. 18 out of 34 games are competitive while 15 out of 34 are non-competitive. Competitive games have
players trying to defeat or score higher than their counterparts. Non-competitive games require the players to cooperate to achieve a goal; win or lose as a team. It is desirable that there is an explicit motivation central to the logic of the game, and competition is one means to generate this [142].

5.2.5 SCM Games Focusing on the Environment

Milk Supply Chain Management Game [19], Shortfall [24], Shortfall Computer Game [24], Sim Green [26], The Green Beer Game [32].

5.2.6 SCM Games Focusing on Economic Factors

Brass [6], CRAC Metal Box Business Game [8], Global Supply Chain Management Simulation [9], HEC Montreal ERP Simulation Game [10], HECOP Sim [11], Internet Supply Chain Simulation Game [12], Lean Leap Logistics Game [13], Littlefield Technologies [14], LOGA Logistics Game [15], Logistics Game [16], Logistics Game [17], Mango Chain Game [18], SBELP: Supply Chain Simulator [21], SCM Design Game [22], Seconds [23], Siemens Brief Case Game Supply Chain Simulator [25], Stock Control [27], The Distribution Game [29].

5.2.7 SCM Games Focusing on Social Aspects

CODEPRO [7], Trust and Tracing Game [35].

5.2.8 SCM Games Focusing on Risk Management

Beer Game [5], Poker Chips [20], The Game [30], The Global Supply Chain Game-The Distributor [31], The Supply Chain Disruption Game [33], The Dice Game [28] board game, The Dice Game [28] computer game, The Supply Chain Game [34].

5.2.9 SCM Games Focusing on all Dimensions

Chain of Command [36]. In terms of SSCM “Chain of Command” [36] and Looper cover the same topics in SSCM except for the following key differences:


Social dimension: Ethics and relationships among different companies are included in “Chain of Command” [36]. Looper does not include this, instead Corporate Social Responsibility (CSR) is included.

A full list of the SSCM dimensions and topics in both games, aside from the key differences displayed above, can be found in section 3.2.

5.2.10 Total Number of Games

A total of 34 games in supply chain management are displayed in Table 16(appendix) there is a total of 14 board games 41.17% and 19 computer games 55.8%. There was insufficient information to
determine if one of the games shown in Table 16(appendix) is a board game or a computer game. The Dice Game [28] and Shortfall [24] are the only games that are available as a board game and a computer game.

There are several games that address the economic aspect of a SC, from 34 games analyzed 18 (52.9%) decide to focus on the economic aspect of a Supply Chain, 8 (23.5%) emphasize risk management, 5 (14.7%) concentrate on the environment, 2 (5.8%) target social aspects and 1 (2.9%) encompasses all dimensions. Looking at the amount of content that SCM games teach Table 16, it appears that researchers emphasize the creation of games with limited scope and focus, to transfer deeper and highly specific knowledge to players. This could be the reason SSCM games are practically nonexistent. As the scope and focus of a game is expanded, there is a tendency to shift from teaching specific solutions to raising awareness; this may not be the desired outcome by the researchers developing games and as such, SSCM games are not being developed.

Table 16 answers the question “What are the contents and characteristics (session length, number of players, pc use and competitive/non-competitive)” of SCM games and SSCM games?
### Table 16 Summary of SCM and SSCM games

<table>
<thead>
<tr>
<th>Game Name</th>
<th>Type</th>
<th>Content</th>
<th>Average Session Length</th>
<th>No. Players</th>
<th>PC Use</th>
<th>Competitive/Non-Competitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beer Game [5]</td>
<td>BG</td>
<td>Bullwhip effect</td>
<td>2 h</td>
<td>8 and F</td>
<td>No</td>
<td>NC</td>
</tr>
<tr>
<td>Brass [6]</td>
<td>BG</td>
<td>Supply chain management</td>
<td>2 to 3 h</td>
<td>2 to 4</td>
<td>No</td>
<td>C</td>
</tr>
<tr>
<td>Chain of Command: A Sustainable Supply Chain Management Serious Game [36]</td>
<td>BG</td>
<td>Closed loop supply chain, product life cycle, CO2 emissions, government environmental regulations, green technology, lead time, production efficiency, supply chain vs supply chain, ethics between firm-firm relationships, risk mitigation by location of suppliers and number of suppliers.</td>
<td>3 to 6 h</td>
<td>2 to 4</td>
<td>No</td>
<td>C</td>
</tr>
<tr>
<td>CODEPRO [7]</td>
<td>BG</td>
<td>Communication, cooperation</td>
<td>NS</td>
<td>11 to 15 and F</td>
<td>Yes</td>
<td>NC</td>
</tr>
<tr>
<td>CRAC Metal Box Business Game [8]</td>
<td>CG</td>
<td>Operations Management</td>
<td>NS</td>
<td>5 and F</td>
<td>Yes</td>
<td>NC</td>
</tr>
<tr>
<td>Global Supply Chain Management Simulation Game [9]</td>
<td>CG</td>
<td>Cost effective flexible supply chain, production planning, forecasting</td>
<td>NS</td>
<td>1 and F</td>
<td>Yes</td>
<td>NC</td>
</tr>
<tr>
<td>HEC Montreal ERP Simulation Game [10]</td>
<td>CG</td>
<td>Enterprise resource planning</td>
<td>1 day</td>
<td>4 and F</td>
<td>Yes</td>
<td>C</td>
</tr>
<tr>
<td>HECOP Sim [11]</td>
<td>CG</td>
<td>Forecasting, warehouse management, transport planning, inventory production planning, order fulfillment, purchasing</td>
<td>1 to 3 days</td>
<td>7 and F</td>
<td>Yes</td>
<td>NC</td>
</tr>
<tr>
<td>Internet Supply Chain Simulation Game [12]</td>
<td>CG</td>
<td>Supply chain core processes and problems</td>
<td>3.5 to 6 h</td>
<td>6 to 12</td>
<td>Yes</td>
<td>NC</td>
</tr>
<tr>
<td>Lean Leap Logistics Game [13]</td>
<td>CG</td>
<td>Process analysis, forecasting, capacity management, production control, inventory control, queuing, lead time management</td>
<td>NS</td>
<td>4 and F</td>
<td>Yes</td>
<td>C</td>
</tr>
<tr>
<td>LOGA Logistics Game [15]</td>
<td>CG</td>
<td>Logistics</td>
<td>NS</td>
<td>4 and F</td>
<td>Yes</td>
<td>C</td>
</tr>
<tr>
<td>Logistics Game [16]</td>
<td>CG</td>
<td>Supply chain planning operations, cross chain control center</td>
<td>NS</td>
<td>1 or more</td>
<td>Yes</td>
<td>C</td>
</tr>
<tr>
<td>Logistics Game [17]</td>
<td>CG</td>
<td>Material disposition, quantity management, supply chain</td>
<td>NS</td>
<td>1 and F</td>
<td>Yes</td>
<td>C</td>
</tr>
<tr>
<td>Mango Chain Game [18]</td>
<td>BG</td>
<td>Maximize company revenue</td>
<td>2.5 to 3 h</td>
<td>7 to 11 and 2 to 3 F</td>
<td>No</td>
<td>C</td>
</tr>
<tr>
<td>Milk Supply Chain Management Game [19]</td>
<td>CG</td>
<td>Food waste, inventory control, negotiation</td>
<td>2.5 h</td>
<td>4 to 8 and F</td>
<td>No</td>
<td>NC</td>
</tr>
<tr>
<td>Poker Chips [20]</td>
<td>BG</td>
<td>Pull vs Push</td>
<td>NS</td>
<td>NS and F</td>
<td>No</td>
<td>NC</td>
</tr>
<tr>
<td>SPKLP: Supply Chain Simulator [21]</td>
<td>CG</td>
<td>Inventory holding, back order cost, upstream-downstream, bullwhip effect</td>
<td>1 h</td>
<td>1 and F</td>
<td>Yes</td>
<td>NC</td>
</tr>
<tr>
<td>SCMDesign Game [22]</td>
<td>BG</td>
<td>Design thinking, logistics, supply chain management</td>
<td>1 h</td>
<td>7 and F</td>
<td>No</td>
<td>C</td>
</tr>
<tr>
<td>Shortfall Computer Game [24]</td>
<td>CG</td>
<td>Strategic decision making</td>
<td>NS</td>
<td>24 and F</td>
<td>Yes</td>
<td>C</td>
</tr>
<tr>
<td>Shortfall [24]</td>
<td>BG</td>
<td>Environmental benign manufacturing, supply chain, supply chain vs supply chain</td>
<td>NS</td>
<td>6 and F</td>
<td>Yes</td>
<td>C</td>
</tr>
<tr>
<td>Siemens Brief Case Game Supply Chain Simulator [25]</td>
<td>BG</td>
<td>Environment benign manufacturing, supply chain</td>
<td>2 h</td>
<td>12 and F</td>
<td>No</td>
<td>C</td>
</tr>
<tr>
<td>Sim Green [26]</td>
<td>BG</td>
<td>Delivery capability, customer delivery, reliability, quality, profit</td>
<td>2.5 to 10 h</td>
<td>9 to 18</td>
<td>Yes</td>
<td>NC</td>
</tr>
<tr>
<td>Stock Control [27]</td>
<td>CG</td>
<td>Carbon footprint, environmental management system, utilization of recycled materials, product life cycle, WEEE directive</td>
<td>NS</td>
<td>NS and F</td>
<td>No</td>
<td>C</td>
</tr>
<tr>
<td>The Dice Game [28]</td>
<td>BG</td>
<td>Inventory management</td>
<td>1 h</td>
<td>1 and F</td>
<td>Yes</td>
<td>NC</td>
</tr>
<tr>
<td>The Dice Game [29]</td>
<td>CG</td>
<td>Production process, lead time, pull vs push</td>
<td>NS</td>
<td>12 and F</td>
<td>No</td>
<td>NC</td>
</tr>
<tr>
<td>The Distribution Game [29]</td>
<td>NS</td>
<td>Inventory and safety stock</td>
<td>10 to 15 min</td>
<td>1 and F</td>
<td>Yes</td>
<td>NC</td>
</tr>
<tr>
<td>The Supply Chain Game [30]</td>
<td>NS</td>
<td>Risk management</td>
<td>+3 h</td>
<td>1 and F</td>
<td>NS</td>
<td>NC</td>
</tr>
<tr>
<td>The Global Supply Chain Game-The Distributor Game [31]</td>
<td>NS</td>
<td>Complexities of global supply chain, exogenous events</td>
<td>NS</td>
<td>Up to 36 and F</td>
<td>Yes</td>
<td>C</td>
</tr>
<tr>
<td>The Green Beer Game [32]</td>
<td>BG</td>
<td>Green supply chain management</td>
<td>1.5 h</td>
<td>4 and F</td>
<td>No</td>
<td>C</td>
</tr>
<tr>
<td>The Supply Chain Disruption Game [33]</td>
<td>BG</td>
<td>Risk Management</td>
<td>3.5 h</td>
<td>5 and F</td>
<td>No</td>
<td>C</td>
</tr>
<tr>
<td>The Supply Chain Game [34]</td>
<td>CG</td>
<td>Forecasting, inventory, production control, supply network design, logistics</td>
<td>NS</td>
<td>2 to 6</td>
<td>Yes</td>
<td>C</td>
</tr>
<tr>
<td>Trust and Tracing [35]</td>
<td>BG</td>
<td>Trust among different stakeholders in supply chain, business ethics, SC optimization</td>
<td>3 h</td>
<td>4 and F</td>
<td>NS</td>
<td>C</td>
</tr>
</tbody>
</table>
5.3 Chain of Command Concept Development

The game was developed as an iterative process. A total of two testing sessions and eight evaluation sessions were conducted. The two test sessions provided valuable feedback that contributed to modifying the game mechanics and game aesthetics. The eight evaluation sessions were contrived to evaluate the game content and its learning outcome. Sessions were performed with graduate students and working professionals.

“Chain of Command (CoC)”: A SSCM game is the result of this research. It is a board game (two to four players) where players need to optimize their SC to meet environmental needs, achieve economic success, uphold ethical behavior in dealings with other players, and manage risk as they try to outperform and eliminate rival SCs. Players must make decisions to go green, invest in technology, establish partnerships with other players, build close loop SCs, optimize their SC to meet their needs and choose which products to manufacture to have an edge over the competition. The game uses event cards to introduce penalties and bonuses as well as a dice mechanic for the strategic combat mechanic in the game.

The development of “CoC” was undertaken following a new game development model to develop SGs. It is not within the scope of this study to fully explain the development model used. The SG development model focuses on gaming, stealth learning, fun, replay value, and visuals. To generate awareness on the topic of SSCM, the game must incorporate the triple bottom line and risk management. The game will serve as a tool wherein players can adopt different strategies and learn about the positive and negative consequences of their actions. The game must serve as a tool to make discussion of SSCM topics easier and to identify strategies that could benefit companies. “CoC” was developed to be played by not only industry professionals, but by anyone regardless of their background or experience.

Learning outcomes were set to assess the intended knowledge acquisition of the players. After experiencing the game “CoC,” players would ideally be able to do the following:

1. Become aware of the triple bottom line.
2. Identify which risks are more prone to affect their company.
   a. Become aware of SC risks.
   b. Know how to mitigate these risks.
3. Identify which SSC strategy is appropriate for their company.
4. Increase discussion of the topic in the classroom or their company.

The specific learning topics were derived from the learning outcomes and are categorized as below.

1. Environment: Closed loop SC, product life cycle (recycle, remanufacture), CO₂ emissions, government environmental regulations, investment in green technology.
2. Economic: SC optimization by shortening lead times and increasing production efficiency, SC vs. SC.
4. Risk management: Risk mitigation by locating suppliers and number of suppliers.
The specific learning topics were selected based on the literature review that was carried out in section 2 of this study. Ethics was chosen as the social aspect in “CoC,” but there seems to be a void in the amount of SCG that consider this topic. The remaining topics specifically address games. Therefore, this game attempts to incorporate all the topics into one cohesive experience and raise awareness about the different tradeoffs when trying to achieve an SSC.

The next step after having defined the game contents through the elaboration of learning outcomes and learning topics, was to fulfill the requirements in four categories: stealth learning, gaming, fun (which encompasses the previous two categories), replay value, and visuals. Stealth learning eventuates when “players are focused not on learning, but on playing” [65].

**Stealth learning:** encompasses the educational topics described earlier in this section.

- **Chance:** Players are not able to accurately predict the future.
- **Money:** Players need to make good use of the money they generate to offset risks, reorganize the SC, and perform other important activities in the game.
- **Turn based:** Players take turns to perform their actions.
- **Competitive:** Players should be directly competing against each other in a race for total supremacy.

Dynamics result from the interactions between the different mechanics over time. Less complex rules enable the mechanics to be easily understood by the players.

**Fun:** The game should not be a simulation, nor should it be overly simple. Fun is the combination of gaming and stealth learning.

**Replay Value:** No game is ever the same, allow for different approaches to be taken, and finally, new learning should happen every time the game is played.

**Visuals:** The visuals should be appealing, provide support to play the game, and free the players’ mental resources.

It was decided that “CoC” would be a two- to four-player, turn-based strategic game. Players would have to play on two different boards; the first is an individual board and the second board is one that everyone plays on. On the individual board, players should manage their SC, ensure operations comply with environmental regulations, and optimize their SC according to their specific needs. The driving idea behind the main board was to provide an arena were players can compete against each other with the units they manufacture in the game, obtain additional suppliers to enhance their SCs, or cooperate with other players. The initial game designs in Figure 56 did not follow the visual requirement of the SG development model used until later iterations. Early iterations of the player board had five equal areas in which players could establish their factories. Player feedback from tests showed that five areas were significantly complicated to operate and subsequently, one area was removed, bringing the total number to four. From the four remaining areas, one area was made different to introduce a player partnership mechanic that allows players to cooperate. The final version of the player board also added
useful information found in the game’s manual to free the player’s mental resources. The player no longer needed to remember all the rules and flow of the game. The main board (hexagon-based movement grid) where players interact was initially less colorful and not so visually appealing. In addition, the board had a substantial number of hexagons to move through, which slowed down the flow of the game. The total number of hexagons and distances between players were reduced to allow for faster gameplay (players start in the red, green, blue, or yellow areas). The number of external suppliers was increased from three to five to encourage a higher interaction among players. Events in the game were handled by an events card deck. The main changes to the event card deck ranged from removing or adding natural disasters, environmental regulations, supplier disruptive events, and changing the text on the cards or the probability at which they occur. An additional deck containing environmental certifications and technology upgrades was later added to give players even more flexibility in terms of how they played the game.

In “CoC,” players are given a randomly generated SC encompassing three factories. The factories can be in any of the four areas on the player board. At each turn, players are given some money and one material that they must transport from factory to factory using roads, if necessary. At each factory, the player can decide to produce a unit using the material they have received or move that material to the next factory to produce a different type of unit. Players can decide to relocate factories to other areas to reduce lead times or distribute the risk of not being able to produce if they are hit by a natural disaster. Players can purchase technology upgrades that allow them to transport and produce units in larger batches or buy environmental certifications to avoid government penalties; obtaining environmental certifications, of course, requires investing in technology upgrades first. Players can also decide to
invest in three additional factories that contribute to creating a closed loop SC that further enhances the production capacity of the player. All the prior choices require capital, which is not easily obtainable; this, forces players to think about how to invest their money.

The units produced by the players are deployed to the main board. The units deployed can be used to establish partnerships with the nonplayable external suppliers or to engage in conflict with the other players. During the game, players can establish partnerships to enhance their SCs and work together to eliminate other players from the game. To win the game, players should aim to have a reliable SC that can outperform that of their rivals’, to defeat them. “CoC” was designed to include risk on the triple bottom line dimensions, and this can be observed in Figure 54. The traditional visual representation of sustainability does not show risk and is used primarily to explain the actions that can be taken in each facet. By visually representing risk, the reader is reminded that risk can occur in any of the areas of the triple bottom line, which allows for discussion of risk management strategies in each area. This is a new way of visualizing SSCM, which can be used outside of “CoC. The final design of CoC can be seen in Figure 57.

Figure 57 “Chain of Command’s” final serious game design
5.4 Chain of Command Stealth Serious Game Flow

A session of Chain of Command proceeds in the following way:

Game Setup:

Setup of initial SC: The player rolls a die 3 times to determine the location of the tier III factory, tier II factory, tier I factory. The numbers 1 to 4 on the die represent the different zones I, II, III and IV on the player board. Should the player roll a 5 or 6 they must roll the die again. The player then places a location marker on the game board on top of the tier III factory, tier II factory, tier I factory in the zone designated by the die roll.

1. Each player takes one player board.
2. Set the battle board between the players
3. Shuffle event card deck. Populate the SC with raw material and products; one per company (tier III factory, tier II factory, tier I factory) and one or two per road depending if the road is used both ways between companies.
4. Pollution meter and environmental regulation level: Calculate the carbon footprint based on the number of roads that the player uses in his/her SC. Place a marker on the carbon pollution meter. Place a marker on the environmental certification level 0 area of the battle board.
5. Take $150 from the bank.
6. Take 1 tank, 2 airplanes and 4 ground to air missiles, place them on the battle board according to the manual illustration.

CoC round flow:

1. Collect funds from the bank minus any alliance cost you may have.
2. Draw an event card and perform the activity described on the event card. Events include earthquakes, fires, tsunamis, floods, supplier shortage, government environmental regulation increment, government environmental audits, government financial incentives and no event.
3. Move environmental pollution token by one square if the player does not comply with the current environmental regulation.
4. Buy technology upgrades, environmental certifications, relocate factories, start alliances, invest in retrieve, recycle, or refurbish.
5. Move materials in the SC based on current technological capabilities. Tier III factory to tier II factory to tier I factory and to retrieve, to recycle or refurbish. if the player owns retrieve, recycle, or refurbish.
6. Convert materials in manufacturing into units.
7. Receive materials
   (1.) Receive 1 material at tier II factory.
(2.) If you control external suppliers receive additional materials.
(3.) If you have an alliance, receive 1 additional material per alliance at the Zone III Seaport.

8. Move units on the battle board and engage in combat.
(1.) If you successfully destroy a unit collect $50 from the bank.

9. Deploy new units to the battle board.
10. End your turn.

11. Winning and game over conditions: To win, the player needs eliminate from the game all other players or be the wealthiest player if the games is not played until all players are eliminated.

Events that affect the player are mostly based on natural disasters, such as earthquakes, tsunamis, fires, and floods. Other events include the government raising environmental regulations, performing environmental audits, or giving financial incentives to the player. A sample of Looper cards can be seen in Figure 58.

The effects of cards are the following:

**Earthquakes (6 cards):** factories in the affected zone lose all the goods in stock and production.

**Fire (9 cards):** All goods currently stocked in factories are lost to the fire.

**Tsunami (3 cards):** all factories and goods in the area are destroyed.

**Flood (4 cards):** Cannot move materials in or out of the affected area and cannot manufacture units.

**Supplier shortage (6 cards):** Cannot receive materials from any player or supplier.

**Environmental regulations (3 cards):** The government raises the environmental certification level required.

**Government Audit (2 cards):** The government audits your company for environmental compliance and penalizes the player if necessary.

**Let it rain! (6 cards):** Provides a cash incentive to the player.

**Relax (19 cards):** No event card.

**Environmental certifications (3 cards):** 3 levels, level 1, level 3, and level 5, these cards show the current environmental compliance the player has obtained.

**Technology upgrade (3 cards):** 3 levels, level 1, level 2, and level 3 these cards increase transportation batch, lower pollution meter, and allow for environmental certifications of the same level to be obtained.

Environmental certifications and technology upgrade cards are not part of the event drawing deck (30 cards), these are upgrade cards the player can invest in.
Figure 58 CoC battle board, player board and sample game cards
5.5 Looper Concept Development

This game was developed in an iterative process. A total of 30 formal tests were performed, each formal test required 1 participant. Formal testing is used to assess the effectiveness of Looper as a tool to bring awareness of SSCM and not used to perform significant changes to the game mechanics or layout. Informal testing involves playing the game to verify game mechanics and layout. No informal testing was conducted by non-developers of Looper. The developers performed all informal testing of the game. Looper is designed upon the same aesthetics and similar game mechanics behind “Chain of Command” [36]. This considerably shortened the development cycle and verification of game mechanics.

“Looper” is the result of this study. It is a single player board game where players need to control a SC comprised of up to 5 companies. Single player games allow the player to carefully think and reflect without external pressure from other players, to improve the learning and awareness experiences. In Looper, players need to comply with environmental regulations, strive for economic success, decide to participate in CSR and manage risk. In the game, investing in technology, obtaining environmental certifications, investing in closing the SC loop, controlling the SC carbon footprint, controlling SC lead times, controlling production, and establishing location of companies are parameters the player can control. Looper makes use of event cards to bring about bonuses or penalties to the player. The game is played for 25 rounds. Each year having 5 rounds, at the end of a year the player can pause and make changes to their SC. The game uses only one product, the product is however, incidental to how Looper operates. Whether the companies are manufacturing computers, automobiles or gas tanks, the principles do not change. Looper is a tool to enhance awareness and discussion of SSCM topics, therefore, its target audience is the public and non-professionals, it may provide some insight to professionals.

The learning outcomes for Looper are the following:

1. Raise awareness of the triple bottom line.
2. Raise SC risk awareness.
3. Increase the discussion of SSCM in the company or classroom.

The consequential learning topics from the learning outcomes are the following:

2. Economic: SC optimization by shortening lead times and production efficiency.
4. Risk management: Risk mitigation by supplier reliability and location, inventory control, supply disruption.

Learning topics for Looper were selected based on the extensive background research performed in section 2. CSR was chosen as the topic for the social dimension of sustainability. Looper is built upon a modified version of the model used to develop “Chain of Command” [36] that does not include
stealth learning. Visuals, replay value, fun and gaming are the categories of the design model behind Looper.

**Visuals:** The visuals for the SG should be appealing and provide the player with sufficient information to not need to remember game details.

**Replay value:** The initial phase of the SG should always provide variability. Additionally, it should determine how easy or difficult the latter stages of the SG become. New learning should happen if the SG is played more than once.

**Fun:** To achieve “Fun” the SG should not be a simulation but also not be overly simplified. There must be enough parameters to control in the SG but not too many as to overwhelm the player.

**Gaming:** SG mechanics are developed from the educational topics. The different choices the player can make and the rules and events the SG imposes on the player are what is known as mechanics. The main SG mechanics present are: chance, finance, strategy, and competition.

**Chance:** The SG uses a 30-card deck to apply bonuses or penalties to the player. The player cannot completely predict what event will or will not happen in the SG. Over the course of the SG the player draws 25/30 cards.

**Finance:** The player must properly manage the capital they possess to buy material, manufacture, reconfigure the SC, invest in technology, CSR and acquire certifications.

**Strategy:** Players must think ahead on how their decisions and capital spending might affect their ability to cope with events in the SG.

**Competition:** Players compete to beat the current high score and become the new high score holder.

Looper, Figure 59, is a one player SSCM game, its purpose is to provide a better alternative to the 2 to 4 player game “Chain of Command” [36].

Figure 60 contains a sample of the game board, cards and calculation sheet used in Looper. Looper does not use a PC, all mechanics are analog, and calculations are performed by the player. The game board for the game has four zones labeled zone I, zone II, zone III, and zone IV. Each zone has a factory, a wholesaler, a retailer, and two companies dedicated to recycling. During the formal tests, minor graphical changes to the game board were introduced such as icons and a round flowchart redesign. The game board in Looper is based on the lessons learned from the development of “Chain of Command’s” [36] player board.

Significant attention was placed into creating a game that could be played in 1 hour. Looper simulates 5 years, each year containing a total of 5 rounds. To simulate risk, the player must draw a card every round. Over the course of the play session the player will draw 25 cards; there is a total of
30 cards to simulate uncertainty as to which cards will not be in the play session. The total amount of cards that have a negative impact is 17, the rest of the cards have neutral or positive events. At first, it might appear as if disasters will disturb the player’s operations often, however, depending on how the player distributes his/her SC he/she will have a lower risk of being the victim of a disaster; the minimum risk is 25% and the highest risk is 100% if the player has companies in all zones.

Figure 59 Overview of Looper
5.6 Looper Serious Game Flow

A session of Looper proceeds in the following way:

Game Setup:

Setup of initial SC: The player rolls a die 3 times to determine the location of the factory, wholesaler, and retailer. The numbers 1 to 4 on the die represent the different zones I, II, III and IV. Should the player roll a 5 or 6 they must roll the die again. The player then places a location marker on the game board on top of the factory, wholesaler, or retailer in the zone designated by the die roll.

1. Shuffle event card deck. Populate the SC with raw material and products; one per company (factory, wholesaler, retailer) and one or two per road depending if the road is used both ways between companies.
2. Carbon footprint meter and environmental regulations: Calculate the carbon footprint based on the number of roads that the player uses in his/her SC. Place a marker on the carbon footprint meter. Place a marker on “Not Certified” on the environmental regulation level area.
3. Choose to participate in CSR or not.

Looper round flow:

1. Draw an event card and perform the activity described on the event card. Events include earthquakes, fires, tsunamis, floods, government environmental regulation increment, government environmental audits, government financial incentives and no event.
2. Move raw materials and products in the SC based on current technological capabilities. Factory to wholesaler to retailer to customer to landfill and to retrieving and then recycling if the player owns retrieving and recycling.
3. Roll die to determine if your raw material supplier can deliver raw materials. If the supplier can deliver, place raw materials order.
4. Receive raw materials at the factory from the supplier and the recycle company.
5. Perform the calculation sheet operations see Figure 60 for sample; this sample repeats 5 times in a sheet to represent 1 year. The calculation sheet requires the following information: units sold to the market, raw material cost, raw materials ordered, manufacturing cost, raw materials ordered plus received from recycling, current carbon footprint penalty, current capital, other expenses such as CSR, technology investment etc. The outputs of the calculation sheet are: revenue, expenses, profit, and current capital.
6. Round over, repeat steps 1 to 5 unless it is the end of round 5. Round 5 signals the end of the year. At the end of the year take time to choose and invest your capital in factory, wholesaler, or retailer relocation, changing raw material supplier, investing in companies for product retrieval and recycling, obtaining environmental certifications and upgrading technology.
Upgrading technology allows the player to lower manufacturing costs and increase transport capacity between companies (factory, wholesaler, and retailer. Technology is also a prerequisite for obtaining environmental certifications.

7. Winning and game over conditions: To win, the player needs to finish the 5 years in the game and have positive capital. Game over conditions: have negative capital by the end of year 5, unable to pay to rebuild the factory, wholesaler, or retailer after a disaster, buy raw materials, manufacture products, or have no potential sales.

Events that affect the player are mostly based on natural disasters, such as earthquakes, tsunamis, fires, and floods. Other events include the government raising environmental regulations, performing environmental audits, or giving financial incentives to the player. A sample of Looper cards can be seen in Figure 60.

The effects of cards are the following:

**Earthquakes (3 cards):** Companies in the affected zone lose all products stored.

**Fire (4 cards):** Companies in the affected zone lose 50% of all products stored.

**Tsunami (2 cards):** Companies and products in the area are destroyed.

**Flood (3 cards):** Products can go in and out of the affected zone.

**Environmental regulations (3 cards):** The government raises the environmental regulations.

**Audit (2 cards):** The government audits your company for environmental compliance and penalizes the player if necessary.

**CSR (1 card):** Player commitment to CSR provides no immediate bonus.

**Let it rain! (3 cards):** Provides a cash incentive to the player.

**Relax (10 cards):** No event card.

**Environmental certifications (4 cards):** 4 levels, level 0 to level 3, these cards show the current environmental compliance the player has.

**Technology upgrade (4 cards):** 4 levels, level 0 to level 3, these cards lower manufacturing costs, increase the number of products that can be moved between companies and allow for environmental certifications of the same level to be obtained.

Environmental certifications and technology upgrade cards are not part of the event drawing deck (30 cards), these are upgrade cards the player can invest in.
Figure 60 Looper game board (top), cards (middle) and calculation sheet (bottom) sample.
6 VERIFICATION & VALIDATION OF SUSTAINABLE SUPPLY CHAIN MANAGEMENT GAMES

6.1 Chain of Command Verification & Validation

Verification of the game CoC mechanics and dynamics was performed during the concept development of the game. The purpose of verification is to assure that the game will be ready for formal testing during the validation phase.

Verification procedures included:

Event Card deck balancing: Card balancing was performed based on probability models: The number of event cards was constantly changed to assure that disasters would occur at an acceptable rate during game play.

Battle board and player board visuals iterative design: The colors, number of hexagons in the battle board and external suppliers were balanced to allow for faster gameplay. The initial battle board’s size was deemed significantly large and did not allow for fast gameplay among the players. The player board became colorful, a simplified turn flow and a cleaner visual appearance with fewer text.

Figure 61 History of visual changes in CoC
**CoC manual iterative design:** The manual was subjected to appraisal by third parties. The initial manual contained a significant amount of text and a minimal number of images. The manual was redesigned based on the feedback obtained to contain significantly less text and more images, see Figure 65 for reference.

**Chain of Command Game Rules**

Players 2-4

If the game is being played by two players it is recommended to start opposite to each other.

**Game Set Up and General Game Rules**

1. Designate a player as the bank, this player will handle money transactions for the rest of the players.
2. At the start of the game each player must roll the dice three times. After each roll the player must place a factory/supplier figure in the zone corresponding to the number rolled. Example, if your first roll is a four then you must place your tier III factory/supplier in zone IV.

2.1. If the player rolls a 5 or 6, please roll the die again until you roll a number between 1 and 4.
2.2. Remember to place factory/supplier figure on your board whenever you add a factory/supplier.
3. Players start with $150.
4. Starting from the second rotation in the game (every player has taken their turn) each player must collect $150 from the bank.
5. Starting from the second rotation in the game, a player must draw a card from the card stack and read it to the other players.

5.1. Perform the activities that the card displays.
5.2. After a full clockwise rotation (every player has taken its turn), the player next to the left of the player who took the last card must take a card.
5.3. Repeat steps 5.1 and 5.2

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Old manual sample page left side

New manual sample page right side

**Figure 62 Old and New manual comparison**
**CoC informal testing:** Informal testing involves playing the game to verify game mechanics, dynamics, and layout. CoC informal testing involved the participation of players that are not related to the CoC development team. Changes to CoC turn flow and the suppression of certain mechanics such as the turn token were the result of the informal testing.

![CoC informal test](image)

**Figure 63 CoC informal test**

After the game achieved a playable state, research shifted to testing the game play and whether the game could accomplish a change in players’ awareness regarding the topics described in section 3. “Quick tests and iterations” were used to change the game’s design. This process developed by Fogg also includes “expanding on success” [143]. While Fogg’s design process includes a total of eight steps, only the two final steps regarding testing and expanding on success were used. These steps, “quick tests and iterations and expanding on success,” were expanded using Fullerton’s, Swain’s, and Hoffman’s guidelines, which subdivide the previous two phases into foundations, structure, formal details, and refinement [144]. The set of criteria to evaluate during each stage included functionality, fun, internal completeness, and balance. A foundations test was not performed as it was already considered during the early game concept development.

Concerning the informal testing of the game, only functionality was tested.

1. Functionality: Do players understand the rules of the game? Is the game playable? Are different game mechanics working together?
During the formal game testing, fun, internal completeness, and balance were assessed. The researchers were mainly concerned with fun and internal completeness and balance.

1. Fun: Do players enjoy the game and think it is entertaining?
2. Internal completeness: Does the game manage to change the player’s awareness about the different aspects that comprise SSCM and how they interact with each other?
3. Balance: Is the pace of the game too fast or too slow? Are events occurring at an acceptable rate?

### 6.1.1 Chain of Command Test Setup & Data Gathering

“CoC,” being an educational game, is required to be tested with students. Graduate students were approached to test the game during the formal testing. During the informal testing, the game was tested with professionals in the field of SCM. Testing was performed in sessions lasting four to five hours.

There were two informal tests, with six people participating. The participants in the informal tests were professionals in the field of SCM or game researchers. The purpose of these sessions was to polish the game prior to the formal testing, obtain an impression of how the game mechanics work, and verify if the game instructions were easily to understand.

During the formal testing of the game, a total of eight tests were completed. Each test had at least two participants or a maximum of four participants, for a sample size of 30 people. The sample has the following characteristics: 20 males and 10 females. Test participants age ranges: 22 people aged 18-25 years, 8 people aged 26 to 34 years. Academic background of test participants: Science and Engineering 20 and social sciences 10. Not all participants had either basic SC or SSCM knowledge. 30 participants have a 4-year college degree. There are 16 nationalities in the study: Vietnam 4, Japan 3, Thailand 3, Netherlands 3, India 3, Germany 2, Malaysia 1, Taiwan 1, China 1, Indonesia 1, Iran 1, Saudi Arabia 1, Italy 1, France 1, Canada 1, Zambia 1.

Before playing the game, participants were required to answer a ten-question presurvey Table 17. The survey covered topics regarding the triple bottom line and risk management. The questions in the survey had no correct answer; instead, the questions measured the participant’s attitude towards specific topics in each of the triple bottom line and risk management categories. The survey included two types of questions: Likert scale and constant sum questions to establish the relative value or importance of the options.

Observation was chosen as an additional way to collect data. It is important for the researchers to record the problems players may have while playing the game and make annotations on the level of enjoyment the players experienced. The observer recorded interesting occurrences, suggestions, and comments.

At the beginning of every session, 20 minutes were set aside to explain the game rules. There was no explanation given about SSCM so as not to bias the choices that players may make while playing the game.
After each session, a post-survey Table 17, consisting of the same questions as those in the pre-survey plus an additional question, was conducted wherein the participants rated the game that was administered. This was done to assess how much the participant’s awareness regarding SSCM had changed after playing the game. Pre- and post-tests allow for observations of changes in performance and can help determine whether the learning goals are being achieved [145].

Pre- and post-questionnaires Table 17 were generated to assess the attitude of the respondents towards specific topics that “CoC” is designed to make the participant aware of. The pre-questionnaire consisted of ten questions, while the post-questionnaire consisted of 11 questions. The post-questionnaire included one additional question that asked the participants to rate the game on several KPI’s such as fun, educational value, simple vs. realistic, replay value, and integration of the triple bottom line and risk management. Answers to the pre- and post-questionnaire were kept anonymous owing to the ethical content of the last two questions. Keeping the questionnaires anonymous prevented participants from feeling that the researchers were judging them.

Sessions were photographed Figure 64, and audio and voice were recorded to capture the interaction that participants had both with the game and with one other. Following each session, minor balance modifications were carried out to the game to speed up the playing sessions and player vs. player interaction. No mechanics were added or removed from the game between formal tests.
Table 17 Chain of Command Pre and Post Questionnaire; Q: Question; A: Answer

| Q1 | In your opinion who is responsible for handling products at the end of their life cycle? Distribute 100 points between the choices. Product life cycle: Cycle through which every product goes from introduction to withdrawal or eventual demise. |
| Q1A1 | Manufacturing companies; Q1A2 The product’s final user |
| Q2 | In your opinion recycling products benefits which of the following the most? Distribute 100 points between the choices. Supply chain: Sequence of processes involved in the production and distribution of a commodity. |
| Q2A1 | The environment; Q2A2. The manufacturing supply chain companies; Q2A3 The product’s final user |
| Q3 | Which of the following do you think provides more flexibility to a supply chain? Please distribute 100 points between the choices. Recycling; Re-manufacturing. |
| Q4 | Were you the general manager of a factory, how likely would you be to preemptively invest in greener technology for manufacturing? Green technology: technology whose use is intended to mitigate or reverse the effects of human activity on the environment. |
| Q5 | In your opinion, how much flexibility do you think re-manufacturing adds to a supply chain? |
| Q6 | When deciding the location of a factory, what do you think is more important? Please distribute 100 points between the choices. Geographical closeness to other suppliers; Low natural disaster risk area. |
| Q7 | With which of the following do you agree more when it comes to supply chain management? Please distribute 100 points between the choices. All suppliers should be in the same geographical area; All suppliers should be in different geographical areas. |
| Q8 | Which of the following do you feel is the most important aspect to control when it comes to supply chain management. Please distribute a 100 points between the options. Environmental impact of the supply chain; Supply chain robustness; Supply chain lead times. |
| Q9 | You are the supply chain manager for a well-known and respected company. Your company needs to increase supply chain robustness by adding additional suppliers. Failing to secure additional suppliers could cause the demise of the company, putting the livelihood of hundreds of people at stake. You begin negotiations with possible partner companies, all of them ask you whether you have certain environmental certifications. You do not have said environmental certifications and obtaining them would take long enough that the company could go out of business. How likely would you be to do one of the following? Please distribute a 100 points between the choices. Proceed with the negotiations, forge the environmental certifications and later replace them with real certifications to avoid a situation that could cause the demise of the company. The risk of being found out is very low. If found out, the company would face government prosecution and penalties. Risk company prestige by telling the possible partner companies the situation regarding the environmental certifications and promise to obtain them as soon as possible if a partnership is agreed. The possible partner companies may not agree to such a deal and if found out both companies would face prosecution and government penalties. Obtain the certifications and risk bankrupting the company. The risk of company bankruptcy in this case is fifty percent. |
| Q10 | You are the supply chain manager of a company. Your company has had a very long and stable business relationship with supplier A. One day, your company is approached by supplier B. They are offering you to expand your market share if you help them take supplier A out of business. How likely would you be to do one of the following? Please distribute 100 points between the choices. Proceed with the negotiations, forge the environmental certifications and later replace them with real certifications to avoid a situation that could cause the demise of the company. The risk of being found out is very low. If found out, the company would face government prosecution and penalties. Risk company prestige by telling the possible partner companies the situation regarding the environmental certifications and promise to obtain them as soon as possible if a partnership is agreed. The possible partner companies may not agree to such a deal and if found out both companies would face prosecution and government penalties. Obtain the certifications and risk bankrupting the company. The risk of company bankruptcy in this case is fifty percent. |
| Q11 | Please drag the slider and rate from 0 to 100 (0 being poor and 100 being excellent) the serious game you just experience in each of the following indicators. The indicator “unrealistic vs realistic” uses a different scale were closer to 0 means unrealistic and closer to 100 means realistic. |
| Q11A | Fun; Education; Unrealistic vs Realistic; Integration of risk management, supply chain management, environment, economics, and social aspects (CSR). |

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Figure 64 Typical CoC formal testing session
6.1.2 Chain of Command Validation Results

The current version of the game does not require a facilitator. Everything the player needs to know is in the manual. The manual, of course, can still be improved upon by rearranging the explanation of the rules to enable a better cognitive flow. A common occurrence was players asking about topics that would further be discussed in the game manual.

The results of the evaluation questionnaire and the degree of change in the players’ answers is summarized in Table 18 and Figure 65 provides data to answer the question “Does the game manage to change the player’s awareness about the different aspects that comprise SSCM and how they interact with each other,” while offers data to answer the question “Do players enjoy the game and believe that it is entertaining?” Observation of all eight tests contributed to answering the questions presented in section 4.1 “Balance.”

The questionnaire administered before and after the tests was designed to measure the attitude of players towards specific measures that can be performed in SSCM and are included in “CoC.” Whether participants had prior knowledge of SSCM or SCM is irrelevant to the questionnaire. Pre- and post-questionnaire answers were congregated by testing groups to identify changes in a group’s attitude towards different measures that can be performed in SSCM.

The final question of the post-test asks the participants to rate “CoC” based on their perception and experience of the game. The rating ranges from 0 to 100. In the following key performance indicators (KPI), unrealistic vs. realistic, closer to 0 represents unrealistic and closer to 100 represents realistic. The results of this question can be seen in Figure 65. The integration of the triple bottom line and risk was rated the highest. As perceived by participants, “CoC” is effective when the different dimensions of the triple bottom line and risk management are integrated. The lowest rated KPI for “CoC” was “Educational.” A possible explanation for the low rating in this area can be the way the tests were conducted. Participants were not briefed on SSCM; they were only instructed to play the game. It is conceivable that a structured SSCM discussion before attempting “CoC” could further enhance the rating given on the “Educational” KPI. The fact that “CoC” manages to have an average education rating of above 50 with no discussion of SSCM prior to playing the game is testament of its ability to teach SSCM via stealth learning. The game was rated a 62 in the “Fun” KPI. While the game is fun to play, there remains a considerable amount of player downtime. Shortening the time, it takes players to take their next turn could considerably lead to enhanced enjoyment. When players were asked to rate the game on its possible “Replay Value,” they assigned an average score of 64.75. Participants did not play “CoC” more than once. The average value achieved is the player’s perception of “CoC’s” replay value. Regarding the “Unrealistic vs. Realistic” factor, “CoC” was not designed to be either overly unrealistic or overly realistic. The perfect score for “CoC,” from the researchers’ point of view, would have been 50. An average score of 67.25 was achieved. It is important to clarify that “CoC” was rated
by non-experts in SSCM. “CoC” could come across as unrealistic when rated by experts. The 67.25 rating assigned by non-expert users is a satisfactory rating.

**Chain of Command Evaluation by Players**

![Chain of Command Evaluation by Players](image)

*Figure 65 Average rating of CoC as provided by all participants*

The results shown in Table 18 confirm that “CoC” managed to change the initial assumptions players made regarding certain actions that can be performed in SSCM. Questions 1 to 5 focus primarily on the environment. Questions 6 to 8 place emphasis on risk and economy. Questions 9 and 10 target ethics. Minimal changes occurred 48 times, implying that the answers the group of players provided on a specific question were not significantly affected after playing the game. Moderate changes were detected 35 times and significant changes 77 times.

Questions 4 and 5 are based on a Likert scale and these questions led to a positive attitude, in general. It is imperative to comment on the two occasions in which there was a negative change. The two negative changes occurred in question 4, where the participant is asked how likely he/she is to invest in greener technology for manufacturing. In “CoC,” investment in greener technology is triggered by an event card that raises environmental regulations. Players then need to invest in green technology to later obtain an environmental certification. If this event card is not drawn, players are not forced to invest in greener technology for manufacturing. During the game session of groups 3 and 7, the event card was not drawn which resulted in a negative attitude to this question. Groups 1 and 4 did not exhibit a change in their attitude towards investment in greener technology. There could have been a change in the answers given by participants in those groups. However, given that the questionnaires were anonymous, it was not possible to trace if any one participant changed his/her answer. The only observation that can be made is that the entire group did not change its attitude towards greener technology in manufacturing.
The results of Table 18 exhibit the capacity of “CoC” to change the awareness about participants regarding the triple bottom line and risk management. It appears that “CoC” either generates a “minimal” or a “significant” change in the awareness and preferences of players towards SSCM.

**Table 18 Change in the answers of “Chain of Command” test groups**

<table>
<thead>
<tr>
<th>Question (Q#)</th>
<th>Answer (A#); Negative signs next to numbers show that “answer” lost preference by the test group.</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>G5</th>
<th>G6</th>
<th>G7</th>
<th>G8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1A1-Manufacturing companies should handle product at the end of the life cycle</td>
<td></td>
<td>1.00</td>
<td>-3.75</td>
<td>-9.75</td>
<td>-16.00</td>
<td>-8.50</td>
<td>10.25</td>
<td>-42.50</td>
<td>-46.00</td>
</tr>
<tr>
<td>Q1A2-The product's final user should handle the product at the end of the life cycle</td>
<td></td>
<td>-1.00</td>
<td>3.75</td>
<td>9.75</td>
<td>16.00</td>
<td>8.50</td>
<td>-10.25</td>
<td>42.50</td>
<td>46.00</td>
</tr>
<tr>
<td>Q2A1-Recycling benefits the environment the most</td>
<td></td>
<td>14.50</td>
<td>4.00</td>
<td>7.25</td>
<td>36.75</td>
<td>6.25</td>
<td>15.50</td>
<td>52.50</td>
<td>-40.50</td>
</tr>
<tr>
<td>Q2A2-Recycling benefits the manufacturing companies the most</td>
<td></td>
<td>-6.75</td>
<td>10.25</td>
<td>-3.50</td>
<td>-26.00</td>
<td>14.50</td>
<td>-0.75</td>
<td>8.75</td>
<td>39.00</td>
</tr>
<tr>
<td>Q2A3-Recycling benefits the product's final user the most</td>
<td></td>
<td>-7.75</td>
<td>-14.25</td>
<td>-3.75</td>
<td>-10.75</td>
<td>14.50</td>
<td>-0.75</td>
<td>8.75</td>
<td>39.00</td>
</tr>
<tr>
<td>Q3A1-Recycling provides more flexibility to a SC</td>
<td></td>
<td>20.50</td>
<td>-5.00</td>
<td>-4.75</td>
<td>39.75</td>
<td>12.25</td>
<td>-4.25</td>
<td>12.25</td>
<td>31.50</td>
</tr>
<tr>
<td>Q3A2-Remanufacturing provides more flexibility to a SC</td>
<td></td>
<td>-20.50</td>
<td>5.00</td>
<td>4.75</td>
<td>-39.75</td>
<td>-12.25</td>
<td>4.25</td>
<td>-12.25</td>
<td>-31.50</td>
</tr>
<tr>
<td>Q4-How likely are you to preemptively invest in greener technology?</td>
<td></td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Q5-How much flexibility do you think re-manufacturing adds to a SC?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q6A1-Locate factory close to other suppliers is more important</td>
<td></td>
<td>0.25</td>
<td>16.75</td>
<td>16.00</td>
<td>-3.75</td>
<td>-5.50</td>
<td>6.00</td>
<td>-18.50</td>
<td>7.00</td>
</tr>
<tr>
<td>Q6A2-Locate factory in a low disaster risk area is more important</td>
<td></td>
<td>-0.25</td>
<td>-16.75</td>
<td>-16.00</td>
<td>3.75</td>
<td>5.50</td>
<td>-6.00</td>
<td>18.50</td>
<td>7.00</td>
</tr>
<tr>
<td>Q7A1-Having all suppliers in the same geographical area is the most important</td>
<td></td>
<td>-20.25</td>
<td>-13.25</td>
<td>5.00</td>
<td>18.25</td>
<td>2.75</td>
<td>5.00</td>
<td>16.75</td>
<td>34.00</td>
</tr>
<tr>
<td>Q7A2-Suppliers should be in different geographical areas.</td>
<td></td>
<td>20.25</td>
<td>13.25</td>
<td>-5.00</td>
<td>-18.25</td>
<td>-2.75</td>
<td>-5.00</td>
<td>-16.75</td>
<td>34.00</td>
</tr>
<tr>
<td>Q8A1-Controlling the environmental impact of the SC is the most important</td>
<td></td>
<td>7.50</td>
<td>12.75</td>
<td>-12.75</td>
<td>7.00</td>
<td>14.00</td>
<td>-1.00</td>
<td>9.75</td>
<td>18.50</td>
</tr>
<tr>
<td>Q8A2-Having a robust supply chain is the most important</td>
<td></td>
<td>-4.25</td>
<td>-17.50</td>
<td>2.00</td>
<td>-4.75</td>
<td>-0.25</td>
<td>-4.75</td>
<td>-14.25</td>
<td>-4.50</td>
</tr>
<tr>
<td>Q8A3-Having short lead times in the SC is the most important</td>
<td></td>
<td>-3.25</td>
<td>4.75</td>
<td>10.75</td>
<td>11.75</td>
<td>-13.75</td>
<td>5.75</td>
<td>-4.50</td>
<td>-14.00</td>
</tr>
<tr>
<td>Q9A1-Ilegally environmentally certify the company</td>
<td></td>
<td>-8.50</td>
<td>-8.25</td>
<td>-8.75</td>
<td>3.25</td>
<td>5.00</td>
<td>15.42</td>
<td>10.00</td>
<td>17.50</td>
</tr>
<tr>
<td>Q9A2-Obtain environmental certification legally but tell SC partners you are not currently certified</td>
<td></td>
<td>9.00</td>
<td>28.25</td>
<td>15.00</td>
<td>1.00</td>
<td>3.75</td>
<td>-1.25</td>
<td>-12.50</td>
<td>7.50</td>
</tr>
<tr>
<td>Q9A3-Be honest and environmentally certify the company legally</td>
<td></td>
<td>-0.50</td>
<td>-20.00</td>
<td>-6.25</td>
<td>-4.25</td>
<td>-8.75</td>
<td>-7.50</td>
<td>-2.50</td>
<td>-25.00</td>
</tr>
<tr>
<td>Q10A1-Start new business relationship with supplier B and terminate relationships with supplier A</td>
<td></td>
<td>-2.75</td>
<td>-3.75</td>
<td>25.00</td>
<td>-21.25</td>
<td>-6.25</td>
<td>-18.75</td>
<td>10.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Q10A2-Keep supplier relationship with supplier A and disregard offer by supplier B</td>
<td></td>
<td>-1.25</td>
<td>21.00</td>
<td>-18.75</td>
<td>5.00</td>
<td>12.50</td>
<td>11.25</td>
<td>-32.50</td>
<td>7.50</td>
</tr>
<tr>
<td>Q10A3-Keep relationship with supplier A and start a relationship with supplier B</td>
<td></td>
<td>4.00</td>
<td>-17.25</td>
<td>-6.25</td>
<td>16.25</td>
<td>-6.25</td>
<td>7.50</td>
<td>22.50</td>
<td>-2.50</td>
</tr>
</tbody>
</table>

**Minimal Change** 48 times  **Questions 4 and 5**

**Moderate Change** 35 times Negative Change - 2 times

**Significant Change** 77 times No Change + 2 times

**Total Q1 to Q3 and Q6 to Q10** 160 times Positive Change + 12 times
6.2 LOOPER VERIFICATION & VALIDATION

Verification of the game Looper mechanics and dynamics was performed during the concept development of the game. The purpose of verification is to assure that the game will be ready for formal testing during the validation phase.

Verification procedures included:

**Event Card deck balancing:** Card balancing was performed based on probability models: The number of event cards was constantly changed to assure that disasters would occur at an acceptable rate during game play. The effect of cards was balanced several times. Initially the effect of specific cards was punishing players considerably during the initial turns of the serious game. In contrast, some event cards were not a threat to players during the final stages of the serious game. Card effects were rebalanced to always pose a threat to the players regardless of the stage of the serious game.

**Player board visuals iterative design:** Looper’s player board draws heavily from the design of CoC player board. Several changes were made to accommodate for the new gameplay. Changes include: 2 additional zones called customer and landfill, changing the location of recycling, and retrieving in zones I to IV, renaming the pollution meter to carbon footprint, renaming the factories tier III to tier I to factory, wholesaler, and retailer to represent a distribution SC instead of a manufacturing SC. Several icons were added to increase the visual appeal of the player board. See Figure 66

**Calculation sheet iterative design:** The calculation sheet visuals and the formula to calculate the parameters in the serious game was changed. During the verification of the calculation it was found that it was penalizing the player for recycling materials and charging full price for said materials. The calculation was updated to avoid penalizing the player for recycling. The updated calculation module clearly highlights the areas where the player needs to calculate a parameter. See Figure 67

**Informal Testing:** As in CoC, informal testing involves playing the game to verify game mechanics, dynamics, and layout. Looper informal testing involved solely the participation of the development team.
Figure 66 Previous and latest player board design

Previous player board design left side.
The player board has no icons.

Latest player board design right side.
The player board has icons.
### 6.2.1 Looper Test Setup & Data Gathering

A feasibility test study was done to validate the design and educational capabilities of Looper. The game had no informal testing with non-developers of Looper. The game instead, proceeded directly to formal testing. Looper benefits from the visual design, game mechanics and dynamics validation behind Chain of Command [36].

The SSCM game Looper has been tested with N=30 people, tests were performed on an individual basis. The sample has the following characteristics: 15 males and 15 females. Test participants age ranges: 13 people aged 18-25 years, 15 people aged 26 to 34 years and 2 people aged 35 to 54 years. Academic background of test participants: Science and Engineering 20, social sciences 6 and other 4. 18 participants have a 4-year college degree, 11 have a master’s degree and 1 has a doctor’s degree. There are 14 nationalities in the study: China 4, Japan 4, Thailand 4, Netherlands 3, Taiwan 3, India 2, Canada 1, Germany 3, Indonesia 1, Iran 1, Italy 1, Morocco 1, Tunisia 1, Zambia 1. Most participants had limited knowledge on SCM and SSCM, only 10% of participants had SCM experience. Prior to playing the game, test participants are required to sign a consent form. Test participants must then answer a pre-questionnaire containing 6 questions. The pre-questionnaire consists of 6 questions regarding SSCM and 4 questions to obtain the characteristics of the sample such as: sex, age, academic background, and highest level of education completed. The survey covered topics regarding environmental, economic, social and risk aspects of SCM. The questions and answers to the

**Figure 67 Calculation sheet module previous and latest design**
The questionnaire can be seen in Table 19. The questionnaire is designed in such a way that there are no right or wrong answers. Instead, the questionnaire measures the preference of the test subject towards specific actions in the triple bottom line and risk management. The questionnaire is comprised of two types of questions, Likert scale and constant sum. At the end of the pre-test participants are not given feedback regarding their answers.

Before the start of every session, 10 minutes were set aside to explain the test participant the rules of the game Looper. A typical Looper testing sessions can be seen in Figure 68

Table 19 Looper Pre and Post Questionnaire; Q: Question; A: Answer

<table>
<thead>
<tr>
<th>Q1. In your opinion who is responsible for handling products at the end of their life cycle? Distribute 100 points between the choices. Product life cycle: Cycle through which every product goes through from introduction to withdrawal or eventual demise.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1A1. Manufacturing companies; Q1A2. The product’s final user</td>
</tr>
<tr>
<td>Q2. In your opinion recycling products benefits which of the following the most? Distribute 100 points between the choices. Supply chain: Sequence of processes involved in the production and distribution of a commodity.</td>
</tr>
<tr>
<td>Q2A1. The environment; Q2A2. Supply chain companies; Q2A3. The product’s final user</td>
</tr>
<tr>
<td>Q3. Were you the general manager of a factory, how likely would you be to preemptively invest in greener technology for manufacturing? Green technology: technology whose use is intended to mitigate or reverse the effects of human activity on the environment.</td>
</tr>
<tr>
<td>Q4. With which of the following do you agree more when it comes to supply chain management? Distribute 100 points between the choices. Supply Chain Management: Is the management of the flow of goods and services. It includes the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption.</td>
</tr>
<tr>
<td>Q4A1. All suppliers should be in the same geographical area; Q4A2. All suppliers should be in different geographical areas.</td>
</tr>
<tr>
<td>Q5. Which of the following do you feel is the most important aspect to control when it comes to supply chain management? Distribute 100 points between the choices. Supply chain robustness: Includes the number of additional suppliers and their geographical location.</td>
</tr>
<tr>
<td>Q5A1. Environmental impact of the supply chain; Q5A2. Supply chain robustness; Q5A3. Supply chain lead times</td>
</tr>
<tr>
<td>Q6. If you were the CEO of a company, how willing would you be to have your company perform corporate social responsibility? CSR is the belief that a company should take into account the social, ethical, and environmental effects of its activities on its staff and the community around it.</td>
</tr>
<tr>
<td>Q6A. 0-34 Low will, 35-67 Partial will, 68-100 Significant will</td>
</tr>
<tr>
<td>Q7. Please drag the slider and rate from 0 to 100 (0 being poor and 100 being excellent) the serious game you just experience in each of the following indicators. The indicator “unrealistic vs realistic” uses a different scale were closer to 0 means unrealistic and closer to 100 means realistic.</td>
</tr>
<tr>
<td>Q7A. Fun; Education; Unrealistic vs Realistic; Integration of risk management, supply chain management, environment, economics, and social aspects (CSR).</td>
</tr>
</tbody>
</table>
Figure 68 Typical Looper formal testing session
Siddiqui et al. found that players complain about the length of text guides [21]. For this reason, although there is a manual for Looper, the researchers opted to explain the rules of the game to the test participants, explaining the rules required 10 minutes. If the rules for a game require substantial reading and understanding, the test participants are less likely to properly read the manual. No SSCM explanation is given to the participants as to not bias the choices players take while playing Looper.

Observation is another method used to collect data. The researchers gather data regarding the flow of the game such as: token usage, and issues while playing the game. Other annotations include: the participants mood, perceived level of enjoyment,

interesting occurrences, comments, and suggestions from participants. In addition to data gathering, sessions were photographed. Minor modifications to language in event cards and board game elements were performed between tests. No game mechanics were added or removed during formal tests.

Testing sessions lasted on average 1 hour 10 minutes. At the end of every test session, a post-questionnaire, consisting of the same questions in the pre-questionnaire, is given to the test participants. Questions in the survey contained explanations of concepts in case the test participant was not familiar with what was being asked; this facilitates and ensures more accurate answers. The objective behind administering the same test before and after is to compare whether the participants had a significant change in their preferences regarding SSCM. Pre/Post questionnaires allow for observation of changes in performance and can help determine whether the learning goals are being achieved [145]. The post-questionnaire consists of the same 6 questions present in the pre-questionnaire regarding SSCM. The post-questionnaire, however, adds 1 question in which participants rate Looper in 5 key performance indicators (KPI): fun, education, unrealistic vs realistic, replay value and integration of the triple bottom line and risk management. If there is a change in the player’s pre and post questionnaire answers, then Looper was successful at raising the player’s SSCM awareness.
6.2.2 Looper Validation Results

Hypothesis testing is performed using Wilcoxon signed-ranked test. It is a non-parametrical statistical hypothesis test used when comparing two matched samples to assess whether their population mean rank differs. A two tail $\alpha = .05$ is used. The critical value $"W_{critical}"=137$ for $\alpha=.05$ and N=30. Shall the obtained value W for the Wilcoxon test statistic be equal or smaller to $W_{critical}$, the results are statistically significant, $H_0$ is rejected.

The null hypothesis $H_0$ is: There is no difference in awareness level of SSCM topics in test participants after playing Looper.

Alternative hypothesis $H_1$ is: There is difference in awareness level of SSCM topics in test participants after playing Looper.

A Wilcoxon’s signed-ranked test is performed for each question and answers of the survey.

Table 20 includes the test respondents to the questionnaire Table 19. Additionally, Table 21 summarizes the positive and negative sums in addition to the absolute value of the parameters. Looper can change the perception of the test participants completely in 5 of 6 questions. $H_0$ is successfully rejected and $H_1$ acknowledged. The only question reporting a non-statistically significant difference in one of the answers is Q5. In Q5 test participants exhibited a notable change in their opinion about SC robustness and SC lead times, opinions regarding the environmental impact of the SC (Q5A1) tended to remain the same. Table 22 depicts the sample’s shift in preference.

Table 20 Pre and Post-test questionnaire responses

<table>
<thead>
<tr>
<th>Test</th>
<th>Q1A1</th>
<th>Q1A2</th>
<th>Q2A1</th>
<th>Q2A2</th>
<th>Q2A3</th>
<th>Q3A1</th>
<th>Q3A2</th>
<th>Q3A3</th>
<th>Q4A1</th>
<th>Q4A2</th>
<th>Q4A3</th>
<th>Q5A1</th>
<th>Q5A2</th>
<th>Q5A3</th>
<th>Q5A4</th>
<th>Q5A5</th>
<th>Q5A6</th>
<th>Q6A1</th>
<th>Q6A2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Post</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Table 19

- Table 21

- Table 22
### Table 21 Wilcoxon's test statistic values [W] and critical value \[W_{\text{critical}}\]

<table>
<thead>
<tr>
<th>Question</th>
<th>Positive Sum</th>
<th>Negative Sum</th>
<th>Absolute Value [W]</th>
<th>Positive Sum</th>
<th>Negative Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1A1</td>
<td>104</td>
<td>-351</td>
<td>104</td>
<td>351</td>
<td></td>
</tr>
<tr>
<td>Q1A2</td>
<td>351</td>
<td>-104</td>
<td>351</td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>Q2A1</td>
<td>448</td>
<td>-17</td>
<td>448</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Q2A2</td>
<td>10.5</td>
<td>-435.5</td>
<td>10.5</td>
<td>435.5</td>
<td></td>
</tr>
<tr>
<td>Q2A3</td>
<td>317.5</td>
<td>-132.5</td>
<td>317.5</td>
<td>132.5</td>
<td></td>
</tr>
<tr>
<td>Q3A</td>
<td>184</td>
<td>-128</td>
<td>184</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>Q4A1</td>
<td>132</td>
<td>-330</td>
<td>132</td>
<td>330</td>
<td></td>
</tr>
<tr>
<td>Q4A2</td>
<td>330</td>
<td>-132</td>
<td>330</td>
<td>132</td>
<td></td>
</tr>
<tr>
<td>Q5A1</td>
<td>253.5</td>
<td>-208.5</td>
<td>253.5</td>
<td>208.5</td>
<td></td>
</tr>
<tr>
<td>Q5A2</td>
<td>323</td>
<td>-136</td>
<td>323</td>
<td>136</td>
<td></td>
</tr>
<tr>
<td>Q5A3</td>
<td>133</td>
<td>-311</td>
<td>133</td>
<td>311</td>
<td></td>
</tr>
<tr>
<td>Q6A</td>
<td>327</td>
<td>-117</td>
<td>327</td>
<td>117</td>
<td></td>
</tr>
</tbody>
</table>

\[W_{\text{critical}}=137\text{ at }\alpha=.05, \text{N}=30\]

Statistically significant result when compared to \[W_{\text{critical}}\]

Non-statistically significant result when compared to \[W_{\text{critical}}\]

### Table 22 Sample's preference shift

<table>
<thead>
<tr>
<th>Q#A#</th>
<th>Participants perceptual change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1A1</td>
<td>Gained preference</td>
</tr>
<tr>
<td>Q1A2</td>
<td>Lost preference</td>
</tr>
<tr>
<td>Q2A1</td>
<td>Lost preference</td>
</tr>
<tr>
<td>Q2A2</td>
<td>Gained preference</td>
</tr>
<tr>
<td>Q2A3</td>
<td>Lost preference</td>
</tr>
<tr>
<td>Q3A</td>
<td>Likely preference increase, 12.32%</td>
</tr>
<tr>
<td>Q4A1</td>
<td>Gained preference</td>
</tr>
<tr>
<td>Q4A2</td>
<td>Lost preference</td>
</tr>
<tr>
<td>Q5A1</td>
<td>Lost preference</td>
</tr>
<tr>
<td>Q5A2</td>
<td>Lost preference</td>
</tr>
<tr>
<td>Q5A3</td>
<td>Gained preference</td>
</tr>
<tr>
<td>Q6A</td>
<td>Participants shifted towards not performing CSR</td>
</tr>
</tbody>
</table>

### LOOPER EVALUATION BY PLAYERS

![Looper Evaluation KPI](image)

**Figure 69** Loop Evaluation KPI
The evaluation of Looper by the test participants can be seen in Figure 69 to properly interpret the graph in Figure 69 the following guide line is given. A KPI score of 70/100 is considered acceptable in the case of “Fun”, “Education”, “Integration of Risk Management, SCM, Environment, Economics and Social Aspects” and “Replay Value”. For “Unrealistic vs Realistic” the value must be within the range of 35 and 65. Looper managed to attain acceptable ratings in 4 of 5 KPI evaluated by the participants Figure 69. Looper’s KPI modelling tier reported satisfactory scores in categories related to enjoyment, learning, integrative and pragmatism. However, the factor related to engagement had a lower score.

Players appeared to enjoy the tension of flipping the event cards and particularly enjoyed rolling the die to see if a natural disaster would strike them. Players going after high scores felt additional tension towards the final year of the game. In many cases, the final year decided if the player would be able to establish a new high score or not. A common comment among players was to have the calculation sheet be performed by a computer. Looper is designed to be played without a PC as to broaden the locations where it can be played.

Looper is rated as satisfactory in 4 of 5 KPI. Looper fails the KPI “Replay Value” by 10.67 points. Expanding the total number of event cards from 30 to 35 while keeping the card draw limit to 25 cards, can possibly contribute to improving the “Replay Value” score of Looper. Looper was not expected to score above 60 in the “Education” KPI, expressly due to the 0-facilitation and debriefing policy in its design. If facilitated and debriefed, the “Education” KPI score could be increased. Fun was core to the design of Looper and the KPI for “Fun” demonstrates that the game is entertaining to players. The KPI score for “Integration of Risk Management, SCM, Environment, Economics and Social Aspects” is also a welcomed result; Looper is not a very complex game and there was always the concern of not achieving an acceptable integration of risk management, SCM, environment, economics, and social aspects. Players tended to think that Looper is marginally more realistic than unrealistic as indicated by the “Unrealistic vs Realistic” KPI. This could be due to Looper being mostly played by non-SC professional. If the sample had included more SC professionals, the score could have been closer to unrealistic.
7 DISCUSSION

7.1 Sustainable Supply Chain Management Game Design

Answering the first research question “Why are there few SSCM games?” It appears that the reason SSCM games are practically nonexistent, is the emphasis researchers place in creating games with limited scope and focus, to transfer deeper and highly specific knowledge to players. Expanding the scope and focus of a game tends to shift the game from teaching specific solutions to raising awareness. More SSCM games would probably exist if researchers focused on raising awareness instead of teaching specific solutions to current SSCM problems. The complexity of having several dimensions interacting with one another requires the elimination or simplification of complex SCM topics such as: market fluctuation, time delay and communication between SC stakeholders.

To cope with the complexity of SSCM Game Design the CRIM is used. This method, allows SG designers to reduce the complexity of concepts to be integrated in a SSCM game, set mechanics related to the concepts wishing to be taught, generate PCV’s affecting mechanics, and through the elaboration of a dynamics map visualize the interactions among all mechanics, concepts, and dimensions of SSCM. The CRIM method is a valuable tool when designing SG that require the interaction of several dimensions such as SSCM games. It is a straight forward method; no significant time is wasted trying to understand how to use CRIM. While the use of CRIM by SG developers will not guarantee a successful SG, it does provide a guideline as to how to diminish complexity and provide visual feedback of the integration of the different dimension and mechanics.

The use of SETP in SG design and development for this research provides evidence of feasibility. However, experience is a key element in designing SG. Complex SG design methods might over-complicate the development for inexperienced SG developers. The most important insight gained from this study is that SG development methods should be very easy to understand and apply. The SG design frameworks included in this study do not use all SETP, some of the methods only used certain technical processes, those being stakeholder analysis, verification, and validation with an iterative design approach. Answering the question “Are SETP suitable for SGD and development?” The answer is no, unless modifications are made to the framework. Based on the problems faced by the developer when creating a SG that is not completely software (computer assisted board game), it is difficult to recommend the use of SETP for SG development. The main barriers to using SETP are having sufficient knowledge, experience, and the right tools (software) to use the framework. When other frameworks such as DPE or MDA offer an easier learning curve to SG development and do not require the use of specialty software, it is difficult to justify the use of SETP. A significant amount of time is spent understanding and internalizing SE knowledge. Even more time is consumed enabling traceability and preserving all the different files updated. Properly assessing how far to decompose use cases into functions, sub functions and elements is also critical to avoid adding unnecessary complexity. The main
advantage SETP has over other frameworks, is that it considers the whole PLC of the entity being
designed (other frameworks only contemplate the design stage of the game), unfortunately, there is no
PLC that specifically addresses SG. To fully exploit this advantage, the creation of a PLC specifically
made for SG must be generated.

The SSGM was developed to deal with the shortcomings of SETP and existing
models/frameworks. The use of SSGM could lead to more compelling SG that can make players learn
without them realizing and provide enjoyment. The next generation of SG should aim to educate and
entertain in equal shares. The difficulty lies in balancing the previous two dimensions. Failing to do so,
results in games that are too serious or games that are not serious enough and therefore, not useful for
learning. By bringing an emphasis on visuals, the SSG model can help create more compelling
experiences that should be able to rival conventional board games or video games. The significance of
having a high replay value is that the player must play the SSG several times to potentially experience
everything the SSG has to offer. The SSG model aim is to develop SG in which no facilitator is required,
at the same time, the SG can teach players regarding the topic for which it was designed. The SSG
model and the five dimensions it encompasses are developed based on the gap current models exhibit
and from the lessons learned from previous SG development and testing [98]. The Fun component of
the SSGM is fundamental to consider during the development of SSCM games. The complexity of
having several dimensions interacting with one another requires the simplification of the dimensions
while not making the concepts in them overly simple. SGD is more an art than a process that can be
repeated over and over with consistent results. Experience in SGD is fundamental to achieve good
results. The SSGM is not significantly useful if the person utilizing it has no SGD experience.

7.2 Sustainable Supply Chain Management Games

The SG developed in this study represent the current state of the art of SSCM games. These
games are useful at raising awareness of the topic of SSCM, however, CoC and Looper are most likely
not very effective at teaching professionals highly specialized knowledge in SSCM, however both
games can expectantly raise the awareness of SSCM in professionals. The complexity of integrating the
environmental, economic, social and risk dimensions of sustainability with complex SC topics such as
market fluctuation, time delay, and communication among SC stakeholders, severely constraint the
depth of the knowledge that can be transferred to players.

SG designers must remember that if they want to teach highly specialized knowledge to the
players of their games, then they must focus on a specific dimension and on very specific knowledge
of SSCM. The collateral effect being that this will not yield a SSCM game but a SCM game. As stated
earlier, an imperfect solution to the problem is to lower the complexity and therefore, lower the amount
of specialized knowledge being transferred to the player. Should SSCM game designers aim for high
complexity, then they are no longer developing a SSCM game but a SSCM simulation.
The general game structure of Looper can be used and improved upon by other researchers in the field of SSCM games. The researcher and designer of Looper encourages other researchers to gain inspiration from Looper to hopefully develop better SSCM games.

### 7.3 Chain of Command

The final design of “CoC” is represented in Figure 57. During informal testing with the game researchers and SC professionals, the game was not played to completion, and there was no victory condition for the games that did not end. Although the instructions for the game were clear, the game manual was not easy to understand. This led to players not reading the manual thoroughly. Throughout the two informal tests, it was also found that the player board design was significantly complex. The players had to remember the location of their factories and what each factory produced. The two informal testing sessions relied heavily on a facilitator. Following each session, changes were made to the player board, the player manual, the main board, and the text on the event cards. Complicated game mechanics were simplified e.g. material transportation. Additionally, confusing rules such as limiting the number of alliances a player could make were removed from the game. Based on feedback, the game manual was redesigned to be player friendly by prioritizing the use of images over text. The player board information and labeling were expanded; this allowed the player to consult the game manual less frequently. Factory and pollution meter tokens were added to present a visual representation of factory locations and current pollution levels. Initial versions of the game were not aesthetically pleasing, a factor that contributed to feeling of boredom in some players. The player board was subsequently made visually appealing, which positively contributed to the player’s feeling of excitement when he/she looked at the game. Having acted upon the feedback of the two informal sessions, “CoC” proceeded towards formal testing.

Enjoyment was observed in the participants of the game. Players experienced a range of emotions from laughter to stress whenever a disaster or positive event occurred during the game. Players became highly competitive with others who they were not doing business with in the game, and no confrontational or adversarial behavior was observed. They enjoyed the event cards and their unpredictability, commented on the diversity of negative events that could occur in the game, and praised the positive event cards. The turn-based strategy that was followed on the main board, based on the output of the players’ SCs, was also appreciated. Participants of the game generally commented on the scarcity of money and sought to carry out several improvements on their SCs; however, they found themselves unable to do so. This, of course, was the intended outcome of the cash flow in the game. It became apparent to players that they needed to invest according to the way they preferred their SC to work.

The necessity to speed up the pace of the game was identified in the eight formal tests. As the game progressed, players took progressively more time to play their turn. No measure was implemented
to solve this issue during the eight formal tests. Most participants commented on the length of the game and their preference to make it a much shorter experience. The current version of the game has players playing their turns one by one. Splitting the player’s turn into two phases (player board phase and main board phase) and setting a two-minute time limit for every player for his/her player board phase would considerably expedite the pace of the game.

While playing the game, some players questioned whether the board game was a serious game. Initially, it was difficult for players to believe they were learning something from the game; however, by the end of the testing session, the players that had questioned the educational content of the game realized that they had indeed become more aware of SSCM, thus, partially validating the stealth learning layer of the game.

### 7.4 Looper

During the formal testing of Looper, cosmetic changes were made to the SG to provide improved visual outlook. No game mechanics were modified. Looper was able to achieve a balance between “unrealistic vs realistic” that enabled “Fun”, unexpectedly, participants perceived Looper as being marginally realistic than unrealistic. The manual for Looper was only used once during one test and comprises an area that can be further improved. The current version of the manual is significantly text based. More images and less text can make the manual more appealing to new users of Looper. The success of Looper depends on its portability and adaptability to fit the needs of the target group.

Analyzing more in detail the data obtained from the sample, the sample behaved in the following way: Place responsibility of product life cycle unto companies, believes recycling benefits the SC companies the most, prefers to invest in greener technology for manufacturing, have all suppliers in the same geographical area, have short lead times, and not perform CSR.

The variety of nationalities present in the feasibility study made it possible to obtain interesting observations regarding CSR. Test participants from developing countries were most likely to avoid participating in CSR activities and question the usefulness of CSR. It is important to state that even test participants who opted into CSR consistently asked what the benefit of CSR in the game was before opting in. It appears that the willingness to be socially responsible is strongly tied to whether the player can benefit or not. A player’s comment regarding CSR in the game; “Corporate Social Responsibility would have cost me a fortune and would have not been worth it, just as in real life, the government should stimulate it because there is no financial incentive for companies to participate, CSR is the weakest factor in society and it reflects properly in this game”. Looper provides minimum incentive for the player to care for CSR, opting to see if the player will do the right thing. Results show that players are not willing to do the right thing if there is no incentive. Most participants opted to environmentally certify themselves only when environmental regulations in the game raised. A retroactive approach to environmental regulations was considerably common. Closing the SC loop is an activity most players...
considered implementing during the third year of the play session. Players focused on achieving a higher and steadier product output during the first two years of the game. Additional evidence for this claim is provided by the results of Q5. In Q5 participants regarded lead times and SC robustness as being more important than the environment. The awareness of environmental health and development of conscience in SSCM could be associated with presence of tighter regulation and policies.

At the start of the game players preferred to keep the random location layout of the SC that was provided by the game. Towards the last two years of the game, some players that are not high risk averse decided to concentrate all their operations into a single area to reduce lead times and achieve higher profits. As players became more financially stable and successful, they were willing to take higher risks. It is significant to state that players concerned with beating the high score set by other players were the most likely to take higher financial risks.

For additional information regarding the player board, calculation, rules of Looper and the different effects and costs of cards please see section 11.3.
8 CONCLUSION

8.1 Chain of Command

This study investigates SSCM and its aspects (triple bottom line and risk management). This study yields a tool that can be used to raise awareness about SSCM. The target of the game is non-professionals such as students and professionals in SCM (the teaching effect may be greatly diminished for professionals). Developing a game that can convey this information and allow for greater awareness about how the different aspects of SSCM interact among each other is of top priority in this study.

This leads to the following four questions: “Which existing games provide SCM or SSCM knowledge?”, “Which specific topics in each of the aspects of the triple bottom line should the game explore?”, “If such a game is developed, how successful would it be in bringing about awareness about the triple bottom line and risk management in SSCM and identifying player preferences towards the different dimensions of SSCM?”, and “Does the game manage to integrate the three dimensions of sustainability and risk management?”

The first question is answered by performing an in-depth review of existing games and categorizing them based on the triple bottom line and risk management aspect that each game represents the most. The second question is answered by the background research on SSCM, which is later reduced to a very specific set of topics in each of the triple bottom line aspects (environment, economy, social, and risk management).

To address the second question, games are selected as the tool to bring awareness to SSCM as games allow for several approaches and strategies. The resulting game “CoC” gives the user the flexibility to pursue what he/she believes is important, e.g., the environment, economy, social, or risk management. Throughout the game, players realize that they may have overlooked the importance of the other triple bottom line dimensions and risk management, prompting them to act in SSCM. “CoC” is designed to be played by a large audience such as, engineers, non-engineers, students, and so on.

Addressing the third and fourth questions, the game is evaluated. Tests show that further improvements can still be made to the game; the game, in its present form, is competent to create awareness about the interaction between the triple bottom line concepts and risk management and manages to successfully integrate the three dimensions of sustainability and risk management. However, CoC underperforms in education and fun when compared to Looper, players do also not welcome the extended play sessions of +3 hours. CoC tries to incorporate market fluctuation, time delay and communication among SC stakeholders; the result is an over complex game that is difficult to play and understand.
8.2 Looper

The use of board games can play a significantly important role in enhancing the quality of the learning process. The first and second research questions “What is the content of SCM and SSCM games?” and “What characteristics (session length, number of players, PC use and competitive/non-competitive) do SCM and SSCM games have?” are answered by performing an in-depth review of existing games in SCM and SSCM to identify the topics and characteristics of these games. Regarding the complexity of the games, it is important to establish if SCM and SSCM games need to be complex and require a facilitator or if the facilitation requirement is a consequence of trying to simulate complex SCM models.

Problems present in CoC are detected. The main problems being the complexity SC topics such as market fluctuation, time delay and communication among SC stakeholders create when developing a SSCM game. To address this complexity, market fluctuation and communication among SC stakeholders are eliminated from the game, while time delay is significantly simplified by having less stock locations along the SC. “Looper” is developed and validated through the fourth research question “Can Looper increase the awareness of SSCM?”. A pre and post questionnaire is given to participants and analyzed using Wilcoxon’s signed-ranked test to accept or reject “H₀: There is no difference in awareness level of SSCM topics in test participants after playing Looper”. There is a statistically significant difference in pre and post questionnaire answers. “H₁: There is difference in awareness level of SSCM topics in test participants after playing Looper” is accepted. Looper demonstrates the ability to change the participants opinion regarding SSCM. Looper could include more social aspects in sustainability, while the current approach to CSR in the game polarized players, it is not enough, additional social issues should be highlighted. An example of this would be to highlight conflict materials and SC due diligence as pointed by Hofmann et al [146]. The CSR aspect however is quite unique in SCM games and the simple implementation is good to test the player’s behavior towards CSR.

Looper adds to the current stock of SSCM games that do not require a facilitator and solves the problems “Chain of Command” [36] possesses. However, this effort is still not sufficient, there is a need for more SSCM games that incorporate different issues in the triple bottom line and risk management and cover other quadrants of the SGC Figure 38. The area of SSCM games is still relatively new and opportunities to develop additional games that target specific demographics abound.
8.3 Contributions

The contribution in the field of SSCM is two SSCM games that are useful to raise awareness or initiate discussion of SSCM topics by students, and to some extent even professionals. Being a multiplayer SSG, CoC is useful in settings were communication and interaction among players is desired. When individual learning and short playtime is desired, the single player game Looper is the preferred option and the most successful at educating beginners regarding the core concepts of SSCM.

The following are minor contributions of this study: The CRIM to deal with the complexity and integration of several dimensions and concepts into a SSCM game. The CRIM serves as a good SGD basis for game whose main purpose is to raise the awareness of topics and provide the user with a holistic view of the several interactions that occur in a complicated system of systems such as SSCM. An additional contribution is the SSG model used to develop SSG such as CoC and Looper. The SSG model can also be used to develop SG that have significant less SL as is the case of Looper. The classification model SGC is a contribution towards the classification of SG. The SGC is a model developed to classify SG in a visual and easy to understand way. By mapping the existing SG of a specific topic to the SGC, researchers can easily identify opportunity areas to develop SG or SSG.

CoC and Looper comprise the only two facilitator-free SSCM games with publications, making them the only two publicly validated SSCM games. The ability of “CoC” and Looper to prompt discussion, create awareness, raise questions, and identify player preferences towards SSCM in non-traditional modus, makes “CoC” and Looper attractive, alternative teaching tools being the latter one the significantly superior option.

You can download Looper as a print and play game, available through the following link:

https://1drv.ms/f/s!AiHSP2fJ2Nmsgbo8cXOnRa8eEVmYbQ

You can download CoC as a print and play game, available through the following link:

https://1drv.ms/f/s!AiHSP2fJ2NmsgcctPLB_XMKOrhWkfg
8.4 Limitations and Further Work

8.4.1 Chain of Command

CoC is a SSCM game that is meant to be played primarily by students and non-professionals. CoC’s value is considerably diminished when played by SSCM professionals. The main purpose of CoC is to provide the player with a holistic view of what is SSCM. According to the validation performed, CoC proved to increase the awareness of SSCM in test participants. The transferability of the knowledge obtained to the work place or the long-term effect of having played the game was not tested. All sessions involved no facilitator and no debriefing. A debriefing could possibly increase the educational value provided by the SSG. Further validation by SCM professionals is recommended. Chain of Command is most likely not suitable for supply chain professionals as they may regard the game as too superficial to provide concise solutions to sustainable supply chain management problems. Develop a multiplayer SSCM game that teaches concrete solutions to SSCM problems by gathering requirements from professionals and the industry.

8.4.2 Looper

This study has a few limitations. Contrary to real life, Looper uses a single person to manage the SC. This limitation makes it impossible for Looper to display inter/intra company dynamics. Additionally, the game only has one product. The main purpose of Looper is to provide the player with a holistic view of SSCM. Although Looper proved to increase the awareness of SSCM in test participants, the transferability of the knowledge and insights acquired during the game play session experience to a work setting was not tested. All results obtained for the tests involve no game debriefing. The benefit of a debriefing could be enhanced understanding of SSCM topics. Further validation by SCM professionals is recommended. Looper is most likely not suitable for supply chain professionals as they may regard the game as too superficial to provide concise solutions to sustainable supply chain management problems. Develop a single player SSCM game that teaches concrete solutions to SSCM problems by gathering requirements from professionals and the industry. Develop a SSCM game for professionals that teaches concrete solutions to SSCM problems.

8.4.3 Serious Games Development

This study presented a systematic review of current models for SGD and tested the SSG model with the development and testing of CoC. Looper was developed with a variant of the SSG model containing significantly less SL. Further validation of the SSG model is still required. Additional SSG using the SSG model need to be developed and tested. The concept of SSG requires additional empirical evidence. The SGC axes limits for playtime and complexity require additional refining. The current limits are an average of the characteristics that SCM and SSCM games have. For the SGC axes limits to be more reliable, supplementary research of SG in different areas is needed. The additional work needed is that of finding SG and collecting their average playtime and number of PCV.
The CRIM requires additional validation through the development and comparison of games developed using it. It was created to tackle the complexity of developing a SSCM game, it may or may not be adequate for the development of other types of SG.

The Origami SG developed for this study was completed following repeated iterations to properly address issues related to complexity, architectural requirements and player engagement. Earlier iterations of the game were overly complicated to understand, execute and not entertaining. Regular board games such as Monopoly® or chess have a very concise set of rules that are easy to follow and understand, this is one of the reasons people play and enjoy them. Since the Origami SG is a computer assisted board game, a software is used to perform the calculations of the game and display the results to the users. The assessment of SETP provided is limited to the development of board games and computer assisted board games. An additional limitation was the limited experience the main developer had with SETP in real projects. Additional research is required to fully validate the use of SETP for SG design. The following approach could be taken; have other developer’s design computer assisted board games and report on issues they faced while using SETP to later compare them with the findings presented here. Additional work includes, refining the SG PLC and proposed development framework based on SETP while developing a serious board game. Further research also includes the testing of the proposed framework for developing serious board games. Refining the framework requires testing the framework to develop additional SG and testing those SG for educational efficiency. Future work related to the assessment of SETP includes the development of an all software SG and documenting the problems and challenges found to later assess if SETP are suitable for 100% software-based SG. An additional research opportunity includes using specialized SE software and then assessing how SE performs when specialized tools are used for the development of a SG.
9 REFERENCES


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10 PUBLISHED PAPERS

Published articles related to thesis:


Cuesta, Victor, Rosly, Maziah and Nakano, Masaru. “A Single Player Serious Game for Sustainable Supply Chain Management”. Simulation and Gaming: *Studies on Simulation and Gaming, Japan Association of Simulation and Gaming*. Accepted May 18th, 2018.

Impact Factor (N/A)

International conference papers (full length papers with peer review):

ISAGA 2015


ISAGA 2017


International conferences (full paper non-peer reviewed):

Cuesta, Victor and Masaru Nakano. JIMA 2016 Program “Sustainable Supply Chain Management and Serious Games: Proposing the idea of a serious game that encompasses the triple bottom line and risk management”. 2016, 10. Okinawa, Japan.

Published articles not related to thesis

Contributing Author


Impact Factor 2.019
11 APPENDIX

11.1 Origami Serious Game Manuals and Materials

**Origami Game Instructions**

**Required hardware and software**

1. PC/Mac with Windows 7/Mac OSX or newer.
   1.2. Printer
2. Power strip
3. 5 chairs
4. 3 tables (each table shall be able to accommodate 2 players).
5. 5 Origami game disposal boxes
6. 4 VGA to USB 3.0 adapters
7. 1600 Origami sheets
   7.1. 400 Red (100 sheets for each player)
   7.2. 400 Green (100 sheets for each player)
   7.3. 400 Blue (100 sheets for each player)
   7.4. 400 Yellow (100 sheets for each player)

**Origami Game Rules**

1. The players must continuously manufacture origami.
2. The player may manufacture any product.
3. All produced origami must be sold every round, the players are not allowed to stock the origami to sell it later.
   3.1. At the start of round 2 they are only allowed to put origami inside the origami disposal box once the helper has collected the origami produced in the last round.
4. No spying on the competition.
5. The player with the most profit and a good market share by the end of the game is considered the winner.

**Origami Game Instructor Manual**

**Follow all steps!**

1. Setup game according to the physical layout.

   ![Diagram Legend]
   - Table
   - Game Controlling PC
   - Origami Disposal Box
   - Display
   - Video Adapters for PC and Displays
   - Game Master
   - Game Assistant
   - Player

   **Function 1.1**

2. Two persons are required to operate the game.
2.1. Game master: Must update the game information. The game master also applies, grades and handles the discussion after the game.

2.2. Helper: Must help the game master in operating the game by collecting the origami manufactured by each player and recording it on the Origami Game Control Sheet.

3. Print Origami Game Control Sheet found in the excel calculation sheet and the post evaluation test and Game Discussion Cheat Sheet found in the Origami Game folder.

4. Corroborate that the Origami Game Excel calculation sheet is in the same folder as the Origami Game PowerPoint files.

5. Update the macro modules in the Origami Game Excel sheet file (note: In order to modify the macro codes the user must verify that the developer tab is enabled in Excel)

5.1. Excel macro code modification:

Sub Update()
    Dim PPT As Object
    Set PPT = CreateObject("PowerPoint.Application")
    PPT.Presentations.Open "C:\Users\Victor\Desktop\Origami Game\Company A.pptm", , False
    ' Note that the file name and the module
    ' name are required to path the macro correctly.
    PPT.Run "Company A.pptm!Module1.UpdateLinks"
End Sub

Modify the section highlighted in yellow to accurately reflect the current directory of the Origami Game PowerPoint files

6. In the “Company Names” sheet in the Origami Game Excel file change the company aliases to reflect player’s names

7. The helper must Record information in the printed Origami Game Control Sheet.

7.1. The helper must collect all origami produced in a round and record it under each player and product type every round (A round lasts 1 minute 30 seconds).

8. Inserting information into the game and updating the PowerPoint presentations:

8.1. All information recorded in the Origami Game Control Sheet must be handed to the Game Master.

8.2. The Game Master insert this information in the calculation sheet labeled “Manufacturing” in the Origami Game Excel file.

8.3. After recording the information, select (left click) one of the Origami Game PowerPoint presentations.

8.4. ReSelect the Origami Game Excel file (left click) then double click the button labeled “Update” located in the upper left corner in the sheet labeled “Manufacturing”.

8.5. Repeat steps 8.3 to 8.5 for each presentation (The process is repeated for each player).

8.6. Warning!!! When recording information in the sheet labeled “Manufacturing” make sure that the active PowerPoint file is a file not being used by the game. Failure to follow this instruction can result in warning messages popping up in some of the player’s screens and in disruption of the game flow. To avoid this scenario please create a blank PowerPoint presentation and make sure it is the active presentation before inserting new data into the “Manufacturing” sheet.

9. Each round lasts 1 minute 30 seconds.

9.1. Players are allowed to put all their manufactured origami inside the origami disposal box during round one.

9.2. At the start of round 2 they are only allowed to put origami inside the origami disposal box once the helper has collected the origami produced in the last round.

10. Have players fold each origami once to assure everyone understands how to fold the different shapes.

11. Explain how to read the player interface (Please see fig 5 in the Origami Game Instructions file).
11.1. In figure 1, # of Total Products in the Market & Your Manufactured Products; number 1 points at the distance between the market and the player’s production. The closer the bar graph is to the player’s line graph the better. This means the player is dominating the market. The further apart the bar graph is from the line graph means the player is not the only one producing that good in the market.

11.2. In figure 2, Market Price & Your Manufacturing Cost; number 2 points at the profit being made by selling a product. The closer the bar graph is to the player’s line graph means the player is not making a lot of profit on that good. The further apart the bar graph is from line graph, the higher the profit the player is making on a good.

11.3. In figure 3, Your Unit Profit by Product shows the profit you are making on a product per unit sold. If you see a decline in profit it might be a good idea to change markets or lower production.

11.4. In figure 4, Market Share by Revenue shows the market share from the players based on their revenue, not their profit. A player with a high market share will not necessarily win the game.

11.5. In table 1, Your Total Profit by Product & Your Total Revenue by Product shows the player the cumulative profit and revenue per profit as well as the total for all products. Start the game.

12. Finish the game once the end of the Origami Game Control Sheet has been reached.
13. Apply the post evaluation test.
14. Gather the tests and discuss with the players the answers and the concepts the game has taught them.
15. Thank everyone for participating.
16. Save data from the game and appropriately label it with location and date.
Figure 1 Red Heart

Heart

Step 1

Step 2

Step 3

Step 4
Figure 2 Green Mt. Fuji
Figure 3 Blue Flower
Figure 4 Yellow Cat
Figure 1

# of Total Products in the Market & Your Manufactured Products

Figure 2

Market Price & Your Manufacturing Cost

Figure 3

Your Unit Profit by Product

Figure 4

Market Share by Revenue

Table 1 Your Total Profit & Revenue by Product

<table>
<thead>
<tr>
<th>Your Total Profit by Product</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Heart</td>
<td>$1,920.00</td>
</tr>
<tr>
<td>Green Mt. Fuji</td>
<td>$605.00</td>
</tr>
<tr>
<td>Blue Flower</td>
<td>$2,219.00</td>
</tr>
<tr>
<td>Yellow Cat</td>
<td>$1,295.00</td>
</tr>
<tr>
<td>Total</td>
<td>$6,039.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Your Total Revenue by Product</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Heart</td>
<td>$3,575.00</td>
</tr>
<tr>
<td>Green Mt. Fuji</td>
<td>$1,410.00</td>
</tr>
<tr>
<td>Blue Flower</td>
<td>$6,208.00</td>
</tr>
<tr>
<td>Yellow Cat</td>
<td>$2,370.00</td>
</tr>
<tr>
<td>Total</td>
<td>$13,563.00</td>
</tr>
</tbody>
</table>

Figure 5 Player interface explanation
Origami Game Player Manual

Setting:
You are the owner of a business in the origami market, your goal is to be the company with the most market share and the most profit by the end of the game. To achieve this you can decide to fold any of 4 types of origami: red heart, green Mount Fuji, blue flower and yellow cat. You can decide to specialize on a single product or you can produce all of them. As the owner of the company, what to produce is your choice. Pay attention to the market and your manufacturing trends. Remember the winner is not always the biggest market share holder.

Origami Game Rules
1. The game is played for 20 rounds, each round lasts 1 minute 30 seconds.
2. You must continuously manufacture origami.
3. You may manufacture any product.
4. All manufactured origami is placed inside the origami disposal box.
5. You must sell all manufactured origami every round, you are not allowed to stock the origami to sell it later.
   5.1. At the start of round 2 you are only allowed to put origami inside the origami disposal box once the helper has collected the origami produced in the last round.
6. No spying on the competition.
7. The player with the most profit and a good market share by the end of the game is considered the winner.
8. In figure 1, # of Total Products in the Market & Your Manufactured Products; number 1 points at the distance between the market and the player’s production. The closer the bar graph is to the player’s line graph the better. This means the player is dominating the market. The further apart the bar graph is from the line graph means the player is not the only one producing that good in the market.
9. In figure 2, Market Price & Your Manufacturing Cost; number 2 points at the profit being made by selling a product. The closer the bar graph is to the player’s line graph means the player is not making a lot of profit on that good. The further apart the bar graph is from line graph, the higher the profit the player is making on a good.
10. In figure 3, Your Unit Profit by Product shows the profit you are making on a product per unit sold. If you see a decline in profit it might be a good idea to change markets or lower production.
11. In figure 4, Market Share by Revenue shows the market share from the players based on their revenue, not their profit. A player with a high market share will not necessarily win the game.
12. In table 1, Your Total Profit by Product & Your Total Revenue by Product shows the player the cumulative profit and revenue per profit as well as the total for all products.
Name:

Background:

Origami Game

Questionnaire

1. Based on your results in the game please plot a graph relating cost vs number of items produced [Marginal Cost Curve] (All products behave the same way, use the data from all the products to plot a graph).

   \[
   \text{Marginal Cost Curve}
   \]

   105
   100
   95
   90
   85
   80
   75
   70
   65
   60
   55
   50
   45
   1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

   \[
   \text{Your Number of Manufactured Products}
   \]

2. What can you observe from the above graph?

3. Looking at your game graphs; to minimize the manufacturing cost, do you think it is better to produce only one type of Origami or diversify production? Why?
4. Based on your results in the game please plot a graph relating product sell price vs number of products [Market Demand Curve] (All products behave the same way, use the data from all the products to plot a graph).

![Market Demand Curve](image)

5. What can you observe from the above graph?

6. Looking at your game graphs, why did you decide to change or diversify Origami production?
11.2 Chain of Command Manual
Game Setup

Player
Start with $150
1 x
2 x
4 x

Player
Start with $150
1 x
2 x
4 x

Battle Board

Events Deck
Technology and Environmental Certifications Deck

Bank
Manages money distribution every rotation and all other financial transactions.
To decide who’s turn goes first, everyone must roll their die. The player with the highest number goes first. Proceed in a clockwise motion.
Player Board Description

**Zone I**
- Standard Zone

**Tier III Factory**
- Manufactures Tanks
  - Retrieve
  - Recovers units destroyed in battle for later recycling or refurbishing

**Tier II Factory**
- Manufactures Fighter Jets
  - Recycle
  - Recycles unit and turns it into a Tier III Material

**Tier I Factory**
- Manufactures Ground to Air Missiles
  - Refurbish
  - Repairs unit to a 100% for later redeployment

**Zone III Seaport**
- Receding Materials from Alliance Partners
- Stock
- Stock

All materials from alliances are received at the Seaport. After receiving a material it must be shipped to

**Roads**
- Roads connecting different zones. Use them to transport materials received at the port or between factories located in different zones

**Pollution Meter**
- The default starting position is determined by counting the number of roads that you need to pass to transport a material from Tier III to Tier II and from Tier II to Tier I.

- If no roads are used the default starting position is 1.

- The pollution meter moves by 1 square every turn whenever the player does not have the currently required environmental certification.

- If it reaches 6 the player cannot produce anything for 1 turn. Reset the pollution meter to square 1.
Before the Game

To set up the initial supply chain

- Zone I or Zone III
- Zone II or Zone IV

Used to keep track of factories owned and their locations

Example

1. Roll die to determine the starting zone of the Tier III supplier.
2. Place in Zone I.
   - Die roll
3. Roll die to determine the starting zone of the Tier II supplier.
4. Place in Zone III.
   - Die roll
5. Roll die to determine the starting zone of the Tier I supplier.
6. Place in Zone IV.
   - Die roll

To set up the initial pollution meter

In the case of this supply chain, the player must make use of roads twice to transport materials.

The default starting position for the pollution meter is then 2.

Place on top of square 2.
Transporting Materials and Producing Units

Standard material
The player receives one standard material every turn at Tier III Stock.

Additional materials can be received based on alliances or external suppliers. Materials must be moved from tier to tier in sequence. The player cannot send a material received in Tier III Stock directly to Tier I Stock. First send it to Tier II Stock. Make use of roads if necessary.

Players can relocate factories at a cost of $500 per factory per time.

Players can only own one factory of each type: tanks, jet fighters, ground to air missiles, recovery, recycling and refurbishing.

IMPORTANT!!!
Players can only transport materials in batches of 1 material unless they have the Technology Upgrade I.

Players can only produce 1 unit per factory unless they have Technology Upgrade II.

Players can transport materials in any batch size and produce any number of units per factory if they obtain Technology Upgrade III.
**Battle Board**

- **Personal unit deployment area**: Not recommended to share access with allies but possible. Allows units to be deployed on top of enemy units if there is no deployment space. Standard combat rules apply.

- **External supplier unit deployment area**: Can quickly deploy units here if the player controls the external supplier. The player can decide to share access with allies for free or for a price. Be creative!

- **Standard terrain**: Has no special properties.

---

**Life Points Area**

3 Life Points

Players lose 1 life point when another player manages to place a unit inside their life points area. (Units that reach the life points area are discarded)

or

1 life point when they do not have enough money to fully pay a penalty given by the game.

Place 1 resource block on top of a life point whenever you lose a life point.

Players are eliminated when their life points reach zero.

---

Important: The player who eliminates another player from the game, gets to use the eliminated player’s area as a quick deployment zone.

---

**External Supplier**

Place a unit inside the pink hexagon to take control of the supplier. To keep control you must always have a unit on top of the pink hexagon.

Benefits while having control:

- **External Supplier**
  - Receive 1 material at 📦
  - Receive 1 material at 🏵️
  - Receive 1 material at 🪜
This diagram explains what the blue tank in the center can and cannot do. Applies to all unit types (tanks, fighter jets and ground to air missiles).

1. The tank can jump over friendly units.
2. The tank can move and then attack.
3. The tank cannot move after attacking.

- Regular battleboard hexagon
- Tank’s attacking range 1 hexagon
- Tank’s maximum movement range 2 hexagons

Move action
Attack action
Allowed action
Prohibited action

Battle Phase

The winner of a battle always collects $50 from the bank!

Attacking VS Defending

Roll dice to determine winner

No need to roll dice

Defeated
Alliances

About Alliances
Allied players cannot attack each other. Alliances last until a player decides to terminate it.

Players may terminate an alliance at any time.

Cost per alliance $25

Benefit: Receive 1 material per alliance at the port

Alliance benefits can be redeemed only if you pay the upkeep costs.

How to win the game

First player to directly control all external suppliers.

OR

Eliminate all the other players.

OR

Be the wealthiest player if the game is stopped.
Add $50 for each unit the player has on the battle board.
Add $250 for each factory owned.
Add $500 for each external supplier held.
Add the cost of all technology upgrades and certifications the player owns.
Add the amount of cash the player has on hand.
Technology Upgrades
Can be bought at any point in the game during your turn.

Level I
Technology Upgrade Level I Cost 500
You have upgraded the technology used to transport materials between suppliers. You can now move materials between factories in batches of up to 2 items.

Level II
Technology Upgrade Level II Cost 750
You have upgraded the technology used to produce your units, making the process faster and more environmentally friendly. You can now produce up to 2 units at each factory.
Move your pollution meter token back up to two squares.

Level III
Technology Upgrade Level III Cost 1500
You have upgraded the technology used to transport materials and produce units, making the process more environmentally friendly.
You can now move materials between factories in any batch size and can produce any amount of units at each factory.
Move your pollution meter token back up to one square.

Environmental Certifications
Can be bought at any point in the game during your turn.

Certified
1 Star Certification - The most basic of certifications
List of gaming certified sites
Requires Technology Upgrade I

Certified
2 Star Certification - Intermediate certification
List of gaming certified sites
Requires Technology Upgrade II

Certified
3 Star Certification - Highest certification level
List of gaming certified sites
Requires Technology Upgrade III

Events Card Deck

Audit
Scanned the city for any new hazards. Every factory and supplier has been carefully checked for any potential problems. The city is now safer than ever.

Fire
A fire has broken out in the city. The fire has spread to several areas, causing significant damage. The city is now in a state of emergency. The cost to the city is $1500.

Earthquake
An earthquake has struck the city. The earthquake has caused significant damage to the city, and several factories have been destroyed. The cost to the city is $2000.

Hazard
A new hazard has been discovered in the city. The hazard is a new species of plant that is causing significant problems for the city. The cost to the city is $1500.

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11.3 Looper Game Materials

11.3.1 Looper Game Manual

Game Instructions v1.1

Tokens

You need the following:

8x tokens to use as markers, same shape, color can differ.
30+ tokens to use as raw material/product, same color.

Game Setup

Setting up your initial supply chain:

There are 4 zones in the game labeled Zone I, Zone II, Zone III and Zone IV, there is no difference between zones. Each zone is represented by a number on the die.

1. Zone I=1 on the die.
2. Zone II=2 on the die.
3. Zone III=3 on the die.
4. Zone IV=4 on the die.
5. 5 and 6 on the die are not allocated to any zones, whenever you roll a 5 or 6, roll the die again.
6. Roll the die three times.
7. The first die roll determines the location of the factory.
   a. Place a marker on the factory.
8. The second die roll determines the location of the wholesaler.
   a. Place a marker on the wholesaler.
9. The third die roll determines the location of the retailer.
   a. Place a marker on the retailer.
10. Place a marker on top of supplier I, located on the lower right corner of the game board.
    a. Remember to change the location of this marker if you change supplier.
11. Fill your supply chain, always choose the shortest path between companies. Note: The crossroad in the middle of the game board has 2 road segments, in that case, place one raw material/product on each road segment connecting the companies.
   a. Place a raw material/product token on the factory.
   b. Place a raw material/product token on the road(s) leading to the wholesaler if any.
   c. Place a raw material/product token on the wholesaler.
   d. Place a raw material/product token on the road(s) leading to the retailer if any.
   e. Place a raw material/product token on the retailer.

Shuffle the event card deck and take the following cards:

1. Not Certified.
2. Technology Level 0.
3. Choose to participate or not in CSR by keeping the CSR card.

Carbon Footprint Meter and Environmental Regulations

Calculate the Carbon footprint meter by adding the number of roads used from factory to wholesaler plus wholesaler to retailer.

Using a road back and forth counts as using that road twice.

1. 0 or 1 road used put a token on top of 1.01
2. 2 roads used put token on top of 1.02
3. 3 roads used put token on top of 1.03

1
4. 4 roads used put token on top of 1.04
5. 5 roads used put token on top of 1.05
6. 6 or more roads used put token on top of 1.06

If over the course of the game, you use more roads or less roads remember to update the carbon footprint meter.

7. Place a marker on the appropriate carbon footprint meter box.
8. Place a marker on top of the box containing “Not Certified” in the “Environmental Regulation Level”

Round flow

1. Round start.
2. Draw an event card.
4. Roll die to determine if the supplier will be able to service you.
5. Place raw/recycled materials order.
6. Receive raw/recycled materials at factory.
7. Do sheet calculations.
8. If it is the year end you can buy technology upgrades, environmental certifications, relocate factories, invest in retrieving, recycling, refurbishing or change raw material supplier.

Ordering raw materials:

1. Roll die to determine if the supplier will be able to service you.
   a. Non-fulfilled orders do not cost.
   b. Non-fulfilled orders are not considered for the next round.
2. If the supplier will service you, place an order.
   a. The most negative capital you can go when placing an order is $-1000.00
3. Immediately receive raw materials ordered at the factory.

Depending on the supplier the fulfillment probability varies:
Your year 1 supplier is always supplier 1.
Supplier I will service you if you roll a 1, 2 or 3.
Supplier II will service you if you roll a 1, 2, 3 or 4.
Supplier III will service you if you roll a 1, 2, 3, 4 or 5.
Players can only change supplier at the end of year 1. To change supplier the player must pay $200, it is then possible to choose any of the other two suppliers.

Raw Materials and Product Flow

Raw materials/products move to the next company or road once per round.

1. Raw materials arrive at the factory.
2. Raw materials are processed into a product and proceed to the wholesaler.
3. From the wholesaler products go to the retailer.
4. From the retailer products go to the customer, the product is then considered sold.
5. From the customer the products go to the landfill.
6. From the landfill products go to the retrieving company.
7. From the retrieving company products go to the recycling company.

At the start of the game the player has Technology Level 0, this means the player can only move one product between companies. By investing in technology, the player can move 2, 3 and finally as much as he/she wants between companies. Please read technology upgrade cards for more information.
Filling the calculation Sheet

1. Write the number of products sold on the units sold section and calculate Revenue.
2. Fill in your raw materials cost (can be found on the lower right side of the game board).
3. Fill in materials ordered.
4. Fill in manufacturing cost (can be found written on the technology card).
5. Fill in materials ordered plus received at factory.
6. Fill in carbon footprint plus penalties (you can find the carbon footprint number on the carbon footprint meter).
7. Fill in CSR expense plus other expenses (rebuilding, technology upgrades etc.).
8. Calculate Expense Total.
9. Calculate your profit Revenue-Expense Total.
10. Fill in Capital from last round.
11. Calculate current capital (Profit+Capital from Last Round).

Retrieving and Recycling

You can only own 1 retrieving and 1 recycling factory at a cost of:

1. $400 for retrieving. Allows you to take products from the “Sold Products Area” at the end of a round and place them the retrieving factory.
2. $400 for recycling, you must own a retrieving factory to be able to buy this factory.
   a. Allows you to recycle the product and obtain a raw material that you can send back to the bronze Factory.

Remember to place a token on top of the location where you bought the factories.
You must transport the material from Retrieving to Recycling in the same way you transport other materials if the factories are in different zones. Remember to update the carbon footprint meter if you make use of roads.

Investing in Technology and Environmental Certifications, Company Relocations, CSR

1. You must not have negative capital by the end of the year if you want to invest and you cannot spend more money than you have.
2. Technology upgrades require the immediately previous technology upgrade to be acquired.
3. Environmental certifications require the equivalent technology upgrade to be purchasable, you do not need to own the previous environmental certification.
4. Relocating companies has a cost of $1000 per company.
5. CSR is a yearly commitment with a cost of $100 per each round, you can decide to participate in CSR or not at the beginning of each year only.

The game has several event cards you can read their effects before starting the game, remind to shuffle the deck.

Important

All expenses made are added and placed in the “All other expenses” box on the calculation sheet of the next Year Round 1.

Winning conditions

1. Finish all 5 years of the game and have positive capital.

Losing conditions

1. Have negative capital by the end of year 5.
2. You are unable to pay a penalty from the game.
3. You are unable to pay to rebuild the factory, wholesaler, or retailer, buy raw materials, manufacture products, and have no potential sales coming up.
Try to beat the High Scores!!! 🎮

High Scores

1. Roser $109,313.50
2. Naomi $42,518.00
3. Hugo $32,584.80
### 11.3.2 Looper Calculation Sheet

<table>
<thead>
<tr>
<th>Round</th>
<th>Sell Price</th>
<th>Units Sold</th>
<th>Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>580</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Raw Material Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Materials Ordered</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manufacturing Cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Materials Ordered + Returned at the Factory from Recycling</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carbon Footprint + Penalties</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>All Other Expenses (CSR, Rebuilding, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Expense Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Profit</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capital from Last Round</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Current Capital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
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<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

You can now decide to change raw material supplier or continue with the current supplier. Breaking and making a new contract with another supplier costs $500.
### Year 2

#### Round 1
- **Sell Price:** $500
- **Units Sold:**
- **Revenue:**
- **Expense Total:**
- **Profit:**
- **Capital from Last Round:**
- **Current Capital:**

#### Round 2
- **Sell Price:** $500
- **Units Sold:**
- **Revenue:**
- **Expense Total:**
- **Profit:**
- **Capital from Last Round:**
- **Current Capital:**

#### Round 3
- **Sell Price:** $500
- **Units Sold:**
- **Revenue:**
- **Expense Total:**
- **Profit:**
- **Capital from Last Round:**
- **Current Capital:**

#### Round 4
- **Sell Price:** $500
- **Units Sold:**
- **Revenue:**
- **Expense Total:**
- **Profit:**
- **Capital from Last Round:**
- **Current Capital:**

#### Round 5
- **Sell Price:** $500
- **Units Sold:**
- **Revenue:**
- **Expense Total:**
- **Profit:**
- **Capital from Last Round:**
- **Current Capital:**

---

You can now decide to change raw material supplier or continue with the current supplier. Breaking and making a new contract with another supplier costs $500.
<table>
<thead>
<tr>
<th>Round 1</th>
<th>Sell Price: $580</th>
<th>Units Sold</th>
<th>Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Material Cost</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Materials Ordered</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Manufacturing Cost</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Materials Ordered + Returned at the Factory from Recycling</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Carbon Footprint + Penalties</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>All Other Expenses (CSR, Rebuilding, etc.)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Expense Total</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Profit</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Capital from Last Round</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Current Capital</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

You can now decide to change raw material supplier or continue with the current supplier. Breaking and making a new contract with another supplier costs $500.
<table>
<thead>
<tr>
<th>Round 1</th>
<th>Sell Price</th>
<th>Units Sold</th>
<th>Revenue</th>
<th>Raw Material Cost</th>
<th>Materials Ordered</th>
<th>Manufacturing Cost</th>
<th>Materials Ordered + Returned Material</th>
<th>Carbon Footprint Penalties</th>
<th>All Other Expenses (CSR, Rebuilding, etc.)</th>
<th>Expense Total</th>
<th>Profit</th>
<th>Capital from Last Round</th>
<th>Current Capital</th>
</tr>
</thead>
</table>

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<tr>
<th>Round 2</th>
<th>Sell Price</th>
<th>Units Sold</th>
<th>Revenue</th>
<th>Raw Material Cost</th>
<th>Materials Ordered</th>
<th>Manufacturing Cost</th>
<th>Materials Ordered + Returned Material</th>
<th>Carbon Footprint Penalties</th>
<th>All Other Expenses (CSR, Rebuilding, etc.)</th>
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<tr>
<th>Round 3</th>
<th>Sell Price</th>
<th>Units Sold</th>
<th>Revenue</th>
<th>Raw Material Cost</th>
<th>Materials Ordered</th>
<th>Manufacturing Cost</th>
<th>Materials Ordered + Returned Material</th>
<th>Carbon Footprint Penalties</th>
<th>All Other Expenses (CSR, Rebuilding, etc.)</th>
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<table>
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<tr>
<th>Round 4</th>
<th>Sell Price</th>
<th>Units Sold</th>
<th>Revenue</th>
<th>Raw Material Cost</th>
<th>Materials Ordered</th>
<th>Manufacturing Cost</th>
<th>Materials Ordered + Returned Material</th>
<th>Carbon Footprint Penalties</th>
<th>All Other Expenses (CSR, Rebuilding, etc.)</th>
<th>Expense Total</th>
<th>Profit</th>
<th>Capital from Last Round</th>
<th>Current Capital</th>
</tr>
</thead>
</table>

| Round 5 | Sell Price | Units Sold | Revenue | Raw Material Cost | Materials Ordered | Manufacturing Cost | Materials Ordered + Returned Material | Carbon Footprint Penalties | All Other Expenses (CSR, Rebuilding, etc.) | Expense Total | Profit | Capital from Last Round | Current Capital |

You can now decide to change raw material supplier or continue with the current supplier. Breaking and making a new contract with another supplier costs $500.
<table>
<thead>
<tr>
<th>Round 1</th>
<th>Sell Price</th>
<th>Units Sold</th>
<th>Revenue</th>
<th>Raw Material Cost</th>
<th>Materials Ordered</th>
<th>Manufacturing Cost</th>
<th>Materials Ordered + Returned at the Factory from Recycling</th>
<th>Carbon Footprint + Penalties</th>
<th>All Other Expenses (CSR, Rebuilding, etc.)</th>
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<tbody>
<tr>
<td>Round 2</td>
<td>Sell Price</td>
<td>Units Sold</td>
<td>Revenue</td>
<td>Raw Material Cost</td>
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You can now decide to change raw material supplier or continue with the current supplier. Breaking and making a new contract with another supplier costs $500.
11.3.3 Looper Game Cards

**Level 0**
- Technology Upgrade Level I Cost $500
- You have upgraded the technology used to transport materials.
- You can now move two products at a time between companies.
- Your manufacturing cost is $100

**Level I**
- Technology Upgrade Level II Cost $1000
- Prerequisite, must own technology upgrade I
- You have upgraded the technology used to transport materials and manufacture.
- You can now move three products at a time between companies.
- Your new manufacturing cost is $70

**Level III**
- Technology Upgrade Level III Cost $2000
- Prerequisite, must own technology upgrade II
- You have upgraded the technology used to transport materials and manufacture products making the process more environmentally friendly.
- You can now move any number of products between companies.
- Reduce your carbon footprint by square.
- Your new manufacturing cost is $50

**Not Certified**
- You are not environmentally certified

**Certified**
- 1 Star Certification: Cost of getting certified $500
  - Requires Technology Upgrade I

**Certified**
- 2 Star Certification: Cost of getting certified $1000
  - Requires Technology Upgrade II

**Certified**
- 3 Star Certification: Cost of getting certified $2000
  - Requires Technology Upgrade III
EARTHQUAKE
An earthquake has hit zone # (Roll Die). (If you roll a 5 or 6 roll the die again) Companies in the natural disaster area lose all the products.

FLOOD
Zone # (Roll Die) has been flooded. (If you roll a 5 or 6 roll the die again) You cannot move products in or out of the affected zone.

ENVIRONMENTAL REGULATIONS
The government has decided to increase environmental regulations by one level. If you do not have the required environmental certification keep this card and add .1 penalty to the carbon footprint as long as you do not comply with the required certification level. This card effect stacks with other environmental regulations cards.

GOVERNMENT AUDIT
You are the target of a government audit regarding environmental compliance. If you do not have the current required certification level pay $750. If you cannot pay you automatically lose the game.

FIRE
A fire has started in zone # (Roll Die). (If you roll a 5 or 6 roll the die again) You lose 50% of the products in every company at the affected zone. For an uneven number of products always round up.

LET IT RAIN!
You have been given a grant from the government. Collect $500 Use it wisely!

TSUNAMI
A tsunami has struck zone # (Roll Die). All factories and goods in the area are destroyed. The cost of rebuilding is $200 per company destroyed and takes one round to rebuild. If you have the CSR Card the government will help you pay half the cost.

Corporate Social Responsibility (CSR)
This card can only be held if you comply with the current environmental regulation and pay $100 each round. The money donated is spent on projects that improve the livelihood of the community. This card can be obtained or lost between year rounds.
RELAX!
Nothing is happening this round.
11.3.4 Looper Game Board
11.4 Consent Form Samples for Origami SG, CoC and Looper

Origami Game Testing Consent Form

You are being asked to take part in a research study of how the ORIGAMI game performs at teaching some specific economic concepts. Please read this form carefully and ask any questions you may have before agreeing to take part in the study.

What the study is about: The purpose of this study is to learn how well people playing the ORIGAMI game learn the following concepts: Marginal Cost Curve, Market Demand Curve and Market Flooding. This will allow me to validate the design of the game.

What I will ask you to do: If you agree to be in this study, you will be required to play the ORIGAMI game. The testing includes playing the game for approximately 30 minutes followed by a post evaluation and a small discussion. The testing session will take around 60 minutes to complete. With your permission, we would also like to take photographs and record your voice.

Risks and benefits:

I do not anticipate any risks to you participating in this study other than those encountered in day-to-day life.

As a benefit, you will hopefully learn the following economic concepts: Marginal Cost Curve, Market Demand Curve and Market Flooding. You will also learn how to create 4 different types of origami.

Compensation: There is no compensation for participating.

Your answers will be confidential. The records of this study will be kept private. In any sort of report we make public we will not include any information that will make it possible to identify you except for the photographs. Research records will be kept in a locked file; only the researcher will have access to the records.

Taking part is voluntary: Taking part in this study is completely voluntary. If you decide to take part, you are free to withdraw at any time.

If you have questions: The researcher conducting this study is Victor Alonso Cuesta Aguiar. Please ask any questions you have now. If you have questions later, you may contact Victor Alonso Cuesta Aguiar at vcauesta@a3.kete.jp

You will be given a copy of this form to keep for your records.

Statement of Consent: I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

Your Signature __________________________ Date __________________

Your Name (printed) __________________________

In addition to agreeing to participate, I also consent to have pictures taken and voice recorded.

Your Signature __________________________ Date __________________

Signature of person obtaining consent __________________________ Date __________________

Printed name of person obtaining consent __________________________ Date __________________

This consent form will be kept by the researcher for at least 3 years beyond the end of the study.
Chain of Command Game Testing Consent Form

You are being asked to take part in a research study of how the Chain of Command game performs at bringing awareness to sustainable supply chain management issues. Please read this form carefully and ask any questions you may have before agreeing to take part in the study.

What the study is about: The purpose of this study is to test the performance of Chain of Command, a game to bring awareness of several sustainable supply chain management issues, specifically the triple bottom line plus risk management. This will allow me to validate the game.

What I will ask you to do: If you agree to be in this study, you will be required to play the Chain of Command game. The testing includes answering a pre questionnaire, playing the game for approximately 2 hours followed by a post questionnaire. The testing session might take up to 3 hours. With your permission, we would also like to take photographs and record your voice.

Risks and benefits:

I do not anticipate any risks to you participating in this study other than those encountered in day-to-day life.

As a benefit, you will hopefully become aware of the difficulties that exist when trying to manage a sustainable supply chain.

Compensation: There is no compensation for participating.

Your answers will be confidential. The records of this study will be kept private. In any sort of report we make public we will not include any information that will make it possible to identify you except for the photographs. Research records will be kept in a locked file; only the researcher will have access to the records.

Taking part is voluntary: Taking part in this study is completely voluntary. If you decide to take part, you are free to withdraw at any time.

If you have questions: The researcher conducting this study is Victor Alonso Cuesta Aguiar. Please ask any questions you have now. If you have questions later, you may contact Victor Alonso Cuesta Aguiar at vcuesta@kcl.ac.uk.

You will be given a copy of this form to keep for your records.

Statement of Consent: I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

Your Signature ____________________________ Date ____________________________

Your Name (printed) ____________________________

In addition to agreeing to participate, I also consent to have pictures taken and voice recorded.

Your Signature ____________________________ Date ____________________________

Signature of person obtaining consent ____________________________ Date ____________________________

Printed name of person obtaining consent ____________________________ Date ____________________________

This consent form will be kept by the researcher for at least 3 years beyond the end of the study.
Looper Game Testing Consent Form

You are being asked to take part in a research study of how the serious game developed performs at bringing awareness to sustainable supply chain management issues. Please read this form carefully and ask any questions you may have before agreeing to take part in the study.

What the study is about: The purpose of this study is to test the performance of the serious game, in bringing awareness of several sustainable supply chain management issues, specifically the triple bottom line plus risk management. This will allow me to validate the game.

What I will ask you to do: If you agree to be in this study, you will be required to play the serious game. The testing includes answering a pre questionnaire, playing the game for approximately 1 hour followed by a post questionnaire. The testing session might take up to 1.5 hours. With your permission, we would also like to take photographs and record your voice.

Risks and benefits:

I do not anticipate any risks to you participating in this study other than those encountered in day-to-day life.

As a benefit, you will hopefully become aware of the difficulties that exist when trying to manage a sustainable supply chain.

Compensation: There is no compensation for participating.

Your answers will be confidential. The records of this study will be kept private. In any sort of report we make public we will not include any information that will make it possible to identify you except for the photographs. Research records will be kept in a locked file; only the researcher will have access to the records.

Taking part is voluntary: Taking part in this study is completely voluntary. If you decide to take part, you are free to withdraw at any time.

If you have questions: The researcher conducting this study is Victor Alonso Cuesta Aguiar. Please ask any questions you have now. If you have questions later, you may contact Victor Alonso Cuesta Aguiar at v.cuesta@keio.jp

You will be given a copy of this form to keep for your records.

Statement of Consent: I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

Your Signature ____________________________ Date ____________________________

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