Tampere University of Applied Sciences

Gamified Mapping for Global Supply Chain Optimization

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ABSTRACT

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Global supply chains face escalating volatility: nearly 80% report recent disruption, natural disasters alone erased US $368 billion in 2024, and a Gen Z workforce is reshaping expectations. This thesis asks how gamified mapping tools can improve decision-making and cut risk in global supply chains.

A mixed-methods design combines (1) literature synthesis; (2) qualitative analysis of two mechanics common in Paradox Interactive titles, Fog of War and Technology Trees; (3) a survey of 374 experienced grand-strategy players recruited via Reddit.

Findings show that visibility is treasured and trade-worthy: 62% rate early exploration 4-5/5, 86.6% routinely spend resources to reveal hidden data, while 29.9% feel frequent penalties when information is missing, evidencing an “earned visibility” dynamic. Staged capability building is equally pivotal: 88.2% consider tech research critical, 81% chart at least a loose roadmap, and 38% iterate plans often, mirroring agile S&OP cycles.

Synthesising these insights, the study proposes a conceptual framework for Gamified Mapping, called: Core-Middle-Shell. In this model, the gamification layer incentives (Shell) drive engagement with a digital-twin map (Middle) grounded in live supply chain data (Core). This model suggests that coupling Fog of War with tiered tech trees can reduce decision latency, encourage proactive data acquisition, and promote resilience investments before shocks strike.

The research advances supply-chain theory by integrating behavioural gamification with digital twin analytics and offers actionable design blueprints for developers and professionals in this industry.

Key words: gamification, gamified mapping, supply chain management, digital twin, decision making, risk management, fog of war, technology tree

CONTENTS

ABBREVIATIONS AND TERMS

SCM	Supply Chain Management
MIT	Massachusetts Institute of Technology
GIS	Geographic Information Systems
VSM	Value Stream Mapping
ERP	Enterprise Resource Planning
ROI	Return on Investment
IoT	Internet of Things
SDT	Self-Determination Theory
SCOR	Supply Chain Operations Reference
SCRM	Supply Chain Risk Management
EU4	Europa Universalis IV
HOI4	Hearts of Iron 4
DLC	Downloadable content
KPI	Key Performance Indicator
S&OP	Sales And Operations Planning
SQ	Supporting Question

1 INTRODUCTION

In an increasingly interconnected yet volatile world, global supply chains confront mounting challenges: nearly 80 % have suffered recent disruption from geopolitical realignments, natural disasters caused US $ 368 billion in losses during 2024 alone, almost half of critical-infrastructure firms still lack full visibility over cyber-vulnerabilities in their supplier networks, and a generational turnover is under way as Gen Z already outnumbers Baby Boomers in the workforce (The Business Continuity Institute 2024; Aon 2025; DNV 2025; Page, Reuss & Zemper 2024). Frequent interruptions can reveal flaws in decision-making procedures, resulting in inefficiencies that can impact various industries. As a result, innovative management approaches are necessary since traditional ones cannot provide instant, adaptable solutions to these constantly evolving challenges. Furthermore, supply chain professionals must devise more creative strategies to manage routine operations and unexpected disruptions, offering a more familiar environment for the younger workforce.

One promising solution is gamification, which involves integrating game-like elements, such as point scoring, competition, and rule-based play into non-game contexts to enhance user engagement and problem-solving (Deterding et al. 2011). Although it has been heavily utilized in different fields, its use in supply chain management is currently in its infancy (Wanick & Bui 2019; Kalya & Sai 2023). Gamified mapping tools, particularly, have the potential to address different bottlenecks. They offer interactive, real-time visualizations and scenario-based challenges (Sundram et al. 2025). These tools would allow SCM professionals to engage with dynamic data, making anticipating disruptions easier and developing more effective responses.

This thesis examines how gamified mapping tools can help optimise and improve decision-making processes in global supply chains. It will focus on examining how these tools can effectively tackle significant supply chain issues such as geopolitical risks, natural disasters, and trade route blockages, which are everyday disruptors in today's interconnected world. By incorporating video game elements such as real-time decision-making, interactive feedback, and strategic problem-solving, gamified mapping tools can offer supply chain managers a more engaging and flexible method for handling disruptions. Moreover, this work will explore how these tools can be adapted to tackle risks specific to certain regions or countries, such as political instability or infrastructure deficiencies. This adaptability ensures that gamified mapping solutions can be deployed worldwide while continuously adjusting to local conditions. To determine how far gamified mapping can reshape supply-chain performance, this study builds a formal evaluation framework that links key game mechanics to three operational levels. Mechanics inspired by the “Fog of War” improve network visibility, while “tech tree” pathways structure strategic capability development; together they are assessed against decision-latency (the time from disruption alert to managerial action), cost-effectiveness, and quantified risk attenuation across the network. These metrics provide a practical benchmark for comparing gamified interfaces with traditional dashboards and for tracking return on investment as organisations scale adoption.

This introduction has underscored the pressing challenges within global supply chains and presented gamified mapping as an instrument for significant improvements. The potential for these tools to enhance how professionals engage with complex data, anticipate disruptions, and strategically plan responses leads directly to the central inquiry of this research.

1.1 Research questions

The preceding section has established the critical need for innovative solutions to address the increasing complexities and risks in global supply chains. Having identified gamified mapping tools as a promising approach to enhance operational effectiveness, this thesis is therefore driven by a primary research question aimed at understanding the precise ways these tools can achieve such improvements: “How can gamified mapping tools improve decision-making to reduce risk in global supply chains?”.

Additionally, the following supporting questions that are aiming to be answered through this work include:

1. “How can video game features like real-time decisions and challenges improve supply chain predictions?”;

2. “How can gamified mapping tools be customised to fit different regional risks, such as political instability or weak infrastructure?”;

3. “What are the best ways to measure the impact of gamified mapping tools on supply chain operations?”.

Therefore, by addressing these questions, this paper aims to create a theoretical structure emphasising the importance of gamified mapping tools in enhancing decision-making and operational adaptability in supply chain management. The study seeks to improve understanding of how these innovative tools can strengthen supply chain resilience in a constantly evolving context.

2 FOUNDATIONAL CONCEPTS AND INDUSTRY APPLICATIONS

2.1 Gamification in Business

The practice of gamification involves incorporating game elements into existing items. The Merriam-Webster Dictionary (n.d.) defines it as “the process of adding games or game like elements to something (such as a task) to encourage participation”. The idea of gamification entails incorporating established game elements to enhance engagement. It is a tactic to encourage desired behaviours in different groups, such as consumers, workers or students (Werbach and Hunter 2012). Nowadays, gamification is applied by businesses and individuals at all levels in order to create more interest and greater returns on investment (Werbach and Hunter 2012; Capatina et al. 2024). By utilising human’s inherent competitive spirit and drive to achieve, gamification inspires individuals through rivalry and attainable goals (Sailer et al. 2017; Deci & Ryan 2008). This approach holds both positive and negative potential by tapping into human psychology. According to Werbach and Hunter (2012), successful gamification requires integrating features like points, badges, leaderboards, and levels, strategically deploying them to craft meaningful experiences. These gaming mechanisms have shown considerable promise across diverse sectors, including education, healthcare, marketing, and finance.

The idea of “gamification” has existed in one form or another for millennia. The earliest accepted form is traced back to 1908 when the Boy Scouts movement was founded. Members of the Boy Scouts were honoured with badges to acknowledge their accomplishments. Scouts could acquire badges by demonstrating skill in an activity, adhering to the organisation's principles, and participating in special events. However, the term “gamification” was coined by the British computer scientist Nick Pelling in 2002 while designing a user interface for commercial electronic devices in a game like manner. Despite that, it would take ten more years to normalise the term and see a substantial rise in gamification at all levels. (Cloke 2019)

The earliest major digital-era implementations of gamification principles in business came from American Airlines in 1981 with their AAdvantage frequent flyer program. This initiative revolutionized customer loyalty by introducing points (miles) that could be accumulated and redeemed for rewards, effectively gamifying air travel. The program's success led to widespread adoption across the airline industry and eventually other sectors, demonstrating the effectiveness of game mechanics in business contexts. (McCall and Voorhees 2010)

Following American Airlines' early gamification success, the field evolved significantly with the emergence of dedicated enterprise gamification platforms. Although starting in 2005, Bunchball emerged as a pioneer by developing Nitro in 2007, one of the first gamification platforms specifically designed for business applications. This platform allowed companies to implement gamified mechanics such as points, badges, and leaderboards into their corporate training and customer engagement programs (BI Worldwide n.d.). One notable example was its integration with the TV series “The Office”, where Bunchball helped NBC create an online engagement tool, called Dunder Mifflin Infinity, which was a virtual branch of the fictional enterprise Dunder Mifflin Paper Company, in order to gamify fan interactions with the show (Ali 2008).

Since then, gamification has matured into a versatile business strategy with documented benefits well beyond basic training exercises, delivering tangible improvements in areas like leadership development, quality control, productivity, knowledge retention, job performance, and even innovation (Capatina et al. 2024). In the realm of corporate leadership training, for instance, Deloitte’s Leadership Academy integrated game mechanics such as missions, badges, and leaderboards into its executive development curriculum and subsequently observed a 37% increase in the number of users returning to the platform each week, alongside higher completion rates of online training (Meister 2013). Likewise, gamification has been leveraged to enhance operational quality and efficiency, such as in the case of Microsoft’s “Language Quality Game” (Smith 2011; Keitt 2010). This game engaged 4500 employees in a competition to identify software localization errors, yielding over 500000 verified translation checks and bolstering the quality of Windows 7’s international release (Smith 2011; Keitt 2010). More broadly, embedding game elements like points, badges, and leaderboards into routine business processes has been shown to positively influence employee engagement, which in turn boosts the ability to retain knowledge (Capatina et al. 2024). While gamification itself may not directly increase knowledge sharing, it fosters social interaction, which then facilitates the sharing of knowledge among employees (Capatina et al. 2024). Furthermore, gamification has been directly linked to significant gains in employee job performance, enhanced particularly when building upon employees' prior knowledge (Capatina et al. 2024). Companies have also channelled gamification into innovation initiatives, like internal idea contests and hackathons, leveraging its potential to enhance skills like innovative and creative thinking needed for problem-solving across their workforce (Capatina et al. 2024). Collectively, these cross-domain successes illustrate gamification's wide-ranging utility in driving engagement and performance, setting the stage for its application in complex fields like supply chain management.

2.2 Gamification in SCM

In order to fully grasp the impact and potential of gamification in Supply Chain Management, it is essential to first explore its historical roots and the evolution of gamified tools within this field. This chapter will trace the journey of gamification in SCM, from early influential examples like MIT's Beer Distribution Game, which highlighted complex system dynamics, to the sophisticated digital simulations and enterprise gamification platforms that emerged in subsequent decades. This is also done by examining how the application of game mechanics has matured, demonstrating benefits in areas such as training, employee engagement, and operational efficiency, as seen in initiatives like Amazon's Fulfillment Center Games. Furthermore, this section will set the stage for discussing how, by moving beyond these foundational applications and drawing parallels from popular video games, more modern and immersive solutions, including advanced mapping tools and simulations leveraging technologies like virtual and augmented reality can be implemented to aid modern SCM challenges.

2.2.1 The 1960s-1980s: Start of Gamified SCM and Widespread Adoption

One of the earliest and most influential examples of supply chain gamification is MIT's Beer Distribution Game, created in the early 1960s by Jay Forrester at MIT Sloan. This simple tabletop simulation puts players in the roles of retailer, wholesaler, distributor, and factory, managing inventory and orders for "beer" or any generic product through a multi-stage supply chain. The Beer Game aids in understanding the bullwhip effect and complex system dynamics, such as how small changes in customer demand can cause wild oscillations in orders and inventory up the chain. The game's key lesson is that supply chains, in the words of Jay Forrester, "must be managed as a system, not as a set of isolated activities". As a result, over the decades, the Beer Game became a staple in business schools and executive training. Not just that every MIT Sloan class has played it, already by now hundreds of thousands or perhaps millions of people worldwide have experienced its lessons. It remains popular till this day because it is a fun, easy to understand game that strongly demonstrates concepts like systems thinking, delays, and interorganizational trust in SCM. (Dizikes 2012 & Martinez-Moyano 2024)

In the following decades, the success of the Beer Game prompted the broader use of gaming in supply chain education and training. By the 1980s, universities and large firms worldwide were regularly using the Beer Game or similar simulations to teach coordination and inventory management, emphasizing the impact of structure on behaviour in a setting relating to supply networks (Senge 2006).

2.2.2 The 1990s: Early Computerized SCM Games

As computers advanced, electronic versions of supply chain games emerged by the 1990s, making simulations more accessible and with more data. MIT and others began offering software versions of the Beer Game, as well as variants so that participants could play via computers rather than physical boards (Martinez-Moyano 2024). Around the same time, new operations management games were developed. A prime example was introduced by Standford in 1997-1998, named Littlefield Technologies. This was a web-based factory simulation that let student teams manage a virtual production line in real-time (Miyaoka 2005). Littlefield and similar games showed how queuing, capacity planning, and lead times impact performance, turning what could be a dry analytical exercise into a competitive, engaging challenge. The impact of these early digital simulations was significant, as they allowed for instantaneous feedback and repetitive play, helping both students and professionals practice decision-making to improve efficiency in forecasting, inventory control, and production scheduling. As a result, by the late 1990s, playing the supply chain was an established pedagogy (Arisha, Tobail & Crow 2011). These games trained a generation of supply chain experts in a risk-free environment, improving their intuition for process optimisation and teamwork. They also established the groundwork for the future of gamification in this field.

2.2.3 The 2000s: Holistic SCM Gamification

The 2000s saw gamification in SCM take on larger, more integrative contents. In 2004, researchers at HEC Montréal in Canada developed ERPsim, a simulation that runs on a real SAP ERP system to teach enterprise-wide process integration (HEC Montréal n.d.). ERPsim and similar platforms turned supply chain management into a game at a whole business level, where teams make decisions on purchasing, production, and sales in a live ERP environment, immediately seeing financial outcomes. This helped participants understand how operational decisions ripple through enterprise systems, by linking SCM decisions to accounting results, and improving analytical skills in using technology. Later in the decade, a Dutch company introduced The Fresh Connection, a cross-functional online supply chain simulation launched in 2008. In this game, teams assume roles, such as purchasing, operations, sales, supply chain at a juice company, and must collaborate to turn around a failing business. The idea behind it is to motivate teams to apply SCM best practices and align decisions across functions to maximize ROI. Its popularity in corporate training and universities around the globe demonstrates how gamified simulations can break improve end to end visibility. Essentially, participants learn how procurement, production, and demand planning must work in concert to improve service and profitability. The impact of these 2000s era games was a deeper integration of supply chain education with real-world decision contexts. (PRWeb 2015)

2.2.4 The 2010s: Mainstream SCM Gamification

By the 2010s the term gamification became a buzzword in many industries, including supply chain management. Companies began applying points, leaderboards, and competitions to traditionally everyday SCM tasks to boost engagement and efficiency. A notable example is Amazon, which by 2019 had rolled out “Fulfillment Center (FC) Games” in many of its warehouses. In these optional games, warehouse workers turn over inventory or pick items to see their work translated into virtual points or progress via a Leaderboard in a video-game style interface, as shown in Appendix 1 and Appendix 2. For instance, games such as Tamazilla and Gone Fishin' are present, where employees engage in virtual tasks that mirror traditional gaming mechanics. In Tamazilla, workers collect and care for digital pets, similar to Tamagotchis, while Gone Fishin' allows them to catch fish and upgrade their in-game character. These games run alongside employees’ real-world picking tasks, where they sort products into the appropriate boxes. Additionally, participants can earn a digital currency, which is redeemable for real-life Amazon merchandise, further integrating incentives into the gamified system. (Atari365 2023; Bensinger 2019; Martineau & Di Stefano 2021; Wollenhaupt 2021)

Other logistics firms followed suit: for example, Kenco Logistics, which is a 3PL in the U.S. introduced warehouse competitions and reported productivity improvements of 3-5% in facilities using gamified metrics (Wollenhaupt 2021). Studies during this period began to quantify the workforce impact: a 2021–2022 survey of 750 front-line warehouse workers in the U.S. and UK found that 84% were more likely to stay with a company that gamified daily tasks with competitions and rewards (MH&L Staff 2024). In other words, gamification emerged not just as a gimmick, but as a tool for improving employee motivation and retention in supply chain roles. The 2010s taught the industry that applying game design to SCM processes and mainstreaming of gamification, slowly made it the norm within the industry.

2.2.5 The 2020s: Serious Games for SCM Resilience

In the 2020s, gamification in supply chain management has evolved with new technologies and urgent business needs. The COVID-19 pandemic and subsequent supply disruptions pushed firms and governments to focus on supply chain risk management and resilience, and they turned to serious gaming as a solution for modern times. For example, the U.S. Department of Defense, via the Acquisition Innovation Research Center in partnerships with several prestigious universities across the US, has explored "serious games" to simulate supply chain disruptions and improve decision-making under stress. At North Carolina State University, researchers designed a Supply Chain Disruption Game where players act as procurement managers balancing a low-cost but risk-prone overseas supplier against a pricier local supplier. This competitive simulation teaches participants about sourcing risk, contingency planning, and the value of flexible capacity in an explicit, hands-on way. Students have responded well to it, and in the words of Tim Kraft, a professor at North Carolina State University "they get very competitive and have a lot of fun with the simulation". (Fathom n.d; Handfield 2024)

Beyond risk management, the 2020s have brought immersive technologies into SCM gamification. Many companies now use virtual reality and augmented reality to create interactive training games for warehouse and logistics operations. Wearing VR headsets, new hires can learn to operate forklifts or navigate a distribution centre in a realistic 3D game environment, practicing procedures safely before doing them on the real floor, like how flight simulators work. These gamified VR trainings dramatically reduce risk and accelerate learning by allowing mistakes to happen in a virtual world with immediate feedback. Likewise, AR apps overlay game-like prompts or points on actual tasks. For example, they can guide a picker to the next item with visual cues and scoring their accuracy. Such approaches gained momentum as remote work and social distancing made traditional training harder. As a result, by proving themselves so effective, Fortune 500 firms are adopting VR/AR at scale for logistics training, finding it both engaging for workers and cost-effective for managers. (United States Postal Service n.d.)

Finally, even the venerable Beer Game has kept up with the times. MIT's School of Business now offers an online multiplayer Beer Game simulation so that students and executives around the world can log in and experience the bullwhip effect together in real-time (Sterman n.d.). This fusion of classic game design with modern connectivity ensures that the lessons from 60 years ago continue to inform today's supply chain challenges.

2.3 Mapping Tools in SCM

Supply chains have grown increasingly complex and global, making effective mapping tools essential assets for organisations looking to visualise, analyse, and optimise their supply networks. They have become increasingly vital as supply chains become laxer and more spread out. The COVID-19 pandemic underscored how a lack of end-to-end transparency can cripple supply networks, prompting companies to digitize processes for real-time insights. Modern supply chain mapping tools leverage technologies, ranging from sensors and geographic data to AI analytics in order to track products from suppliers to customers, visualize every link, and anticipate disruptions. These tools help organisations understand, analyse, and optimise their supply chains more effectively. (Deloitte n.d. & Cambridge Intelligence n.d.)

As defined by Gardner and Cooper (2003), supply chain mapping refers to creating visual representations of the relationships between all entities involved in producing and distributing a product or service. This encapsulates the essence of mapping tools, which help elucidate the often-unclear nature of supply chains. They significantly improve visibility across the supply chain, facilitate better stakeholder communication, and enhance decision-making processes by identifying potential risks and vulnerabilities.

Several types of mapping tools have gained prominence in the field of SCM. A prime example is Geographic Information Systems, which offer powerful tools that integrate geographical data with tabular data to map, analyse, and assess real-world problems (Delen et al. 2011). By placing supply chain data within a spatial context, GIS allows businesses to optimise transportation routes, identify geographical risk factors, and manage distribution networks more effectively.

These tools are precious for global supply chains where geopolitical or environmental risks may affect operations. An example of such an instrument is ArcGIS, developed by Esri, arguably the most used GIS tool in SCM. It provides advanced geospatial analytics for visualising supply chain networks, monitoring assets, and simulating different scenarios to evaluate risks. A 2021 systematic review identified that GIS is applied in SCM for route and transportation analysis, facility location selection, spatial demand analysis, integration with optimisation models, and real-time visualisation/monitoring (Tsakiridi 2021). In practice, GIS tools help answer strategic questions on cost minimization, supplier selection, site location, and network configuration by overlaying supply chain data onto maps (Tsakiridi 2021). GIS-driven mapping has become even more vital as companies emphasise resiliency and “what if?” scenario planning in their global logistics networks.

Another important example is value stream mapping, a lean management methodology, that has gained traction in this industry in recent years. Analysing the existing condition of a supply chain and creating a future state that minimises inefficiency and maximises value creation is the focus of this approach. As Forno et al. (2014) note, VSM enables organisations to understand the complete flow of materials and information, from raw materials to final delivery, helping them identify areas where resources are misused or where inefficiencies arise.

IoT and blockchain technologies have become pivotal for real-time supply chain mapping and transparency. The IoT refers to networks of physical sensors and devices that collect and transmit data, such as GPS trackers on trucks, RFID tags in warehouses, and temperature sensors in containers. By instrumenting shipments and assets, IoT enables continuous, live visibility into the movement and condition of goods. In logistics, IoT adoption has grown exponentially, giving companies the ability to monitor deliveries in real-time and track inventory with greater accuracy, thereby improving operational efficiency. For instance, sensors can report a container’s location and temperature every few minutes, and this data populates dashboards that visualise the entire supply pipeline in motion, with said becoming a new standard, not a luxury. (Döhrmann et al. 2024; Srhir et al. 2023; Oliynyk 2024)

Blockchain complements IoT by providing a firm, shared ledger for supply chain transactions and status updates. Each handoff or change of state check can be recorded as a blockchain transaction, for example, a pallet being loaded onto a vessel or a lot passing a quality check can be recorded as a blockchain transaction. The tamper-proof nature of blockchain builds trust among partners and ensures data integrity in these real-time maps (Sharma et al. 2025). Thus, using blockchain improves supply chain transparency and traceability while also reducing administrative overhead (Deloitte n.d.). In combination, IoT devices feed live data into blockchain-secured platforms, yielding an up-to-date, trustworthy visualization of the supply chain. One prominent example is the integration of IoT and blockchain in high-value supply chains, like in the case of diamonds: real-time sensor data is written to a blockchain, resulting in a secure, end-to-end view of the product's journey and custody (Sharma et al. 2025). Overall, IoT and blockchain together enable unprecedented visibility across all tiers of a supply chain.

Artificial Intelligence has started to revolutionise supply chain mapping by automating complex data analysis and enabling predictive insights. AI-driven mapping tools can ingest massive amounts of supply chain data, from ERP systems, IoT sensors, logistics events, and even unstructured documents, and then identify patterns or anomalies that are not evident to human planners. A significant benefit of AI in SCM is improved predictive analytics: machine learning models can forecast demand more accurately, predict transit time variations or flag likely disruptions, thus helping companies move from reactive to proactive planning. In fact, surveys indicate that supply chain management has seen some of the highest cost savings from AI adoption of all business functions, according to a study done by McKinsey in 2022. AI adds value to supply chain planning by refining production schedules, optimising inventory levels, and selecting more efficient shipping options based on predictive insights. (McKinsey 2022 & Alicke et al. 2022)

A prime example of a company revolutionising that space is the AI startup called Altana. They have developed a generative AI system that compiles data from public and private sources to create dynamic maps of global supply chains, automatically mapping a company's extended supplier network and even allowing natural-language queries about that map. In contrast, traditional supply chain maps often stop at first-tier suppliers. Still, new AI tools, such as the startup mentioned earlier, can map multi-tier supplier networks by intelligently mining data from shipment records, trade databases, and documents and, as a result, enable a dynamic, multi-tier supply chain map where hidden sub-suppliers are uncovered. Additionally, AI-driven document processing can digitise and link unstructured supply chain information (invoices, bills of lading, etc.), further enriching the digital map of operations. The outcome is that managers gain an interactive, intelligent map of their supply chain, coupled with predictive analytics that can simulate scenarios and answer “what if?” questions. (Cohen and Tang 2024 & Revell 2023)

A technology that combines most of the aforementioned tools is digital twins. They are a virtual replica of a physical object or system, in this case, a real-time digital mirror of an entire supply chain or a segment of it. Digital twin technology has emerged as a mapping tool beyond static models or basic simulations. By crunching data from IoT sensors, operational databases, and historical records, a supply chain digital twin can accurately mirror the actual supply chain network's real-time conditions and behaviours (Sengupta 2024). This live model connects all nodes and flows, such as suppliers, inventories, facilities, transport links, and customers, into a unified virtual environment. Businesses can monitor this virtual supply chain in real-time, run simulations of various scenarios, and analyse performance to spot bottlenecks or forecast disruptions before they happen (Sengupta 2024). In other words, the digital twin serves as a safe testbed: managers can pose questions like “What if demand spikes 30% next month?” or “What if we re-route shipments through a different port?” and observe outcomes in the twin without risking the real operation. This capability to test-drive ideas in silico is transforming supply chain design and risk management. A digital twin provides value through visualisation, diagnostics, prediction, and optimisation. All without direct interference in the physical supply chain (Döhrmann et al. 2024). Recent advances in sensor tech, cloud computing, and AI have greatly enhanced digital twins’ realism and accuracy, expanding their scope from individual machines to entire supply ecosystems (Döhrmann et al. 2024). For instance, companies can now maintain a live digital twin of a warehouse that tracks every pallet in motion or a twin of a global logistics network that updates with each shipment event. The digital twin of a supply chain essentially functions as a continuously updated simulation model, fed by real-time data, which can forecast future states, including inventory projections and transport ETAs (anyLogistix n.d.).

Industry adoption of supply chain digital twins is still emerging but accelerating; according to Döhrmann et al. of DHL (2024), the global supply chain digital twin market is valued at US $12.8 billion in 2024, with robust growth expected as more firms embrace this technology.

Since the beginning of 2023, there have been rapid advancements in supply chain mapping tools, driven by both technological progress and urgent industry needs for resilience. A clear trend is the integration of AI, IoT, and real-time analytics into unified “control tower” platforms. Instead of siloed tools, companies seek end-to-end visibility solutions incorporating live IoT feeds, AI-based forecasting, and even blockchain verification on one dashboard. This is exemplified by the proliferation of supply chain control towers and platforms offered by major tech providers (SAP, Oracle, IBM, AnyLogic Company, etc.), which combine mapping and analytics. In fact, leading enterprise software firms have all invested in digital twin and AI-driven supply chain mapping solutions, signalling strong industry backing (Sengupta 2024). These platforms often employ cloud-based data lakes to ingest all supply chain data and apply AI to generate a real-time digital model of the network. Another notable trend is the push for multi-tier transparency. Regulatory pressures for ethical sourcing, sustainability, risk management, and the lessons of pandemic disruptions have pushed companies to map deeper into their supplier networks. Innovative startups and data analytics firms are partnering with large manufacturers and retailers to illuminate hidden supply chain tiers using big data and AI. As mentioned, Altana’s generative AI mapping tool is one such 2024 innovation (Cohen and Tang 2024).

All in all, the aim is to democratise these gamified tools so that they can be used not just by data scientists but by everyday supply chain managers and planners. All these trends point toward a supply chain mapping environment that is more real-time, data-rich, predictive, and user-friendly than ever before. The convergence of technologies in this space is yielding powerful capabilities to manage supply chains proactively, which is an important development given the volatility and complexity of global logistics in recent years.

2.3.1 Traditional vs Gamified Mapping Tools

The evolution of supply chain mapping mirrors technological advancements. There has been a shift from static documentation methods to interactive and even game-like digital solutions designed to enhance understanding and decision-making (Arias-Vargas, Sanchis & Poler 2024). Traditional mapping approaches, such as those using flowcharts, value stream maps or basic GIS tools as discussed in section 2.3, excel at providing a clear, static snapshot of the existing supply chain structure and process flows. Their strength lies in documenting the current state simply and accessibly. However, these traditional tools often lack real-time data integration and interactive capabilities, making them prone to becoming outdated quickly and limiting their utility for exploratory analysis or scenario planning. Engagement beyond the core experts involved can also be challenging, as static diagrams may not inherently motivate broader participation or deeper learning about system dynamics (Capatina et al. 2024).

In contrast, gamified mapping tools leverage game design elements within non-game contexts, transforming the mapping process into an engaging, experiential activity (Arias-Vargas, Sanchis & Poler 2024). Often taking the form of simulations or interactive scenarios, these tools allow users to actively manipulate supply chain variables and immediately observe outcomes in a risk-free environment (Arias-Vargas, Sanchis & Poler 2024). Examples range from educational tools like the digital Beer Game that illustrates the bullwhip effect to specialised simulations designed to enhance supply chain resilience against disruptions or even gamified interfaces for operational tasks like warehouse picking, as detailed in section 2.2 (Arias-Vargas, Sanchis & Poler 2024; Martinez-Moyano 2024; Sterman n.d.; Wollenhaupt 2021).

The core strength of these gamified tools lies in their ability to promote significantly higher user engagement, motivation, and enjoyment (Capatina et al. 2024; Wollenhaupt 2021). This active participation facilitates deeper learning, better knowledge retention, and improved job performance compared to passively observing traditional maps (Capatina et al. 2024). Gamified simulations, specifically, provide a valuable platform for testing decision-making under various conditions, increasing awareness and preparedness for potential disruptions, and offering cost-effective, repetitive learning opportunities (Arias-Vargas, Sanchis & Poler 2024).

However, gamified approaches face challenges. Effective design is crucial; overly simplistic simulations may not reflect real-world complexities, while excessive complexity can deter users (Arias-Vargas, Sanchis & Poler 2024). Aligning game objectives and rewards with actual business KPIs is also essential to prevent users from merely "gaming the system" (Wollenhaupt 2021). Furthermore, concerns about increased employee stress or intrusive monitoring can arise, particularly in operational gamification (Wollenhaupt 2021). Developing sophisticated gamified mapping tools can be resource-intensive, and successful implementation often requires robust underlying processes and data systems (Wollenhaupt 2021).

Ultimately, the trend leans towards integrating the strengths of both approaches. Traditional mapping software increasingly incorporates interactive elements, while data from gamified simulations can inform static analysis. Gamification enhances supply chain mapping by making it a more engaging, insightful practice, potentially involving a broader set of people in understanding and improving complex global networks. While static maps remain vital for documentation, interactive and gamified tools are proving indispensable for dynamic analysis, training, and strategic planning in contemporary SCM (Arias-Vargas, Sanchis & Poler 2024; Capatina et al. 2024).

2.3.2 Industry Applications

In order to illustrate how these mapping tools come together in practice, one can draw inspiration from the approaches of companies like DHL & Maersk. Each operates a complex supply chain and has invested in advanced mapping and visualisation to drive efficiency and resilience.

DHL has been aggressively adopting digital twin technology and AI analytics to optimise its supply chain services. One notable initiative is DHL's digital twin of customer supply chains. DHL is developing a tool that creates a virtual copy of a customer's entire supply chain, which is used to run scenario analyses for optimisation. DHL's initial implementation of this technology was back in 2019 through a collaboration with Tetra Park in Singapore (DHL Group 2019). This location remains their only officially confirmed one that benefits from this technology. (te Lindert 2023)

Leveraging digital twins, DHL can simulate how shifting a distribution centre or changing transport modes (air vs sea) would impact both costs and carbon emissions before implementing changes in the real world. Carsten Lützenkirchen, DHL's SVP of Customer Solutions & Innovation, explained that with the digital twin, they aim to "...optimize and reduce transport flows", with a beta version being rolled out for customers to analyse and optimise their supply chains collaboratively with DHL. Katja Busch, CCO, added that achieving optimisation requires using "…data, algorithms and artificial intelligence", emphasising that the tool was developed closely with a warehousing customer. In practice, if a customer wants to achieve sustainability targets, the technology supports sustainability goals by modelling strategies like regional warehousing to shorten distance or alternative routing, quantifying emission reductions alongside cost trade-offs. They bolster supply chain resilience, enabling simulated stress tests against various disruptions. This complements their AI-driven risk monitoring via the Everstream Analytics platform, formerly Resilience360, while related digital concepts inform other DHL applications like warehouse heat maps and AR-assisted picking processes. (te Lindert 2023; Döhrmann, Gesing & Ward 2019; Döhrmann et al. 2024)

In the words of Döhrmann, Gesing & Ward (2019), when integrated with real-time IoT input, cloud infrastructure, and AI-driven analytics, digital twins serve as a "single source of truth" for decision-makers, offering a unified view of the supply chain to support accurate, fast, and collaborative responses to disruptions or optimisation opportunities.

Another prominent example is Maersk, one of the world's largest shipping and logistics companies, which has strategically prioritised digital mapping, by using AI for route optimisation and enhanced end-to-end supply chain visibility. In ocean shipping, where factors like weather, port congestion, and fuel efficiency necessitate complex routing decisions, Maersk implemented advanced digital solutions early on. Collaborating with ABB and MeteoGroup as early as the mid-2010s, Maersk developed and deployed an AI-driven advisory system across 140 of its container ships (VesselFinder 2015). This application functions as a dynamic map, integrating weather forecasts with specific vessel performance data to recommend optimal routes and visualise potential danger zones for captains, thereby improving safety and efficiency at sea (VesselFinder 2015).

Beyond ocean navigation, Maersk has significantly invested in integrated supply chain platforms that provide customers with comprehensive door-to-door visibility of their shipments. A prime example is Maersk’s NeoNav, a 4PL SCM solution that offers a “panoramic view” of end-to-end logistics (Maersk n.d.b). It facilitates a control tower perspective by consolidating data from multiple sources, including different platforms, players, and operational systems, allowing clients real-time access to container status and location alongside predictive insights (Maersk n.d.b). This end-to-end mapping capability is increasingly underpinned by AI, with Maersk actively partnering with technology firms to innovate in supply chain traceability and visibility. Internally, AI is also leveraged to streamline operations, such as predicting delays or optimising port loading sequences. This commitment is central to Maersk's vision of “zero touch” logistics, aiming for greater automation in planning tasks through extensive data collection and analysis from its network assets. The benefits manifest both externally, through improved customer service via live tracking and proactive communication, and internally, through enhanced operational agility and cost savings. In essence, Maersk utilises mapping tools across strategic (AI-optimised global routing) and tactical (integrated shipment visibility) levels, reinforcing its position as one of the leaders in digital logistics transformation. (Maersk 2023)

These examples from DHL and Maersk illustrate the significant investments major logistics players are making for the future of this field, ranging from digital mapping and AI-driven optimisation to gaming and gamification.

2.4 Gaming and SCM

Gaming has become a massive cultural and economic phenomenon in recent years. In 2023 alone, the video game industry reached a worldwide market value of roughly 184 billion dollars, with over 3.2 billion people playing games across the globe (International Trade Administration n.d.). Gaming is especially prevalent among younger generations; over 80% of internet users aged 16-44 play video games on some device (Clement 2024). In other words, the omnipresence of gaming amongst the youth underlines a certain level of familiarity with such mechanics. Thus, saying that these people are accustomed to real-time feedback, intuitive heads-up displays, levelling systems, and achievement badges that games provide. This means that expectations and habits are increasingly relevant beyond entertainment, carrying over into how young professionals learn new skills and engage with technology.

Furthermore, this synergy between gaming culture and logistics is visible in high-profile marketing and recruitment efforts. Large logistics companies increasingly establish strategic partnerships within the eSports industry to reach younger, tech-literate audiences. Since 2018, DHL has been the official logistics partner of ESL Gaming, later ESL FACEIT Group, providing transportation and logistics support for major tournaments like ESL One and Intel Extreme Masters. This partnership extends beyond logistics services, incorporating interactive content and fan engagement activities that have reached millions of viewers across various platforms (DHL Group 2021). In addition, DHL has leveraged these eSports partnerships for targeted marketing and recruitment, resulting in over 10000 job applications since 2022 (DHL Group 2024). Similarly, in 2022, Maersk entered the eSports sector through a partnership with BLAST Premier, a Danish-based global eSports tournament organiser, as part of its strategy to embrace digital innovation and connect with a younger, eSports-engaged audience (Blast 2023). Maersk's career website encourages applicants who are passionate about eSports to explore opportunities with Maersk, highlighting the company's collaboration with BLAST Premier (Maersk n.d.a). This is despite Maersk starting with the 2024 season no longer sponsors their whole circuit, but rather only specific tournaments.

This deep familiarity with such digital environments means that expectations shaped by gaming naturally extend into professional settings, influencing how younger employees engage with workplace technology and training. The psychological appeal is strong, rooted in elements like instant feedback, the potential for “flow” or deep concentration, and the inherent motivation derived from progressive difficulty and achievement (Monahan et al. 2016). Recognising this, developers of business software are starting to incorporate these game design principles more and more, enhancing standalone training simulations, as discussed in section 2.2, but also to improve user engagement with operational systems. In the SCM industry, a sector undergoing digital transformation as well as facing challenges with employee turnover and skill retention, companies are discovering the potential of gamified interfaces to make complex processes, employee training, and daily operations more intuitive and motivating (Wollenhaupt 2021). Applying established game elements within traditionally non-game contexts, such as warehouse management systems, transport management systems or driver applications, can facilitate onboarding, sustain engagement, and build skills through active, feedback-driven learning, effectively offering a form of experiential practice in a safe, simulated context, while also tapping into the natural need for competence and autonomy (Deci & Ryan 1985; Monahan et al. 2016; Luarn et al. 2023). Creative implementations might include “secret” badges for unexpected achievements or tiered, resetting leaderboards to maintain competition fairness and motivation, such as in the case of Deloitte (Joy 2018).

Furthermore, companies adopting gamified learning report significant improvements. Deloitte, for example, documented a 37% rise in weekly returning users for its gamified Leadership Academy (Joy 2018). Gamification can also reduce boredom and increase workplace happiness (Carstarphen 2022). Beyond training or direct operational enhancement, the concept extends to "productivity games", where mechanics motivate participation in necessary work tasks that leverage human computation (Smith & Bean 2013). Such outcomes are particularly valuable for logistics firms needing to rapidly onboard staff and reinforce critical skills effectively in a dynamic operational environment.

While these examples illustrate gamification’s growing presence in both SCM and workforce development, much of the current focus remains concentrated on training and employee engagement. As companies experiment with gamified tools to improve recruitment, retention, and operations, the broader academic conversation has only partially kept pace. In particular, there is still limited research examining how gamification might be strategically embedded into supply chain management systems themselves. However, while the general benefits of gamification are increasingly recognised, the specific potential of utilising gamified mapping tools to address complex decision-making and risk management challenges within global supply chains represents a developing area in the literature.

3 THEORETICAL FRAMEWORK

3.1 Gamification Theory

Gamification is commonly defined as the use of game design elements in non-game contexts to engage and motivate people (Merriam-Webster n.d.). In essence, it means taking features people recognise from games, such as points, rules, challenges, and feedback, which are then applied to real-world activities. For example, one scholarly definition describes gamification as "a process of enhancing services with (motivational) affordances in order to invoke gameful experiences and further behavioural outcomes" (Huotari & Hamari 2012; Hamari 2013; Hamari, Koivisto & Sarsa 2014). Key contributors in this field, such as Sebastian Deterding and Juho Hamari, helped formalise this concept in the early 2010s, grounding it in established psychological theories.

A fundamental part of gamification theory is that it works by appealing to basic human motivators (Rutledge et al. 2018). A well-known motivation model often used to explain why gamification can be effective is Self-Determination Theory (Deci & Ryan 2008; Rutledge et al. 2018). It asserts that people are driven by needs for competence (mastery of tasks), autonomy (control over choices), and relatedness (connection with others) (Deci & Ryan, 2008). Gamified systems try to satisfy these needs. For instance, when a task is redesigned to feel more like a game, users might feel more competent as they achieve goals, more autonomous as they make meaningful choices, and more connected through competition or collaboration (Rutledge et al. 2018). By aligning with these innate motivators, gamification aims to turn what might be mundane or challenging tasks into engaging experiences that people want to participate in, rather than feeling they must.

To put gamification into practice, designers employ a variety of core game mechanics (Sailer et al. 2017). These are the building blocks of games, such as the points one scores, the levels they progress through, the badges or trophies they earn or the leaderboards where one compares their performance with others (Deterding et al. 2011; Sailer et al. 2017). Such mechanics provide continuous feedback and incentives (Sailer et al. 2017). Research has shown that these elements can indeed influence user behaviour and motivation in measurable ways (Sailer et al. 2017). For instance, one study done by Sailer et al. (2017) found that adding features like badges and leaderboards to an online system boosted users' sense of competence and perceived task meaningfulness. At the same time, narrative themes and team challenges enhanced their sense of social relatedness (Sailer et al. 2017). Points, badges, and leaderboards are among the most commonly used mechanics (Sailer et al. 2017; Werbach & Hunter 2012). Points serve as an immediate reward and progress indicator for completing activities; badges symbolise achievements or milestones reached; and leaderboards introduce a competitive ranking, tapping into the human drive for status and recognition (Sailer et al. 2017; Werbach & Hunter 2012). Feedback loops are also crucial, as users see their progress, such as through points climbing or new badges earned, they receive a steady sense of accomplishment and an indication of how they are doing, which in turn encourages further participation (Sailer et al. 2017). These game mechanics are not arbitrary add-ons but carefully chosen tools to trigger positive psychological responses (Deci & Ryan 2002; Sailer et al. 2017). For example, completing a task might award points along with instant feedback (e.g. "Great job, you scored 100 points!"), which reinforces the behaviour and makes the user more likely to repeat it (Sailer et al. 2017). Over time, these mechanics can guide users through a series of actions in a manner that feels enjoyable or at least satisfying, thereby supporting the underlying objectives of the system, be it learning, working, or, as in this case, managing a supply chain (Sailer et al. 2017).

Beyond individual mechanics, gamification frameworks provide structured approaches to designing gamified systems. As seen in Appendix 18, One widely recognised framework is Yu-Kai Chou's Octalysis model, which breaks down user motivation into eight core drives and maps them in an octagon shape. The Octalysis framework systematically organizes gamified elements according to these drives, and it has become one of the most famous tools for influencing user behaviour through game-like design. The popularity of this framework in industry and academia underlines the importance of understanding why certain game elements work. It is not just about adding points or badges but about addressing the deeper motivational core drives that make those elements meaningful to people. (Chou 2016; Mohanty & Christopher 2023; Rutledge et al. 2018)

Furthermore, other frameworks, such as the Mechanics-Dynamics-Aesthetics from game design research, offer a lens to think about how rules (mechanics) lead to system behaviour (dynamics), which in turn creates emotional responses (aesthetics) in players (Costa et al. 2017; Mohanty & Christopher 2023). In gamification, a similar line of thought is used, meaning that designers consider how the rules and rewards they implement will lead to certain user behaviours and experiences (Hamari et al. 2014; Mohanty & Christopher 2023). A consistent lesson from the literature is that gamification is not a magic bullet; simply adding a leaderboard to a complex task will not automatically make it fun, but when grounded in sound psychological principles and well-designed game mechanics, it can significantly enhance motivation and participation. (Deci & Ryan 2008; Hamari et al. 2014; Mohanty & Christopher 2023; Rutledge et al. 2018)

Gamification theory provides a toolkit and a scientific basis for injecting game-like engagement into real-world processes, which could be leveraged in the context of global supply chain decision-making.

3.2 Supply Chain Management Theory

Supply Chain Management, in its most basic form, deals with the flow of goods, information, and finances as products move from raw materials to end customers. It encompasses everything from planning and sourcing to production, logistics, and even returns. A widely accepted definition from the Association for Supply Chain Management, formerly APICS, describes SCM as “the design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronising supply with demand, and measuring performance globally” (ASCM 2024, 191). In simpler terms, SCM is about coordinating all the steps and partners involved in delivering a product or service in a way that optimises efficiency and customer value. Classic supply chain theory frames these activities on three levels. Those beings: strategic (long-term decisions), tactical (medium-term), and operational (day-to-day).

Over the years, various models and standards have been developed to guide supply chain professionals. One of the most prominent is the Supply Chain Operations Reference model, initially developed by the Supply Chain Council (now part of ASCM) in 1996 (APICS 2017; Huan, Sheoran & Wang 2004). The SCOR model serves as a strategic planning tool that helps managers simplify and standardise the complexity of supply chain management (Huan, Sheoran & Wang 2004).

SCOR provides a unique framework and common language by linking business process, metrics, best practices and technology, categorising supply chain activities into six core process types: Plan, Source, Make, Deliver, Return, and Enable (APICS 2017; Vegter, van Hillegersberg & Olthaar 2020). By describing supply chains using these process building blocks, the model can be used to describe supply chains that are very simple or very complex using a standard set of definitions (APICS 2017). By mapping any company's supply chain within these process categories, SCOR makes it easier to analyse performance, identify weak points, and benchmark against industry standards (APICS 2017; Huan, Sheoran & Wang 2004).

Given its comprehensive approach, SCOR has become a de facto standard framework in the field, as people within the industry and academics alike consider it an indispensable reference for supply chain analysis and improvement (Huan, Sheoran & Wang 2004; Vegter, van Hillegersberg & Olthaar 2020). It is firmly rooted in industry practice and has evolved over time (through revisions by APICS) to include modern concerns like sustainability and risk (APICS 2017; Huan, Sheoran & Wang 2004).

A key strength of the SCOR model is its direct linkage of defined processes to key performance metrics. For each process, SCOR outlines performance attributes such as reliability, responsiveness, agility, cost, asset management efficiency, and specific metrics, such as order fulfilment rate, cycle time or supply chain flexibility index (APICS 2017). This linkage of processes to metrics displays a core tenet of SCM theory, which states that you cannot manage what you do not measure. By measuring performance globally across the supply chain, managers can make educated decisions to optimise the whole system, not just individual parts (APICS 2017; ASCM 2024; Huan, Sheoran & Wang 2004).

3.2.1 Risk Management in Supply Chain

Two fundamental concepts in SCM theory are optimisation and risk management (Huan, Sheoran & Wang 2004; Jodlbauer et al. 2023). The former is about finding the best possible way to design or operate the supply chain under given constraints. Since the 1950s and 60s, researchers have applied operations research and mathematical modelling to supply chain problems, ranging from the classic economic order quantity model for inventory to linear programming models for network design to complex algorithms for vehicle routing and scheduling (Huan, Sheoran & Wang 2004). These models help answer questions like: “How much of each product should a factory make and when, to minimise costs and meet demand?”, “Where should a company locate its warehouses to balance delivery speed against overhead cost?”, “What is the optimal transportation plan to distribute goods to stores?”. By formulating such problems mathematically, one can compute solutions that achieve a provable level of optimality or at least near-optimality. In practice, supply chain optimisation means better asset utilisation, shorter lead times, and lower operating costs. All of these factors contribute to a more competitive and resilient supply chain. However, real-world complexities, such as uncertain demand or lead times, and multiple objectives often mean no single optimal solution. Instead, there is a need to adjust and improve continuously. This is where decision-making comes in. Supply chain managers must constantly make decisions that trade off various performance metrics. Frameworks like SCOR assist by structuring those decisions and highlighting the relevant metrics, but human judgment and experience still remain critical, especially in strategic choices or in responding to unexpected events (Huan, Sheoran & Wang 2004; Jodlbauer et al. 2023).

Risk management has become an increasingly prominent pillar of SCM theory, especially in the last two decades (Jodlbauer et al. 2023). Global supply chains face many risks, ranging from natural disasters, supplier failures, demand shocks, and geopolitical events (Jodlbauer et al. 2023) to more recent occurrences like pandemics. Supply chain risk management is the systematic process of identifying, assessment, and prioritization of risks followed by coordinated and economical application of resources to minimize, monitor, and control the probability and impact of unfortunate events (ASCM 2024). The goal is to anticipate potential disruptions and put measures in place to either prevent them or minimize their impact (ASCM 2024; Jodlbauer et al. 2023). The theory behind SCRM borrows concepts from risk management in finance and engineering but adapts them to multi-organizational supply networks. It involves mapping out the supply chain to identify critical nodes and vulnerabilities, quantifying the likelihood and severity of different risk events, and then deciding on mitigation strategies (ASCM 2024; Jodlbauer et al. 2023). These strategies might include building buffer stocks of inventory (safety stock), qualifying multiple suppliers for important materials (multi-sourcing), diversifying transportation routes or even redesigning products to be less reliant on at-risk components (ASCM 2024). A key insight of supply chain theory is that efficiency (e.g. lean, just-in-time operations) must be balanced with resiliency (the ability to absorb shocks) (Jodlbauer et al. 2023). For instance, while keeping inventory low is cost-efficient, a completely lean supply chain might break down if there's an unexpected surge in demand or a delay in supply. Therefore, decision-making in SCM often involves scenarios and contingency planning (APICS 2017; ASCM 2024). Managers ask "what if?" questions and use both qualitative judgment and quantitative models to prepare responses. Modern developments in SCM theory also emphasize the ability to respond quickly to changes, also known as agility, as a form of risk mitigation (APICS 2017; Jodlbauer et al. 2023). An agile supply chain is designed to adapt swiftly rather than optimize for a single steady-state solution (ASCM 2024).

3.2.2 Importance of SCM Theory

SCM theory provides a comprehensive foundation for understanding how complex supply networks function and how to manage them. It combines structured frameworks, like SCOR and APICS guidelines with analytical models for optimization and robust approaches for managing uncertainty and risk (APICS 2017; ASCM 2024; Huan, Sheoran & Wang 2004; Jodlbauer et al. 2023). This theoretical backbone will support the exploration of how gamification and mapping can be applied to supply chain decision-making, by clarifying what needs to be optimised and what risks and metrics must be considered in a global supply chain context.

3.2.3 Logistics and Transportation Management

Within Supply Chain Theory, one of their core components are logistics along with transportation management, which are a subset of supply chain management. They involve the planning, coordination, execution, and control of the movement, handling, and storage of resources from origin to destination to meet customer requirements (Association for Supply Chain Management 2024, 107, 191, 202). Beyond this foundational role, the field must grapple with high complexity and uncertainty in global operations. People within the field effectively play a “strategy game” against real-world conditions: they have to make decisions with incomplete information, unpredictable events, and constrained resources. Keeping goods flowing under such conditions demands resilience and an ability to navigate pervasive complexity and turbulence. Effective logistics and transportation management are critical for global supply chains, as they directly link supply with demand across geographies. Drljača and Sesar (2023) note that the transportation process literally connects all phases of the supply chain, meaning that without transportation, no supply chain activity can proceed.

A well-managed logistics system enables firms to achieve cost-efficient and reliable delivery performance, which is a central goal in global supply chain optimization. In practice, logistics management involves carefully balancing service levels (e.g. speed, reliability of delivery) against costs (transportation, inventory, warehousing). Transportation tends to be the single largest logistics cost component, often accounting for over half of total logistics expenditures. For instance, industry analysis indicates transportation constitutes roughly 58% of total logistics costs globally. This makes transportation decisions a prime target for optimization, as even small improvements can yield significant cost savings. At the same time, transportation performance heavily influences customer service. A faster, more dependable shipments improve customer satisfaction but typically at higher cost. Thus, logistics theory emphasizes trade-offs: managers must design networks and choose transport modes that meet required service levels at minimal total cost. The use of analytical tools and advanced logistics, lean management, and optimization methods helps achieve efficient, cost-effective, and even sustainable supply chains. In essence, logistics management takes a total cost approach, coordinating transportation, inventory, and facility decisions so that the overall supply chain cost-service position is optimized rather than sub-optimizing individual elements. (Rodrigue 2024; Global Supply Chain Institute at the University of Tennessee 2020)

Fundamental trade-offs are central to logistics theory and dictate strategic and tactical decision-making in global operations. The first trade-off, Cost vs Service Level, illustrates that achieving higher customer service (e.g. faster delivery or more reliable transit) often raises costs. For example, choosing air freight or maintaining more distribution centres can shorten lead times but incurs greater transport and facility cost. Firms may pay a premium (such as higher rent for a warehouse near an airport or port) to reduce transit time, illustrating the classic trade-off between logistics cost and responsiveness.

The second major trade-off is between Efficiency (Lean) vs Redundancy (Resilience). Streamlining the logistics network for efficiency (e.g. reducing buffer stocks, using a single carrier or hub to maximize scale economies) lowers day-to-day costs but can make the supply chain less resilient to disruptions. Conversely, building in redundancies, such as alternate transport routes, multiple suppliers or extra capacity, improves the ability to absorb shocks at the expense of higher operating costs (Pettit, Fiksel & Croxton 2010). For example, a lean logistics strategy with sole-source transportation or minimal spare capacity may crack when unexpected port closures or demand surges occur, whereas a more flexible strategy can adapt effectively.

These trade-offs also relate to global network design decisions. At the strategic level, companies must decide how to structure their worldwide logistics networks, like how many warehouses or distribution centres to operate, where to locate them, and which transportation modes to use for global freight flows. Such supply chain network design decisions are foundational in logistics management, as they determine the long-term cost and service capabilities of the supply chain. In particular, facility location choices “play a critical role in the strategic design of supply chain networks" by defining the layout of sourcing and distribution links (Melo, Nickel & Saldanha-da-Gama 2009). A more centralized network (fewer, larger distribution hubs) can minimize inventory and facility costs, but typically lengthens transport distances and lead times to far-flung markets. Conversely, a decentralized network with regional warehouses closer to customers improves responsiveness and reduces shipping times, at the cost of higher facility and handling expenses. Global firms must calibrate these factors based on their service commitments, product characteristics, and market dispersion. Additionally, modal selection is a strategic consideration (e.g. air, sea, rail or truck), because each mode offers a different balance of transit time, capacity and cost. High-value or perishable goods may justify expensive air freight to ensure rapid delivery, whereas bulk commodities move via slower ocean or rail to save cost. The network design and mode choices also have implications for sustainability and risk. An example of that is relying on ocean shipping minimizes cost but exposes the supply chain to port delays and geopolitical risks, whereas multimodal solutions can provide backup options. Supply chain planning models integrate location decisions with transportation decisions, recognizing that the optimal logistics performance emerges from jointly planning these elements rather than treating them in isolation (Melo, Nickel & Saldanha-da-Gama 2009). By iterating scenarios (for instance, comparing the cost-service outcomes of a centralized vs. regional distribution structure), planners can quantitatively assess trade-offs and thus make informed strategic decisions.

At the operational and tactical levels, logistics and transportation management focuses on execution and continuous optimization of the flow of goods. This includes route planning, scheduling shipments, managing carriers, and real-time tracking of goods in transit. Transportation managers strive to maximize asset utilization (e.g. truckload fill rates, container utilization) while meeting delivery deadlines and coping with day-to-day variability (traffic, weather, customs clearance, etc.). In global supply chains, operations must also navigate complex international regulations and cross-border procedures. Differences in national infrastructure and customs processes mean that moving goods globally involves additional uncertainty and coordination effort. In fact, the World Bank's Logistics Performance Index, which ranks countries on factors like customs efficiency, infrastructure quality, and shipment timeliness, highlights significant variability in logistics environments worldwide. Developed economies tend to have streamlined border processes and better transport infrastructure, enabling more predictable flows, whereas emerging markets may pose challenges (e.g. port congestion, bureaucratic delays) that logistics managers must plan for. Effective global logistics management therefore requires building some slack or agility to handle these international frictions. (Kostoulakos 2023; Arvis et al. 2023)

To cope with the inherent complexity of logistics decision-making, companies increasingly implement advanced technologies and analytical tools. Digitization of logistics has given rise to powerful platforms such as Transportation Management Systems and digital supply chain “twins”, which provide real-time visibility and decision support. Döhrmann, Gesing and Ward (2019) describe how digital twins serve as a “single source of truth” for decision-makers by offering a unified, real-time view of the supply chain and enabling fast, collaborative responses to disruptions or optimization opportunities. For example, if a sudden transport network disruption occurs (such as a closed border or natural disaster), a digital twin system can immediately simulate alternative routes or re-routing of inventory, allowing managers to evaluate options virtually before implementing changes on the ground.

3.2.4 The Role of Gamification and Simulation in Logistics

In a related vein, researchers and people within the industry have shown growing interest in gamified simulations and scenario-based planning for logistics. Borrowing principles from gaming, serious games and simulation tools create interactive environments where logistics professionals can practice decision-making and explore “what if?” scenarios in a risk-free setting. Recent studies in logistics education find that serious game simulations are effective for integrating theoretical knowledge with practice, and they help develop key competencies such as problem analysis and decision-making under uncertainty (Rzezczycki, Chrząstek & Niemcewicz 2024). This suggests that gamified mapping and planning tools could likewise be applied in professional logistics management to improve strategic and tactical decisions. For instance, a logistics manager could use a gamified scenario tool to virtually test different transportation strategies (routing choices, mode mix, etc.) under various demand or disruption scenarios, receiving immediate feedback in the form of costs, service outcomes, and even competitive "scores". By making the complex trade-offs of logistics more transparent and engaging, such gamified mapping approaches may enhance learning and innovation in supply chain planning. They build on established academic theories, such as logistics trade-offs and network optimization, but package them in interactive, user-friendly formats that encourage experimentation.

Logistics and transportation management provides the operational backbone of global supply chains, and its theoretical foundations (cost-service trade-offs, network design, and optimization under constraints) are increasingly augmented by digital and gamified tools. Grounded in these theories, gamified mapping techniques can offer a new way to optimize global logistics by enabling the possibility to simulate, visualize, and improve supply chain decisions (Rzezczycki, Chrząstek & Niemcewicz 2024). This alignment of logistics management theory with modern, engaging decision-support tools holds significant promise for advancing global supply chain optimization.

3.3 Mapping in Decision Making

The mapping aspect of these modern decision-support tools, as highlighted in the context of logistics, plays an important role in broader supply chain decision-making. Supply chains are inherently spatial and networked. They consist of facilities linked by transportation routes across regions and countries. Visualising these networks on a map or diagram helps decision-makers grasp the big picture of operations and the flow of goods. As global supply chains grew more elaborate, scholars noted that human managers struggle to comprehend all the moving parts and their interdependencies unaided. Large-scale systems can exhibit non-linear behaviour. For instance, small changes have substantial effects down the line, with feedback loops causing oscillations like the well-known bullwhip effect. The human cognitive limits mean they are not naturally equipped to predict how a disruption in one corner of the world will ripple through a supply chain. This is where mapping and visualisation come in. By translating data into a visual form, whether it is a geo-map, a process flow chart or a dashboard, individuals leverage the brain's strength in pattern recognition. As one analysis put it by Lind et al.

(2024), supply chains are so complex that independent, siloed decisions often lead to suboptimal outcomes, but with a *"comprehensive, system-wide view"* provided by a true-to-life model, one can better foresee consequences and coordinate actions.

In other words, mapping the supply chain helps create a common frame of reference, enabling more coherent and informed decision-making. Visualisation tools and techniques, ranging from simple Gantt charts of shipment timelines to advanced network graphs of multi-tier supplier relationships, serve as decision support by making abstract data concrete and highlighting aspects such as bottlenecks, high-risk nodes or real-time shipment delays.

Integrating gamified simulation into mapping elevates this decision support to a more interactive and analytical level. For the purpose of this thesis, "gamified mapping" often refers to leveraging map-based simulations, like digital twins, enhanced with game mechanics for engagement and learning. These tools combine the rigorous modelling of simulation with engaging game elements, creating a safe "sandbox" for strategy exploration. Researchers note a growing interest in such serious games for logistics planning, as they allow for people to practice decision-making and explore "what if?" scenarios in a risk-free setting. This approach aligns with gamification theory, where elements like interactive control and immediate feedback can enhance user motivation by appealing to intrinsic needs for competence and autonomy (Deci & Ryan 2008; Rutledge et al. 2018). Recent studies, such as the one of Rzezczycki, Chrząstek & Niemcewicz (2024) or the ones commissioned by the U.S. Department of Defense, via the Acquisition Innovation Research Center, have indeed found that simulation-based games can effectively bridge theoretical knowledge and practice in SCM, building key skills like problem analysis and decision-making under uncertainty.

In a gamified mapping platform, managers can visualize risk scenarios and resource allocations dynamically (Deghedi 2023). For instance, a user might virtually enact a disruption (e.g. a port closure or supplier failure) on a digital twin of the supply chain and observe how inventory and service levels are affected. This kind of scenario planning is enhanced by immediate feedback loops, a core game mechanic, allowing a logistics manager test different transportation or inventory strategies under varying conditions and instantly see the impact on costs, lead times, and service levels. By making the complex trade-offs inherent in SCM more transparent and allowing experimentation, such tools support more informed strategic and operational decisions. Crucially, they encourage a proactive approach to risk. People in positions of decision making can identify vulnerabilities and rehearse responses to disruptions before they happen, rather than reacting in the moment. (Lind et. al 2024; Döhrmann, Gesing and Ward 2019; Rzezczycki, Chrząstek & Niemcewicz 2024)

3.3.1 Experience Learning in Gamified Mapping via Video Games

A compelling case of gamified mapping in action is the use of Factorio as a supply chain simulation tool. Factorio is a manufacturing simulation game, originally developed for entertainment by Wube Software, that allows users to collect resources, build factories, and design automated production systems in a virtual world. In essence, it provides a map-like factory environment where players must manage workflows and constraints, which can then aid in illustrating supply chain concepts. Boardman and Krejci (2021) documented an academic application of Factorio for production and inventory control training, using the game to demonstrate production line design, inventory management policies, and the theory of constraints. In their study, a small virtual assembly line in Factorio was created to serve as a visual simulation of cause-and-effect relationships in a production system. Students could watch how changes in one element (e.g. work-in-process limit or machine speed) impacted other metrics like throughput and cycle time in real time. This interactive mapping of the factory helped to verify optimization algorithms taught in class and made abstract concepts, like Little’s Law, more concrete. Notably, the game environment allowed learners to qualitatively view the entire system before delving into calculations. Thus, mirroring the way expert problem-solvers mentally model systems prior to making quantitative decisions. The Factorio module was well-received, with students engaging in the “learning-by-doing” aspect of the game and strengthening their understanding of inventory. While focused on a factory setting, this case proves to be an example of how gamified mapping tools can act as an instance of supply chain networks, where theory is put into practice through decision simulation. (Boardman and Krejci 2021)

Mapping therefore, plays a role in supply chain decision-making by converting complexity into a more comprehensible form. When enhanced with gamified simulation, these tools become powerful platforms for strategic and operational decision support, applicable not only within manufacturing but also to broader challenges like global logistics network design or multi-tier supplier risk visualization. They enable risk analysis, resource allocation testing, and scenario planning in an immersive, engaging way that traditional charts or spreadsheets cannot easily match. By engaging decision-makers in an interactive model of their supply chain, gamified mapping tools help build intuition and insight, tapping into motivational drivers outlined in gamification theory and ultimately leads to better-informed decisions in the real world (Rzezczycki, Chrząstek & Niemcewicz 2024). This alignment of advanced visualization with decision theory and systems thinking principles holds great promise for optimizing global supply chain management in both educational and professional settings.

3.4 Conceptual Framework for Gamified Mapping in SCM

Bringing the above elements together, this section outlines a conceptual framework that merges gamification principles with mapping technologies for supply chain management. The aim of this framework is exploratory and to propose how “gamified mapping” can enhance decision-making in global supply chains by leveraging human motivation alongside advanced digital tools. In essence, the framework suggests that if one takes a rich visual model of a supply chain (like a digital twin or GIS-based dashboard) and embed game-like features into it, they could increase user engagement, learning, and ultimately optimise decision outcomes. This idea is inspired by known models in both gamification and SCM. On the gamification side, using the approach described by Hamari, Koivisto & Sarsa (2014), who conceptualize gamification as having three components: (1) the implemented motivational affordances (game elements added to a system), which lead to (2) certain psychological outcomes for the user (such as enjoyment, engagement, a sense of achievement), which in turn drive (3) behavioural outcomes (the user’s actions or performance).

On the SCM side, the framework aligns with established supply chain models and principles that emphasize holistic visibility and measurable performance. The affordances are the gamified features within the mapping tool, the psychological outcomes are the increased motivation and clarity the decision-maker experiences, and the behavioural outcome is better decision-making. For example, choosing a more efficient shipping route or responding faster to a disruption. The framework is informed by the process-oriented view of models like SCOR. This approach recognizes that any supply chain solution must align with core processes (Plan, Source, Make, Deliver, Return, Enable) and performance metrics. Thus, the framework ensures that the gamification elements are not just for fun, but are tied to real supply chain objectives, like reducing lead time, improving service level, cutting cost or mitigating risk. In fact, one can think of this gamified system as a layer on top of a SCOR-style map: the underlying structure shows the supply chain flows and KPIs, and the gamification layer highlights those flows and KPIs in an interactive, user-centric way. By integrating these perspectives, the proposed model draws inspiration from both a gamification model (focusing on user motivation) and a supply chain model (focusing on process and performance), effectively creating a hybrid that leverages the strengths of each. This integration is also reminiscent of approaches in serious gaming and simulation used in operations management education. For instance, the famous Beer Distribution Game is essentially a gamified simulation of a supply chain, which for decades has been used to teach managers about complex concepts like the bullwhip effect through active participation (Alabdulkarim 2020). The framework seeks to translate a similar idea into a decision-support context: using game elements not just to educate, but to actively guide and improve real decisions in real time.

Building on both the motivational (gamification) and analytical (SCM mapping) foundations, the conceptual framework, as seen in Figure 1, is structured into three integrated layers that together could enhance decision-making:

1. **Supply Chain System Layer:** This base layer represents the actual supply chain system. It includes all of its entities (suppliers, factories, warehouses, transport links), processes (e.g. Plan, Source, Make, Deliver, Return as per SCOR), and data flows. It encapsulates the complex real world

conditions, constraints, and performance measures of a global supply chain. In essence, it is the source of truth about how the supply chain operates, providing the content that needs to be visualised and manipulated for decision support. Any changes or scenarios explored in the framework ultimately refer to changes in this underlying system.

2. **Mapping/Digital Twin Layer:** The second layer is a digital twin or mapped simulation of the above supply chain system. Here, the physical supply chain is mirrored in a virtual environment, combining data visualization with simulation capabilities. This layer translates the complexity of the supply chain into a user-friendly, interactive model (a “single-player sandbox” of the network). It offers a common frame of reference by displaying facilities, inventory levels, shipment routes, etc., and allows users to run simulations (e.g. a facility shutdown, demand surge or transport delay) to see projected impacts on key metrics like service level or cost. By supporting real-time feedback and thousands of “what if?” scenarios computationally, the digital twin layer allows for spotting patterns in system behaviour and evaluate alternative strategies rapidly (Tozanli & Sáenz 2022). In short, this layer provides the visibility and analytical engine of the framework. Similar to a traditional supply chain control tower, but with enhanced interactivity.

3. **Gamification Layer:** The top layer introduces game design elements and user interaction mechanisms onto the mapping layer. Its purpose is to harness human motivation and engagement, drawing on Self-Determination Theory, to turn the digital twin into a learning-by-doing decision environment. This layer adds features such as clear goals or challenges (e.g. “minimize total cost under a disruption scenario”), rules and constraints (mirroring real SCM policies or physical laws), immediate feedback on actions (visual and numeric feedback whenever the user adjusts something), and even progress mechanics (levels, scorecards or scenario achievements). These motivational resources are designed to produce positive psychological outcomes for the user (e.g. heightened engagement, a sense of control and achievement) which in turn drive behavioural outcomes like proactive decision-making and deeper exploration of scenar-

ios. In practice, the gamification layer might present the user with an interactive scenario on the digital twin and incentivise them to experiment with solutions by scoring their performance or providing real-time risk indicators. The result is an immersive serious game for supply chain management, where the player's decisions in the game correspond to strategic or operational choices in the real supply chain model. This playful yet purpose-driven interface encourages repeated use, collaboration (if multiplayer features are included), and continuous learning, effectively making complex decision exercises more approachable and rewarding.

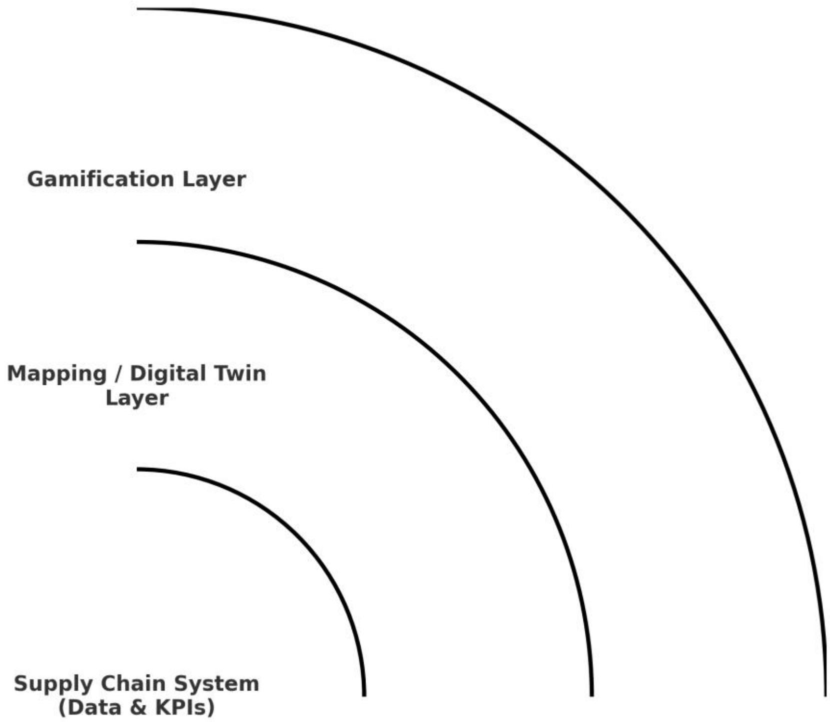

Figure 1. The Gamified Mapping Framework.

In the proposed framework (Core-Middle-Shell), the three layers work together in order to enhance decision-making. The supply chain system layer provides the factual and structured foundation (the "hard data" and processes to manage). The mapping/digital twin layer acts as the bridge, rendering those facts into an explorable model. In this layer, the systems' thinking is activated, as users can visually trace interdependencies and figure out what might happen next by simulating different scenarios. The gamification layer then covers this model with an engaging problem-solving context, guiding users through challenges and reinforcing learning outcomes via feedback and rewards, acting as a motivational shell for the user.

A light example of this integrated approach can be seen in the use of Factorio as a supply chain learning tool. Boardman and Krejci (2021) found that a custom Factorio scenario allowed students to visualize production workflows and verify inventory algorithms in real-time, making abstract concepts like throughput and Little's Law more concrete. The game environment's bird's-eye view and interactive controls gave participants unprecedented visibility into system-wide interactions and built their analytical capabilities in a sandbox setting. In a similar fashion, this framework puts forward that a gamified mapping platform would grant supply chain professionals a holistic view of their network and the ability to safely experiment with decisions. Thereby cultivating intuition and expertise.

In short, the conceptual framework attempts to show that gamified mapping tools serve as an effective mediator between human decision-makers and the complexity of global supply chains. By leveraging a rich digital twin (for accuracy and analysis) together with gamification (for engagement and skill-development), such a system can drive better decisions through enhanced user motivation, clearer system visibility, and iterative learning.

4 RESEARCH METHODOLOGY

4.1 Research Design

This study adopts a mixed-methods research design with an emphasis on qualitative analysis to fully understand how gamified mapping tools can enhance decision-making in global supply chains. The overall approach is exploratory and aims to triangulate findings from multiple sources to develop theory and identify thematic patterns. Triangulation refers to the use of different methods and data sources in combination to cross-verify results and build a coherent understanding (Denzin 2017, 313). Specifically, this research employs methodological and data triangulation by integrating insights gathered from a literature review, game analysis, and a questionnaire of a target group. Findings will be developed by comparing the data obtained from these distinct sources to ensure a comprehensive and validated perspective on the research questions. The primary goal is to analyse how mechanics from video games can be adapted and further implemented in supply chain gamification to improve decision-making and mitigate risks, as well as overall optimisation.

The literature review establishes the theoretical foundation for applying gamification in supply chain management by examining existing research on game mechanics, decision-making processes in SCM, and real-world implementations of gamified systems. The game analysis focuses on specific mechanics such as technology trees and fog of war, as featured in Paradox Interactive's Grand Strategy games. These titles are among the most prominent in the genre and are examined to evaluate their relevance to supply chain contexts. In parallel, the questionnaire gathers quantitative data from a broad pool of participants to assess how familiar and intuitive these mechanics are in players' cognitive frameworks. By presenting respondents with comparable scenarios, the study aims to determine how deeply these mechanics, and their understanding are embedded in their playstyles.

When integrating these three components, the research design achieves methodological triangulation. Each method addresses the topic from a different angle (theoretical, design-analytic, and experiential), allowing findings to be cross-compared for consistency. The purpose of this design is to strengthen the study's conclusions and support an introductory theory development. Insights from the game analysis and survey are interpreted in light of established theories to craft new propositions about gamified mapping in supply chain contexts. Conversely, any novel patterns observed in player responses or game mechanics can suggest extensions to existing theory. The combination of evidence sources enables the identification of recurring thematic patterns. For instance, themes of visibility vs uncertainty or incremental capability-building. They might not be apparent from a single-method approach. In qualitative terms, this is similar to a triangulated coding process where concepts that surface in multiple datasets are given particular emphasis. Overall, the research design's logic is that the convergence of evidence from literature, simulated environments (games), and real user perceptions provides a comprehensive basis for answering the research questions. This multi-method strategy enhances both the validity and the richness of the results: conclusions supported by all three sources carry greater weight and credibility, and divergent findings can also be analysed to provide nuance.

4.1.1 Literature Review Methodology

The foundation for this research was established through a comprehensive literature review. The search focused on identifying existing research and theoretical frameworks related to the core components of this thesis. Key academic databases and search engines consulted included the Tampere University of Applied Sciences library portal (TAMK Finna), Google Scholar and Scopus. Search terms included various combinations of "gamification", "gamified", "supply chain management", "SCM", "mapping tools", "simulation", "logistics", "digital twin", "decision making", and "risk management". To enhance the efficiency of the research process and text preparation, several digital tools were employed. For identifying relevant academic literature, AI-powered tools, specifically Gemini and ChatGPT Deep Research, were used strictly as aids to rapidly surface potentially relevant papers based on keywords, complementing traditional database searches, and not for primary content generation. Additionally, Grammarly was utilised for proofreading and editing to improve the clarity and correctness of the text. Certain visuals were generated using DALL-E, based on author prompts. The intellectual content and final argumentation presented in this thesis are entirely the work of the author. The gathered literature informed the development of the theoretical framework (Chapter 3) and the identification of gaps addressed by the primary research methods detailed below.

4.2 Data Collection

The primary data collection for this research was accomplished through a questionnaire-based survey on Google Forms, administered via online channels. This approach was selected in lieu of interviews to efficiently reach a larger sample of participants and to capture a breadth of viewpoints from the target population of strategy game players. The data collection process was carefully structured in terms of the questionnaire’s design, distribution method, and sampling frame.

The questionnaire was designed specifically to gather data relevant to the research questions by exploring player interactions with key game mechanics analogous to SCM concepts. Following an informed consent statement, the survey collected background information on participants' age range, specific Paradox games played, and hours invested, and their self-reported familiarity with the field of Supply Chain Management. The core sections focused on Technology/Capability Building (Tech Trees) and Exploration/Information Management (Fog of War), using a mix of linear scale (1-5 rating) and multiple-choice questions. These questions aimed to quantify player attitudes and behaviours regarding strategic planning, adaptation to discoveries, the importance and impact of information (or lack thereof), and decision-making under uncertainty. An optional open-ended question allowed for additional qualitative comments. The design systematically captured player approaches to these mechanics to provide data for analysing their potential relevance to SCM decision-making frameworks

To reach the largest possible number of respondents, the survey was shared at various times on different days across four relevant Reddit communities (subreddits). These subreddits were chosen for their alignment with the research topic and their large, active user bases. Additionally, tools such as “LaterForReddit”, which analyse optimal posting times for maximum engagement, were used. Specifically, a survey invitation with a brief description and a link to the online questionnaire was posted on r/EU4, r/ParadoxPlaza, r/Stellaris, and r/HOI4. Reddit was selected as the distribution platform because it hosts the largest online fan community for the Paradox Interactive grand strategy games that are central to this study. Utilising these subreddits as distribution channels provided direct access to the desired sample. Meaning, strategy gamers with experience in Europa Universalis IV, Stellaris, Hearts of Iron IV, and related titles. This approach can be described as a purposive sampling strategy (within a convenience sampling framework), targeting participants based on their membership in communities of interest. The rationale was that members of these subreddits are likely to have substantial exposure to the game mechanics under investigation and thus can provide informed responses. The choice to use an online survey, in contrast to in-person or email distribution, was motivated by both practicality and reach, because it allowed global participation with minimal cost and time, and it leveraged the existing interest of community members to improve response rates. Each subreddit post was tailored to abide by that community's rules, like moderators preapproving the post before submission. The questionnaire remained open for a defined period of 8 days with 374 valid respondents. By centralising responses in a single digital form, data collection was streamlined and automatically recorded, reducing the risk of transcription errors. Overall, Reddit proved to be an effective medium to circulate the survey to a concentrated group of relevant respondents in a short time frame.

The four selected subreddits were chosen based on their size and thematic alignment with the thesis, ensuring both a sufficient pool of potential respondents and relevance to the subject matter. As seen in Figure 2, r/ParadoxPlaza (a general hub for Paradox Interactive enthusiasts) has approximately 255 thousand subscribers as of the 16th of April 2025 (r/ParadoxPlaza n.d.). Thus, making it one of the largest communities of grand strategy players. This large membership increases the likelihood of obtaining a robust number of survey responses. The other subreddits are dedicated to specific games: r/EU4 (Europa Universalis IV), r/Stellaris, and r/HOI4 (Hearts of Iron IV). Each of these boasts a substantial following: 374 thousand, 470 thousand and 455 thousand members, respectively, as of the 16th of April 2025 (r/EU4 n.d.; r/Stellaris n.d.; r/HOI4). Therefore, resulting in a potential reach of at least 1.635 million users that have experience with these titles. Moreover, they represent a distinct facet of Paradox's game portfolio: historical empire management, science-fiction strategy, and World War II strategy, respectively. The thematic alignment of these communities with the research is clear: the games in question all involve complex mapping interfaces (world maps or galactic maps) and require strategic resource management and progression planning by players. In Europa Universalis IV, for instance, players manage economics, military, and exploration on a world map; Hearts of Iron IV centres on wartime production logistics and territory control; Stellaris involves exploring and exploiting a galaxy with technological research guiding expansion. These gameplay activities mirror key concepts in supply chain and logistics management (such as managing supply lines, dealing with the "fog" of uncertain information, and investing in technology development). By surveying users from these subreddits, the study targets respondents who are familiar with such concepts in a gamified context.

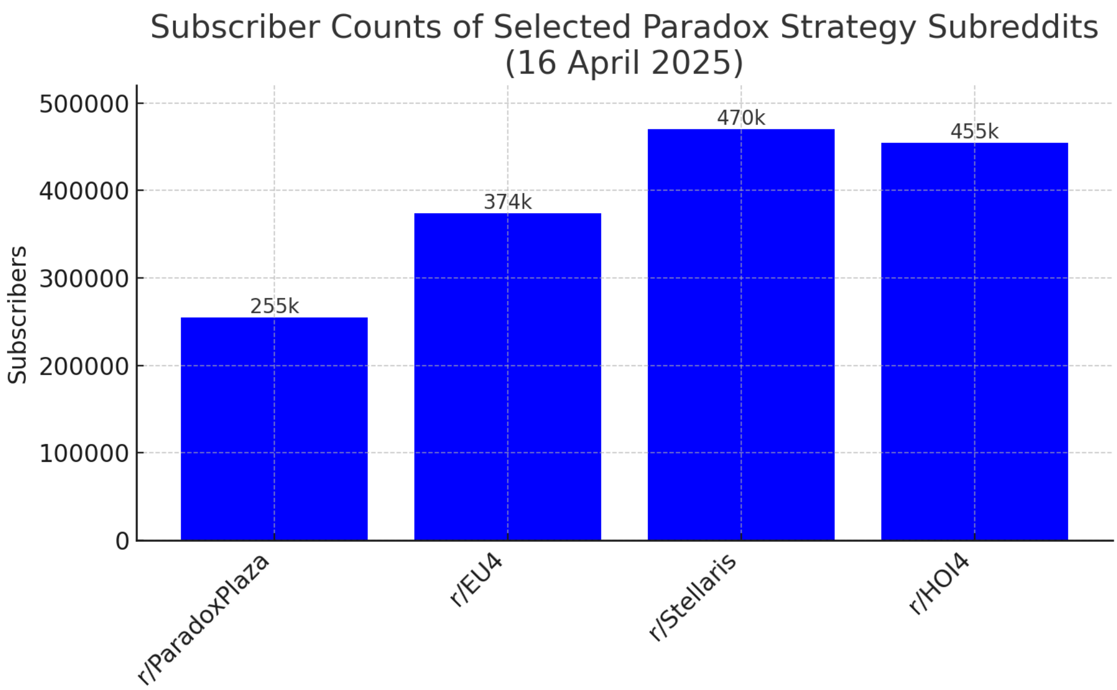

Figure 2. Subscriber Counts Chart

It is safe to assume that the typical consumer of such titles is a strategy gaming enthusiast who has navigated in-game scenarios of planning and optimisation. It is reasonable to assume many have an intuitive grasp of strategic trade-offs, risk management, and long-term planning due to their gaming experience. This makes their input especially valuable for drawing parallels to real-world supply chain decision-making. Additionally, focusing on multiple subreddits rather than just one mitigates sampling bias toward a single game’s community culture; it broadens the respondent base to include different perspectives. For example, a Stellaris player might have a different mindset than a historical war-game player and including both enriches the data.

While the survey did not collect personally identifiable information, it did include optional, basic demographic questions such as the respondent’s age range and an inquiry about their familiarity with supply chain concepts, in order to gauge how many respondents have formal knowledge in addition to gaming experience. By using voluntary self-selection through Reddit, a degree of self-selection bias is acknowledged, since those particularly interested in the topic might be more likely to respond. Nonetheless, given the niche subject (intersection of games and SCM), attracting those engaged enough to respond was actually beneficial to ensure informed answers. The communities’ scale helped gather a sufficient sample despite this self-selection; even a small response rate out of the combined subscriber count of these forums can yield dozens or hundreds of responses. All participants were informed about the academic nature of the survey and gave implicit consent by choosing to complete the questionnaire. No incentives were provided aside from the appeal to contribute to research (to avoid attracting unreliable responses solely seeking a reward). The data collected was stored securely and analysed in aggregate.

The data collection via an online questionnaire on targeted Reddit communities was an effective and appropriate method for this study. It provided access to a large, relevant audience of strategy game players whose insights form the practical cornerstone of the research. Carefully selecting well-populated and thematically pertinent subreddits, the study maximised the relevance of responses while maintaining an acceptable sample size. This community-driven data collection approach, combined with the literature review and game analysis, completes the methodological framework. The coherence between the data collection method and the research design (mixed-methods triangulation) lies in the fact that the survey data can be compared and contrasted with insights from the literature and game analysis, thereby fulfilling the study’s goal of linking theory, simulated environments, and real-world perceptions in a credible and methodical manner.

4.3 Game Analysis

Hearts of Iron IV, Europa Universalis IV, and Stellaris were chosen for analysis due to a combination of the researcher's deep familiarity and their enduring popularity and design approach. Each of these grand strategy titles by Paradox Interactive has been played extensively by the author (exceeding 300 hours of gameplay each since tweenhood), ensuring nuanced insight into their mechanics. Moreover, they continue to sustain massive player communities years after release. As of April 2025, Hearts of Iron IV maintains roughly 36000 average concurrent players over 30 days, with Stellaris and Europa Universalis IV each around 13000–14000 (SteamDB n.d.a; SteamDB n.d.b; SteamDB n.d.c). Such persistent engagement attests to the rich, complex decision-making challenges these games offer. A key contributor to their longevity is Paradox Interactive's unique business model of frequent, high-cost downloadable content expansions. This model continuously adds new scenarios, features, and content, keeping players invested over the long term. For instance, Hearts of Iron IV was launched in 2016. However, it hit its all-time peak of 93,196 concurrent players in November 2024, with the launch of the "Götterdämmerung" expansion pack. This exemplifies how regular DLC releases prolong a game's lifespan and maintain strategic depth in the gameplay experience (Newzoo 2023). These characteristics (expert-level strategic systems, large, sustained user bases, and ongoing content evolution) make the three titles ideal candidates for studying advanced strategic decision-making. In the context of this thesis, they provide tangible analogues for how gamified systems might enhance supply chain decision-making. The following analysis focuses on two core mechanics common to these games, the "Fog of War" and the "Technology Tree", examining how each operates in-game and how similar concepts could be lightly adapted to a digital twin or mapping tool for supply chain management.

4.3.1 Fog of War Mechanic

All three strategy games implement a "Fog of War" mechanic that deliberately limits the information visible to the player, thereby simulating the uncertainty of complex operations. In Hearts of Iron IV (a World War II simulation), vast portions of the map and enemy forces remain hidden unless one has units or intelligence assets in the area. A nation’s military cannot directly see opposing troop positions or movements outside its reconnaissance range. Only once scouts, spies, or radar coverage are deployed does the “fog” lift for those regions. Stellaris, a science-fiction grand strategy game, similarly shrouds unvisited star systems and any areas beyond a fleet’s sensor range. Meaning that unknown planets and alien empires lie in darkness until the player’s ships explore or improved sensors reveal them. Europa Universalis IV, set between the Renaissance and the early modern era, uses both terra incognita (completely uncharted lands that require exploration) and a fog of war over discovered regions where the player has no active presence. In all cases, the design forces players to make decisions with incomplete information: one must infer or assume what lies in the shrouded areas. For example, a Europa Universalis IV player might deduce an opponent’s troop movements from indirect clues (such as reports from allies or changes in border control), much like a Hearts of Iron IV player relies on intercepted communications or an estimate of enemy divisions based on limited intel. This element of uncertainty adds realism and challenge, as strategy unfolds in a probabilistic environment rather than with perfect foresight.

Critically, this gaming mechanic mirrors real-world supply chain challenges wherein managers rarely have full visibility over all operations. Just as a general in HOI4 cannot see beyond the front lines without scouts, a supply chain planner often contends with blind spots in the network. Empirical studies indicate that less than 30% of businesses that operate internationally have full visibility into their supply chain and logistics operations (te Lindert 2024). In practice, firms may have incomplete supplier data (especially beyond first-tier suppliers), uncertain geopolitical conditions, and untracked inventory in parts of their logistics network. Geopolitical disruptions can arise with little warning and without “visibility” on a corporate dashboard, analogous to an ambush emerging from an unexplored zone on a game map. Likewise, missing or stale data about inventory and shipments can lead to the “fog” of not knowing stock levels at certain nodes, complicating decision-making. A notable consequence is that supply chain decisions are often made on partial information, which can result in suboptimal outcomes (Regnet 2024). Managers, much like strategy game players, must rely on indirect clues and experience. For instance, trusting a local partner’s updates or analysing market signals, to fill in knowledge gaps when data is ambiguous or delayed.

In the games, players actively work to reduce the “Fog of War” over time by investing in reconnaissance capabilities (spies, scouting units, radar, etc.) and by gradually exploring unknown regions. This concept suggests an intriguing parallel for a digital twin or gamified supply chain mapping tool. One could envision implementing a fog of war layer in a digital supply chain map interface: initially, the user might see only a basic outline of their immediate supply network, with distant tiers or details obscured. As the user engages in effective decision-making or completes certain tasks, the system could incrementally reveal previously hidden areas or data. In other words, better performance confers better visibility. A user who skilfully navigates a disruption scenario might unlock detailed information about secondary suppliers or logistics routes that were initially concealed. This adaptation would serve both as a reward mechanism and a learning tool. It mirrors the way success in a game is rewarded by expanding the player’s knowledge of the map, thereby empowering them to make more informed strategic moves going forward. In a supply chain context, gradually lifting the “fog” through strong performance could train managers to handle uncertainty. Thus, meaning that they must first make do with limited data, but as they demonstrate competence (in, say, a simulated exercise), additional real-time data streams or analytics become available to them. Such a feature in a digital twin interface would highlight the value of supply chain visibility as an earned strategic asset, in much the same way that military intelligence is earned in war. This thesis posits this “Fog of War” analogy as a design consideration for gamified decision-support tools. However, its practical implications (e.g. ensuring it remains motivational and not simply frustrating) will be examined in Chapter 5 alongside user feedback and results.

Applying this “earned visibility” concept, derived from the Fog of War mechanic, could therefore directly contribute to answering how gamified tools improve decision-making and risk reduction, enhance predictive capabilities through better information, allow for customization to model specific regional risks, and potentially offer novel ways to measure user engagement and performance within the system.

4.3.2 Technology Tree Mechanic

Another defining feature of these strategy games is the technology tree (or “tech tree”), which is a branching progression system for long-term upgrades and capabilities. In each title, the tech tree governs how a player develops new technologies or skills over the course of the save, typically requiring choices under constrained resources and uncertainty. A technology tree is defined by Morris & Hartas (2004, 141) as “a structure that controls progress from one technology to a better technology, enabling the player to create better facilities or more powerful units”, with certain prerequisites that must be met to unlock each subsequent technology. In Hearts of Iron IV, for example, the player allocates research slots and time to develop specific technologies in categories such as infantry equipment, aircraft, industry, or encryption. These tech trees are semi-linear graphs: basic upgrades (like 1930s-era infantry weapons) lead to advanced ones (late-war weaponry or nuclear research), often branching into mutually exclusive paths. Stellaris presents a different twist. Its technology system offers randomised choices from three categories (Physics, Society, Engineering) at each research interval, but it still effectively creates a web of prerequisites and cumulative advancements (e.g. one must research improved lasers and power generators before unlocking the next tier of starship weapons). Europa Universalis IV uses a more linear technology scale (Administrative, Diplomatic, and Military tech levels increase sequentially using accrued monarch points) alongside an idea system that branches into specialised bonuses. Despite differences in presentation, all three games demand staged capability development: players start with modest abilities and must decide how to spend limited research resources to gradually unlock superior capabilities. Crucially, pursuing one path means delaying or forgoing others. A nation might invest heavily in naval technology at the expense of its army development. A gamble that may pay off if maritime dominance proves decisive or backfire if land wars dominate that run. This necessity of prioritisation under uncertainty forces players to weigh trade-offs and make strategic bets on what future scenarios are most likely or most dangerous, given that resources (be it research points, time or in-game currency) are always finite.

The tech tree mechanic closely models real-world strategic planning, where organisations must build capabilities progressively and cannot do everything at once. In supply chain management, this is akin to capability development roadmaps: a firm might sequentially invest in improved forecasting tools, then in automation, then in AI-driven analytics, each step enabling the next. Just as a game player does not instantly obtain all advanced technologies, a company must phase its improvements, and these decisions are often made under uncertainty about competitors and market conditions. There is a parallel in the notion of capability maturity. This mirrors established concepts in SCM, such as capability maturity models which propose staged development. For example, the Lockamy and McCormack (2004) SCM process maturity model outlines five levels “Ad hoc, Defined, Linked, Integrated, Extended”, suggesting that firms advance capabilities incrementally, with each level providing the foundation for achieving the next, and higher maturity levels associated with greater process control, predictability, and effectiveness. Basically, businesses that excel tend to advance through stages of process improvements and learnings over time, rather than achieving full mastery overnight. The games’ tech trees also illustrate the value of iterative learning. Early technologies, such as basic inventory management systems in an SCM analogy, must be understood and leveraged before more complex ones, like autonomous supply chain AI, become available. This staged progression encourages a form of iterative mastery. Players (or managers) internalise how each new tool or capability works, and this confidence equips them to handle the next, more complex challenge. Notably, the tech tree injects uncertainty in that the payoff of a given research choice is realised only later; similarly, a supply chain manager investing in a new system may not see its full benefit until a disruption tests it.

In a gamified digital twin environment, imagine an analogous system through what might be termed “Decision Points”. This concept, inspired by tech trees, would grant users points or credits for effective performance that can be redeemed to unlock new decision-support features or expanded data access within the tool. For example, in a simulated supply chain scenario, successfully averting a stockout or efficiently rerouting shipments could earn the user “Decision Points”. Accumulating these points then allows the user to unlock enhanced functionalities in the digital twin, much like unlocking a new technology in the game. Concretely, a manager might use points to activate a higher-tier analytics module (e.g. a predictive risk alert system or an optimization algorithm) or to reveal additional layers of the supply network (e.g. mapping second or third-tier suppliers that were initially hidden, paralleling an “unlock” in the Fog of War discussed earlier). This mechanism creates a branching path of upgrades in the decision-support tool. An example of this would be how the user could choose to spend points on improving visibility (analogous to an exploration or intelligence tech in a game) or on improving efficiency (analogous to an economic or engineering tech). Over time, different users might customise their digital twin’s capabilities in different sequences, fostering engagement and a sense of agency in mastering the tool. However, careful calibration would be essential; just as users can become frustrated with overly slow progression or seemingly arbitrary gating in software or loyalty programs, the “Decision Points” system must feel rewarding and transparent, rather than simply restrictive or overly “grindy”.

Most importantly, this approach incentivises continuous improvement and learning. The user is rewarded for practising good supply chain decision-making with greater capabilities, which in turn enable handling more complex scenarios. It also reflects a core principle seen in tech trees: trade-offs. If a user has limited points, they must decide which new feature to unlock first (perhaps improved forecasting vs a wider map view), just as a player must choose one research focus over another. By structuring the digital twin’s feature set as something to be earned and expanded, users engage in a form of strategic planning and long-term thinking, mirroring the mindset required in effective supply chain management.

This “Decision Points” system, inspired by tech trees, directly addresses the thesis's core research questions. By allowing users to unlock progressively more powerful decision-support features (like predictive analytics or deeper network visibility) based on performance, it offers a mechanism to improve decision-making and prediction accuracy under uncertainty, addressing the main and second research question, respectively. The choice of which capabilities to unlock allows for customization to potentially focus on specific challenges, such as regional risks. Furthermore, the accumulation of points or the specific path of unlocked capabilities could serve as tangible metrics for measuring the impact of the gamified tool on user learning and performance.

4.4 Data Analysis

The objective of this analysis is to synthesise quantitative trends and qualitative themes, enabling a triangulated approach to address the research questions regarding the potential of gamified mapping tools in supply chain management decision-making. This process specifically entails detailing the procedures used for processing and interpreting data derived from the online questionnaire administered to strategy game players, as detailed in section 4.2, and the qualitative insights generated through the structured analysis of selected game mechanics from section 4.3.

4.4.1 Quantitative Data Analysis

The quantitative data collected from the questionnaire's linear scale and multiple-choice questions were analysed using descriptive statistics. Prior to analysis, the dataset obtained from Google Forms was reviewed for completeness. Descriptive statistics were calculated to summarise participant responses and identify general trends. The specific statistical measures employed included frequencies & percentage, and means & standard deviations. The former were used to describe the distribution of responses for categorical data, including participants' background information (e.g. games played, hours invested, self-reported SCM familiarity) and their choices in multiple-choice questions related to strategic preferences and behaviours within the games. Whereas the latter were calculated for the linear scale (1-5 rating) questions to gauge central tendency and variability in player attitudes concerning aspects like strategic planning horizons, adaptation to new information, the perceived impact of visibility (or lack thereof), and decision-making under uncertainty.

The analysis of descriptive statistics was conducted relying on Google Forms summaries. This quantitative summary provides an overview of the respondents' collective experiences and perspectives related to the Fog of War and Technology Tree mechanics, forming an empirical baseline for subsequent triangulation.

4.4.2 Qualitative Data Analysis

Qualitative data within this study encompassed two distinct forms: the interpretive analysis of the Fog of War and Technology Tree mechanics documented in section 4.3, and the optional open-ended text responses provided by participants in the questionnaire. Both qualitative datasets were subjected to thematic analysis to discern recurring patterns, conceptual categories, and nuanced insights pertinent to the research inquiry.

The game analysis itself involved interpreting how the selected mechanics function within the chosen Paradox Interactive titles and drawing parallels to SCM concepts like uncertainty, visibility, risk management, and capability development. This process yielded preliminary themes regarding the potential implications of these mechanics for SCM decision support.

Qualitative data within this study encompassed a primary form. The interpretive analysis of the Fog of War and Technology Tree mechanics documented in section 4.3. The qualitative dataset was subjected to a basic analysis to discern recurring patterns, conceptual categories, and nuanced insights pertinent to the research inquiry.

The game analysis itself involved interpreting how the selected mechanics function within the chosen Paradox Interactive titles and drawing parallels to SCM concepts like uncertainty, visibility, risk management, and capability development. This process yielded preliminary themes regarding the potential implications of these mechanics for SCM decision support.

This qualitative analysis aimed to uncover deeper insights into how and why players interact with these mechanics, complementing the quantitative overview and providing context for understanding the potential transferability of them to gamified SCM tools.

4.4.3 Triangulation and Synthesis

Integral to the mixed-methods design adopted for this research, the final stage of analysis involved triangulating the findings from the quantitative survey data, the qualitative game analysis, and the open-ended survey comments. This process involves a systematic comparison of the statistical trends identified in the survey data (e.g. players' reported tendency to plan long-term versus adapt opportunistically) with the conceptual themes emerging from the game analysis and open-ended responses (e.g. specific examples of adapting to Fog of War discoveries, rationales for Tech Tree choices).

These integrated empirical findings, presented in Chapter 5, and subsequently discussed in Chapter 6 by comparing them against the foundational concepts, theories, and industry examples explored in the literature review Chapters 2 and 3. Points of convergence, where the primary data supports existing literature or theory (e.g. confirming the importance of visibility), and points of divergence (e.g. novel insights from player strategies that challenge traditional SCM assumptions or suggest specific gamification benefits) will be highlighted. This methodological triangulation serves to enhance the validity of the conclusions and provides a more comprehensive and nuanced answer to the research questions concerning how game mechanics like Fog of War and Tech Trees can inform the design and application of gamified mapping tools for enhancing global supply chain decision-making and optimisation.

4.5 Limitations

Several limitations should be acknowledged regarding this study's methodology. Firstly, the reliance on self-reported data gathered through a questionnaire presents a potential source of bias, as responses may be influenced by factors such as social desirability or subjective interpretation. Secondly, the requirement for respondents to possess some sort of knowledge in both supply chain management, gaming and the game mechanics themselves narrows the potential participant pool. This specificity might limit the representativeness of the sample compared to the broader population of SCM professionals, potentially impacting the generalizability of the findings derived from the questionnaire data. Furthermore, given the topic's novelty and potential appeal to those newer to the field, the respondent sample may predominantly reflect the perspectives of students or people at the beginning of their careers, offering insights perhaps more indicative of future trends than current, established viewpoints within SCM.

Additionally, the analysis of game mechanics, while structured, involves an element of researcher interpretation, and the focus on specific Paradox Interactive titles may not capture all potentially relevant mechanics from other game genres. A further consideration is the inherent gap between game simulations and real-world SCM environments; mechanics effective in a game may face unforeseen challenges when translated to complex, dynamic operational contexts.

Finally, despite efforts towards objectivity, the potential for unconscious researcher bias in the selection of games, design of the questionnaire or interpretation of findings cannot be fully excluded. However, these limitations are mitigated using methodological triangulation. By integrating and comparing findings from the literature review, game analysis, and questionnaire data, the study aims to produce more robust and validated conclusions, reducing the dependence on any single data source and counterbalancing potential biases inherent in the self-reported questionnaire responses.

4.6 Ethical Considerations

This research adhered to ethical principles throughout its execution. Regarding the questionnaire involving human participants, ethical conduct was prioritized. Participants were presented with clear information about the study's purpose, the voluntary nature of their participation, and how their data would be used and stored before they began the survey, ensuring informed consent. No personally identifiable information (e.g. names, specific contact details) was collected to guarantee participant anonymity. All questionnaire data collected has been stored securely and will be presented only in aggregated form in this thesis to maintain confidentiality and prevent the identification of individuals. Participation was entirely voluntary, and respondents could choose to discontinue the questionnaire at any point. Furthermore, the analysis of existing literature and game mechanics was conducted objectively, with all sources properly cited. The research complies with the ethical guidelines provided by Tampere University of Applied Sciences and relevant data protection regulations, such as GDPR, concerning the handling of participant data.

5 RESULTS AND DATA ANALYSIS

5.1 Survey Results

The online questionnaire, distributed via relevant Reddit communities (as described in section 4.2), garnered 374 valid responses. All participants consented to the use of their anonymised data for this research. This section summarises the respondent profile and analyses the quantitative data related to the core themes of technology/capability building and exploration/information management within the context of Paradox Interactive's grand strategy games.

The survey's respondent profile captured responses from a highly engaged and experienced group of strategy game players. The age distribution indicates a concentration in the 18-24 age bracket, representing the majority, and the 25-34 age bracket. They represent the typical demographic for these complex game titles (Appendix 3).

Regarding gaming experience (Appendix 4), the most frequently played titles among respondents were Stellaris (71.1%), Europa Universalis IV (37.4%), and Hearts of Iron IV (33.7%), aligning well with the games selected for the mechanic analysis in section 4.3. A significant portion of the respondents reported extensive playtime (Appendix 5), with 52.7% indicating over 1000 hours invested and another 25.5% reporting between 501-1000 hours. This high degree of experience suggests respondents possess a strong intuitive understanding of the games and game mechanics under investigation.

The strategic approaches employed by the survey respondents appear largely shaped by their gameplay experience, offering valuable insights from a perspective distinct from formal Supply Chain Management training. Responses regarding familiarity with SCM or Logistics concepts (Appendix 6) show the largest segments identifying as only “Slightly familiar” (41.4%) or “Moderately familiar” (37.7%), while just 6.1% reported being “Very familiar”. This context highlights that the observed player behaviours primarily reflect intuitive strategic thinking and cognitive frameworks developed within the game, aligning with the study's aim to explore their potential transferability. A key element of this strategic gameplay involves navigating technology research systems ("tech trees"), which serve as a practical analogue to capability development processes in SCM. The data indicates that players attribute significant strategic importance to this aspect of the game, viewing systematic capability enhancement as fundamental to achieving their objectives.

Metric	Headline Statistic	Insight
Importance of technology research	88.2% rate 4-5 on a 5-point Linkert scale (Appendix 7)	Capability development is perceived as the prime lever of success.
Ex-ante planning of research path	25.9% "specific plan"; 55.1% "general idea" (Appendix 8)	Players sketch a trajectory but keep optionality open.
Frequency of plan changes	38.2% alter plans "often/very often" (Appendix 9)	Iterative planning mirrors agile S&OP cycles.
Exploration feedback into tech choice	49.5% "frequently" influenced; 37.7% "sometimes" (Appendix 10)	Information gains feed directly into capability investment.
Technologies that reshape exploration	31.6% "frequently" change behaviour; 37.4% "sometimes" (Appendix 11)	A recursive loop: better tech → better intel → better tech.

The implication of these results relating to Technology & Capability Building ("Tech Trees") suggest that progression systems resonate strongly with individuals. Any gamified mapping tool should include tiered capability unlocks that adapt in real time to new data, reflecting how firms roll out digital-twin functionality in waves.

Beyond capability building, the survey data reveals that managing information scarcity and improving visibility, which is often represented by the "Fog of War" mechanic in games, tends to be perceived by players as a critical aspect of strategic decision-making. This dynamic of making choices with incomplete information mirrors fundamental challenges related to visibility and uncertainty within the field of supply chain management. How players prioritize exploration, react to information gaps, and invest in intelligence gathering within the game context is detailed in the following table.

Metric	Headline Statistic	Insight
Importance of early exploration	62.0% rate 4-5 on a 5-point scale (Appendix 12)	Early visibility is viewed as a strategic asset.
Perceived penalty of missing information	29.9% rate 4-5 on a 5-point scale (Appendix 13)	A notable minority feels acute pain from data gaps.
Decision style when information is incomplete	69.3% act immediately or hedge; 23.0% seek more info; 5.9% delay (Appendix 14)	Most players move despite uncertainty, so supply-chain tools must enable rapid yet risk-mitigated actions.
Active spend on visibility	86.6% invest resources “frequently/sometimes” (Appendix 15)	Information is treated as an investable commodity.
Value of rival intelligence	72.2% rate 4-5 on a 5-point scale (Appendix 16)	Competitive intel commands a premium.

From this section, a clear parallel emerges between the two fog-of-war items: respondents who regard early exploration as highly important (Q9) are also the ones who most frequently feel penalised by missing information (Q10). Roughly 42% of the 232 players who rate exploration 4-5 also rate the penalty 4-5 (Appendix 17). This interplay suggests that the appetite for visibility and the discomfort with opacity are two sides of the same strategic coin.

The implications result in respondents displaying a willingness to trade present resources for future certainty, more precisely the cost–benefit calculus firms confront when funding deeper supplier-tier mapping or IoT sensor layers.

The quantitative questionnaire result indicate that experienced strategy game players engage deeply with mechanics analogous to core SCM challenges. Their approach to technology progression reflects a blend of strategic planning and significant adaptation to new information, while their interaction with information scarcity demonstrates a high value placed on visibility and a willingness to invest resources to mitigate uncertainty. These observed patterns provide a quantitative baseline for understanding player mindsets, which will be further reinforced by the qualitative analysis in the subsequent section.

5.2 Game Analysis Results

This section presents qualitative observations from the game content analysis, focusing on how Fog of War and Technology Tree mechanics are implemented in the base versions of Hearts of Iron IV, Europa Universalis IV, and Stellaris. The aim is to highlight similarities and differences in how these mechanics function and affect gameplay, and to draw parallels with supply chain management themes. Each subsection objectively examines the mechanics in the three games, noting concrete examples of its operation and linking those findings to SCM concepts (e.g. uncertainty, visibility, strategic planning, capability growth) where applicable. This analysis is based on the games' design and observed behaviour, without reference to player perceptions, avoiding overlap with the player survey results in Section 5.1.

5.2.1 Fog of War Analysis

All three strategy titles employ a Fog of War mechanic that deliberately limits the information visible to the player, thereby simulating the uncertainty of operating with incomplete knowledge. In Hearts of Iron IV, a World War II-era game, the world map is fully drawn from the start, but enemy forces and movements are hidden unless the player has military units or intelligence assets (such as scouts, spies or radar) in the vicinity. For example, an HOI4 player cannot directly see opposing divisions massing beyond their border or fog-covered ocean areas without deploying reconnaissance aircraft or establishing radar coverage. This means that planning an offensive requires either moving units to scout or investing in intelligence (e.g. codebreaking) to infer what lies behind the front. As seen in Figure 3, a portion of the map, where there is a territory that goes beyond the line of sight of friendly troops, remains obscured, indicating how enemy-controlled regions are greyed out until recon assets are present. This implementation of Fog of War in HOI4 directly affects gameplay by making military intelligence a crucial element of strategy. Thus, players must allocate resources (spies, reconnaissance planes, cryptography research, etc.) to reduce uncertainty about enemy positions before committing to major operations, mirroring real-world doctrines that “knowledge is power” in conflict scenarios.

Figure 3. Fog of War in Hearts of Iron IV

In Europa Universalis IV, which is set in the age of exploration, Fog of War takes on two forms: terra incognita and the standard fog. Large swathes of the world start as terra incognita, completely uncharted and inaccessible until explored by the player’s units. For instance, a European nation in 1444 can initially see only Europe and the Mediterranean; the Americas, sub-Saharan Africa, and parts of Asia are hidden behind a “blank map” veil. Players must dispatch explorers and conquistadors across seas and continents to physically reveal these unknown regions. Once an area is discovered, it becomes part of the known world map, but it can still be covered by Fog of War if the player has no active presence there. In other words, even after discovering, for example the coast of India, a European player will not continuously see local happenings unless they maintain units or have allies in the area. As a concrete gameplay example, if Sweden has no ships in the Indian Ocean, movements of rival fleets or armies in India remain unseen despite the geography being known. Thus, EU4's Fog of War affects visibility on two levels: initial exploration to unveil new territories, and ongoing observation to monitor activity in known lands. This dual nature adds a significant exploration and discovery aspect to gameplay. Players are incentivised to invest in exploration ideas and naval expeditions early (at the cost of other advancements) to gain access to valuable new lands and trade routes. It also means that surprise attacks can come from regions a player thought they "knew" but was not actively watching. For instance, an opponent could gather troops in a distant colony and launch an invasion before the player realises it. As seen in Figure 4, an example of how terra incognita covers most of the Americas, it forces players to proactively explore to lift the fog. In EU4, this mechanic introduces a strong element of geographical uncertainty, shaping strategic decisions.

Figure 4. Fog of War in Europa Universalis IV

Stellaris, based in a science-fiction world, implements Fog of War on a galactic scale in a manner analogous to EU4's exploration but with a futuristic take. At the start of a Stellaris game, the player's empire knows only its home star system and perhaps a few neighbouring stars, meaning the rest of the galaxy is essentially in darkness. Unvisited star systems are entirely shrouded, and the player has no information about what planets or events are there until a science ship is sent to survey them. Upon exploring a system, its planets, resources, or alien species become visible. However, even explored systems can fall under Fog of War if they lie outside the sensor range of the player's ships or star bases. This means that other empires' fleets or colonies do not automatically appear on the map unless the player has sufficient sensor coverage or intelligence in that region. For example, suppose an opposing empire is on the other side of the galaxy. In that case, the player might know the star systems in between (from prior exploration or shared star charts) but will not see enemy fleet movements or newly built stations there without extending their sensor network or establishing spy networks. In gameplay terms, Stellaris players must prioritise exploration early on (i.e. building additional science ships to chart hyperlane routes and find habitable planets) and later invest in sensor technology upgrades (like listening posts or advanced radar) to improve situational awareness. The Fog of War creates tension and risk. An uncharted system might contain a strategic resource or a hostile alien fleet, analogous to "known-unknowns" in a supply chain. Figure 5 illustrates how the game shows a portion of the galaxy map where the systems belonging to the coloured region demarcating known imperial territory within the Abbanis Nebula are identifiable, while the vast surrounding galactic regions appear only as dim stars with no details. The nebula's explicit sensor-blocking property further illustrates how access to real-time information is limited not only by the extent of exploration but also by the reach and environmental limitations of sensors.

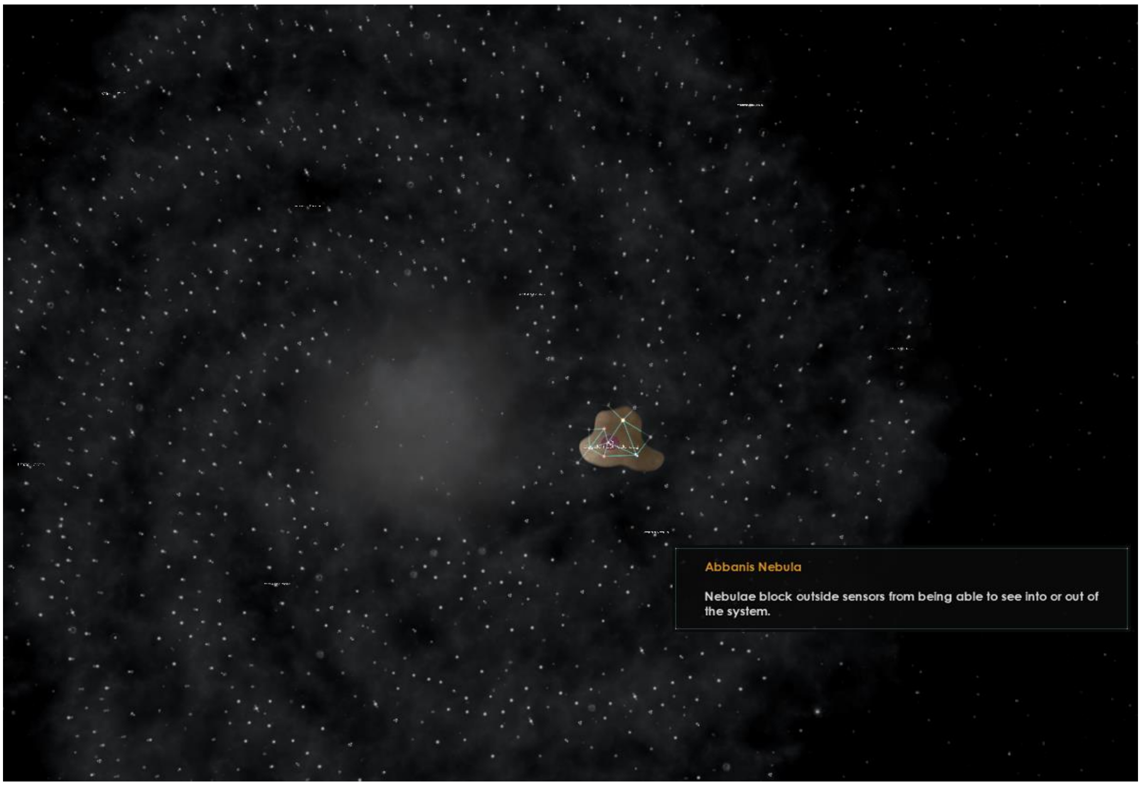

Figure 5. Fog of War in Stellaris

Despite the thematic differences, these implementations share a common function: information restriction. In all three games, Fog of War forces players to make decisions with incomplete data, managing risk and uncertainty about the unseen. This directly parallels uncertainty management in supply chain management. Just as a general in HOI4 or Stellaris must infer what lies beyond the visible area (e.g. guessing enemy troop strength from limited intel or anticipating unknown star systems), supply chain managers often operate without full visibility of all components of their network. In fact, studies indicate that at most, as many as 70% of businesses do not have complete visibility into their supply chain operations (te Lindert 2024). There are often “blind spots”, such as a company not having real-time data on a second-tier supplier’s inventory or being unaware of a disruption brewing in a remote region. This is analogous to EU4’s terra incognita or Stellaris’ uncharted space, them being areas where no information is available until an effort is made to obtain it (through audits, sensors or intelligence gathering). Even within known areas, information can lapse if not actively monitored, similar to how known provinces or star systems go dark when one has no presence there. The result is that both game strategists and SCM professionals must strategise under uncertainty, planning contingencies for what might be happening out of sight. In the games, this might mean holding a reserve army in case an unseen enemy force appears or sending a scout unit to peek behind the fog. In supply chains, it could mean maintaining safety stock in case of unforeseen delays or investing in tracking technology to illuminate those blind spots. The Fog of War mechanic thereby serves as an experiential analogue for visibility challenges in supply chains. It highlights the value of information and the need to invest in visibility. Just as players gradually lift the fog by exploring and deploying intelligence assets, companies can mitigate uncertainty by improving data sharing, installing real-time monitoring, such as IoT sensors in shipments, and facilitating transparency with partners. The key difference is that in games, the Fog of War is an intentional design for challenge and realism, whereas in real supply chains, the “fog” is an obstacle to overcome. Nonetheless, the qualitative effect is similar: decisions must often be made with partial information, and success often hinges on how well one can reduce uncertainty or cope with it.

Another caveat worth mentioning is the differences in how Fog of War affects gameplay emphasis across the three titles. Exploration is a major gameplay pillar in EU4 and Stellaris because of the unknown territories. It incentivises players who explore aggressively, as they often gain advantages (new resources, strategic positions) akin to first-mover advantage in entering new markets or sourcing regions in SCM. In contrast, in HOI4, the game has a predetermined map (no new territories to discover), so the Fog of War there emphasises intelligence and deception in warfare, reflecting how gathering intel or concealing troop movements can tip the balance, much as information asymmetry can be decisive in supply chain negotiations or competitive strategy (Vosooghidizaji, Taghipour & Canel-Depitre 2020). EU4’s fog gradually recedes as the world is fully charted by late game, in a way mirroring how global supply networks today are far more mapped than in the 15th century, while Stellaris retains pockets of mystery longer due to its procedural galaxy, as there is always the possibility to run into unknowns if there was not any expansion done in that direction. HOI4’s fog can actually increase during gameplay if enemies develop encryption or if your reconnaissance assets are lost, showing a dynamic tug-of-war in information, similar to how a supply chain can lose visibility when a data feed goes down or a partner becomes uncooperative.

Fog of War in these games injects uncertainty and the need for information-gathering into gameplay, directly mirroring the importance of visibility and uncertainty management in supply chains. Players must decide when to invest in reducing the fog (through scouts, exploration, sensors) versus when to act with the information at hand. Striking a strategic balance very much like real world decisions on investing in supply chain transparency versus proceeding with assumptions and buffers.

5.2.2 Technology Tree Analysis

Another core mechanic examined is the Technology Tree, which governs long-term upgrades and capability development in each game. All three titles require the player to research or unlock technologies over time, but the structure and presentation of these tech trees differ, affecting gameplay pacing and strategy. In general, a technology tree is a branching progression system where certain prerequisites must be fulfilled to access more advanced technologies (Morris & Hartas 2004, 141). This mechanic compels players to plan ahead and make choices about capability development under resource constraints, much like organisations charting their strategic improvement roadmaps. Analysing how HOI4, Stellaris, and EU4 implement their tech trees, with examples of how these mechanics guide long-term planning, drawing parallels with SCM concepts such as strategic planning and capacity growth.

In Hearts of Iron IV, the technology system is organised into multiple thematic trees (e.g. infantry equipment, artillery, armour, aircraft, naval, industry, electronics, doctrines), as partially illustrated in Figure 6.

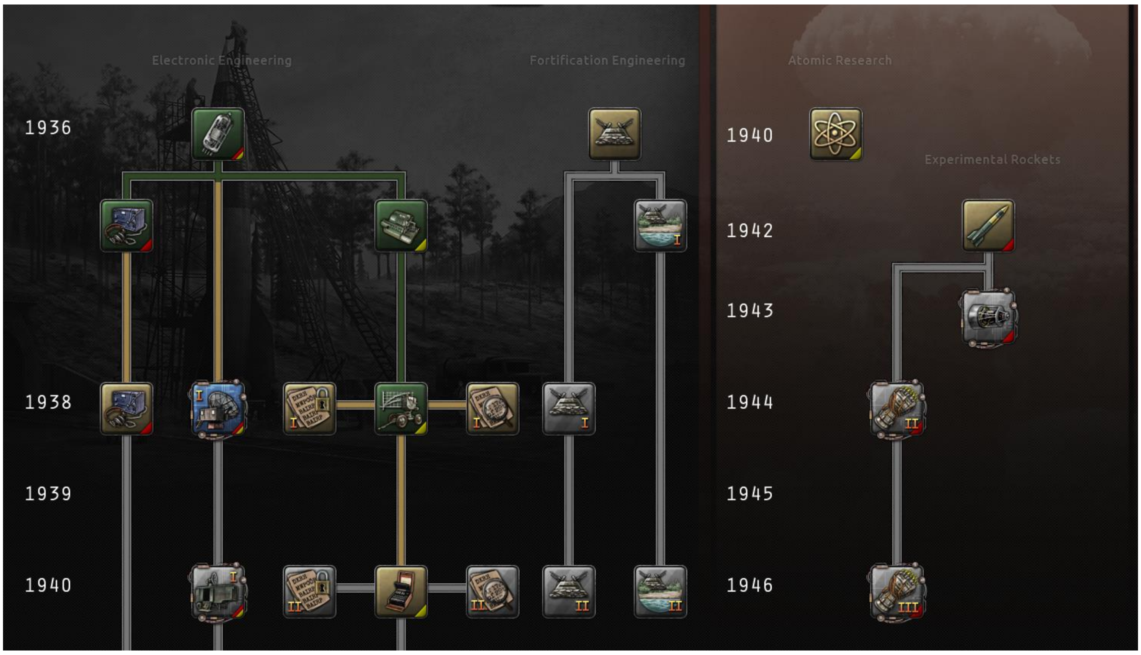

Figure 6. Technology Tree of Electronics in HOI4

A crucial constraint is that the player possesses only a limited number of research slots, which typically starts with 3 or 4, potentially expandable later, meaning they cannot research everything simultaneously and must constantly prioritise. The tech trees themselves are semi-linear: early, basic technologies unlock the possibility to research more advanced versions, forming chains of upgrades often marked by historical years. At various points, these tree branches, presenting choices between different development paths. For example, within the Electronics tree shown, early research into Electronic Engineering branches into paths focusing on Computing, Radio, and Radar technologies. While not always strictly mutually exclusive like some doctrine paths, the limited research slots force a strategic choice: dedicating a slot to improving computing machines might mean delaying advancements in crucial radar detection or radio signal interception for a significant period. Furthermore, because technologies have an ahead-of-time penalty (researching far ahead of the historical year greatly slows progress), players must also consider timing, balancing immediate needs (e.g. basic radio for command efficiency) versus long-term breakthroughs (e.g. advanced atomic research or rocketry). The effect on gameplay is that HOI4's tech tree, constrained by research slots and time penalties, demands long-term strategic planning under uncertainty about the war's direction. A nation that invests heavily in one domain (like early radar development) may gain superiority there, but at the opportunity cost of neglecting others (like industrial efficiency or advanced decryption), which could prove costly if the war unfolds in an unexpected way. This echoes a classic strategic dilemma: you cannot excel at everything at once, so you must pick your priorities and accept risks.

Stellaris approaches technology with a different twist: rather than a fixed visible tree, it uses a semi-randomised deck of technologies system. The game divides research into three categories (Physics, Society, Engineering), and at any given time, the player is presented with a few random choices of techs to research in each category. Each tech still has prerequisites and tiers. For example, you must research basic laser weapons and improved power generators before the next tier of starship laser weapons becomes available. However, the player cannot research everything in a linear sequence. They are dealt options and must decide which to pick, adding an element of adaptability to the research strategy. Over the long term, the Stellaris tech web does encompass essentially all technologies (ranging from colonisation modules to AI to advanced military ships). Still, the order in which a player obtains them can vary greatly between playthroughs. This structure influences gameplay by introducing uncertainty and flexibility in long-term planning. Players might have a goal (e.g. aim for Battleships or jump-drive travel), but since the exact tech draws are semi-random, they often need contingency plans. As an example, if the desired tech for advanced propulsion has not appeared as a choice, the player may invest in an alternative, like improved weapons or economic tech, in the meantime. Overinvesting in one research path is also tempered by the random system, as the player cannot simply beeline down one fixed branch, because they might not see the next step immediately. That said, Stellaris allows some steering of research through scientists' specialities (hiring a scientist specialised in Voidcraft increases chances of drawing ship-related techs) and through rare "drawing from a deck" events. The net effect is that long-term capability growth in Stellaris is a bit more exploratory; it requires adaptive planning. Players must be strategic about broadly progressing all fields to some extent (so as not to be crippled by a missing tech in one area), while also pushing key techs when the opportunity arises. This can lead to divergent technology profiles for different empires. For instance, one empire might accidentally leap ahead in robotics while another excels in propulsion, adding a dynamic asymmetry to gameplay. One playthrough might see an empire unlock advanced shields and weapons early (dominating militarily), whereas another playthrough with identical initial conditions might yield advanced economy techs first (allowing faster expansion). From a planning perspective, Stellaris' tech system emphasises resilience and opportunism: plan for the long haul but must adjust tactics based on what innovations become available. This mirrors real-world innovation strategies in uncertain R&D environments, where companies have roadmaps but must remain agile when research yields unexpected results or when certain breakthroughs take longer than anticipated.

In Europa Universalis IV, the technology progression is more linear and tied to time and resources in a deterministic way, supplemented by an Ideas system that provides branching choices. EU4 has three technology categories: Administrative, Diplomatic, and Military tech. They increase in level sequentially from 0 upward by expending monarch power points. There is no branching within these tech tracks: each tech level is a number (e.g. Diplomatic Tech 15) that unlocks specific new units or bonuses, and all nations typically progress through the same levels (though at different paces). Thus, the "tech tree" in EU4 is essentially a straight line for each category, with important breakpoints (for example, Military Tech 5 might grant new infantry units, Tech 7 new artillery, etc.). However, EU4 introduces choice and specialisation through Idea Groups. Idea Groups are sets of bonuses that players can unlock (spending the same monarch power resources), which branch into different areas like Economic (boosting taxation and production), Offensive (enhancing army strength), Naval, Trade, Exploration, Innovative, etc. Each nation can adopt a limited number of idea groups over the course of a playthrough, and each group has a tree of ideas that must be unlocked sequentially. For example, choosing the Exploration Ideas group allows a player to unlock, step by step, abilities like hiring explorers, increased colonial range, and faster colonists, crucial for a colonial empire, but if one takes this path, they might forego an army-focused group like Defensive Ideas for some time. In essence, EU4's technology system combines a fixed incremental backbone (everyone will eventually reach level 32 in tech if the game goes that long) with a customised branch of capability enhancements via ideas. The gameplay impact is that players face strategic decisions on how to spend their finite monarch points: whether to tech up immediately or invest in ideas, and which ideas to prioritise. Falling behind in the core tech levels can be dangerous, meaning there is a constant tension between short-term needs (keeping up in tech to avoid immediate disadvantage) and long-term development (pursuing ideas that yield economic or military advantages later). For instance, spending administrative points on Administrative Tech vs using them to unlock an Economic idea that will boost income. The former might give an instant benefit like unlocking a new building type, while the latter could compound benefits over time. This reflects a gameplay trade-off between maintaining parity in basic capabilities and building unique strengths for the future.

Across HOI4, Stellaris, and EU4, the technology tree mechanic shapes long-term strategy by enforcing staged growth and prioritisation. In all cases, players start with relatively modest capabilities and must decide how to allocate scarce research resources (be it research slots and time, monarch power or research points) to progressively unlock superior capabilities. Crucially, pursuing one path usually means delaying or forgoing others. A nation in HOI4 that pours effort into naval technology (e.g. better battleships and carriers) will, by necessity, lag in another area like air power or tank development due to limited research slots and time, which in the end it is a deliberate gamble that may pay off if wars are decided at sea, or backfire if air superiority turns out to be more critical. Similarly, a Stellaris player might focus on economy and expansion techs early at the cost of military tech, betting that they can secure territory and catch up militarily later, again, a risk if a war breaks out before the military tech is developed. In EU4, investing heavily in Diplomatic ideas (e.g. trade and colonisation) could leave one's army technologically behind an aggressive neighbour, posing immediate risks in wars. These trade-offs under uncertainty force players to weigh their strategy against possible future scenarios. Because none of the games allow a player to research everything at once, there is an implicit need to anticipate what capabilities will be most needed given the game context (geopolitical situation in HOI4, galaxy neighbours and threats in Stellaris, rival nations and goals in EU4). This is highly analogous to strategic planning in supply chain management. In SCM, companies also face constrained resources and cannot implement all improvements simultaneously; they must prioritise. For example, a company might have to choose between investing this year in a new warehouse management system versus expanding its transportation fleet. Pursuing one initiative may mean postponing another. Just as a HOI4 player might choose to focus on aircraft, expecting an air war, a supply chain manager might invest in faster logistics, expecting that speed to market will be the key competitive differentiator. Both are making a strategic bet under uncertainty about the future.

The tech tree concept in these games models real world capability development roadmaps remarkably closely. In practice, organisations build up capabilities in stages (Lockamy & McCormack 2004). For instance, a company could first implement basic data analytics, then more advanced forecasting tools, and later AI-driven decision systems, each step building on the last. Generally, a firm cannot skip straight to the most advanced system without laying foundations (just as the player cannot research jet engines in HOI4 without first developing basic aircraft engines). Indeed, maturity models in SCM literature, such as the Lockamy & McCormack (2004) process maturity model, explicitly describe levels of progression from ad-hoc processes to fully integrated supply chains. These models argue that firms progress through defined stages. In the aforementioned case, it goes “Ad hoc → Defined → Linked → Integrated → Extended”, meaning that each stage provides the necessary experience and infrastructure to move to the next. The games’ tech trees similarly require players to master earlier tech before the next becomes available, and this staged progression encourages an iterative learning approach. For example, in Stellaris, a player might unlock basic automation (droids) and learn to integrate them into their economy before the game offers the option to research full AI. In doing so, the player understands the value and limitations of droids, which prepares them to leverage more complex robotic workers later, analogous to a process comparable to a supply chain manager implementing a basic warehouse automation system and then scaling up to a fully automated distribution centre once the team is comfortable with the technology. The delayed payoff inherent in tech trees is another parallel: investing in a research now often yields benefits only down the line. In the games, researching an expensive technology may not impact gameplay until a future conflict or scenario where it can be used. Similarly, a supply chain innovation (e.g. a new planning software) might not show its true value until a peak season or a disruption occurs, revealing the benefit of that prepared capability.

While all three games enforce the notion of sequential capability building, the differences in their tech tree designs lead to different gameplay experiences and strategies. HOI4's clear visual tree structure (with branching and mutual exclusivity) puts emphasis on strategy alignment, meaning the player decides on a path and commits to it. Stellaris' partly random tech draw system emphasises adaptability, having a strategic direction in mind, but must constantly adapt to the order in which technologies become available, which can simulate the unpredictability of real technological innovation. EU4's linear tech with additive idea branches emphasises a balance between staying up to date (tech levels) and differentiation (ideas). These differences also affect how player decisions feel: in HOI4, there is often a significant opportunity cost to each tech choice, which adds weight to the decision. In Stellaris, opportunity cost is present (researching one tech means you're not researching others at that time), but the randomness injects a bit of forced opportunism; sometimes the game decides what is not available to the player yet, so you shift focus. In EU4, the opportunity cost is largely in resource allocation: the player can eventually have most things (all tech levels and many ideas by end game), but allocating resources sub-optimally might create a situation of lagging when it matters most. Despite these nuanced differences, the overarching theme is consistent: progression systems require foresight and prioritisation, core tenets of strategic management.

In conclusion, the Technology Tree mechanics in HOI4, Stellaris, and EU4 guide the long-term evolution of player capabilities and directly reward effective strategic planning, much like capability development in SCM. They all ensure that gameplay involves not just short-term tactics but also an ongoing investment in future advantages. The need to choose a path under uncertainty mirrors how supply chain planners must make investment decisions without complete foresight of market changes or disruptions. By comparing these implementations, a common principle emerges: gradual, managed growth of capabilities is key to success. The differences in implementation, whether it is branching versus linear or deterministic versus random, collectively offer insights into various ways to handle strategic development. For instance, HOI4's model underscores the impact of committing to a strategy (and the risk/reward of specialisation), Stellaris demonstrates innovation under uncertainty, which can be compared to navigating emerging technologies in an R&D portfolio, and EU4 highlights the importance of maintaining core competencies (tech levels) while selectively innovating (ideas). For a supply chain context, these translate to lessons about focusing on core process improvements while also pursuing differentiators and being adaptable in execution. Ultimately, the tech tree analysis reveals that structured progression mechanics in games serve as an engaging analogue for strategic capability-building in business, reinforcing how deliberate planning and prioritisation can shape outcomes over the long term.

5.3 Comparison with Literature

This section forms the empirical evidence collected in sections 5.1 and 5.2 (in-game behaviour) against the theoretical pillars assembled in Chapter 2. The discussion is organised around (1) information-management behaviour under Fog of War, (2) capability-building behaviour in Technology Trees, and (3) the engagement-and-learning effects of rich game mechanics. In each subsection, the data are first summarised, then interpreted through the relevant literature lens, and finally extended where the findings suggest a refinement of extant theory.

5.3.1 Information Management & Visibility

Based on the empirical evidence, the questionnaire items Q9-Q13 capture players' attitudes to uncertainty. Nearly two-thirds (62%; 232/374) rated "exploring unknown areas and reducing the Fog of War early" as either important or very important (scores 4–5 on Q9). A still larger share, 86.6% (324/374), consciously invested resources (scout units, sensors, diplomatic actions) to gain additional map information (Q12). Conversely, 30% (112/374) reported that information gaps frequently or very frequently harmed their strategic decisions (Q10). Gameplay logs corroborate the survey: players who delayed reconnaissance typically incurred avoidable troop losses or inefficient routing, mirroring the bullwhip-style surprises documented in section 5.2.1.

Regarding the literature analysed, these patterns map neatly onto the visibility gap highlighted in section 2.3, where only a minority of firms possess end-to-end supply-chain transparency (te Lindert 2024). However, according to Alicke et. al

(2023), 79% say they have at least a dashboard that stitches together data across functions, which is evidence that visibility tools are spreading, but depth and data quality still lag. In industry, that gap has triggered heavy investment in GIS-based dashboards, IoT sensor streams, and, most recently, digital twins that promise a “single source of truth” (Döhrmann, Gesing & Ward 2019). DHL’s customer-facing twin, piloted with Tetra Pak, and Maersk’s NeoNav control-tower platform exemplify the same logic the players exhibited, by trading short-term resources for superior situational awareness (DHL Group 2019; te Lindert 2023; Maersk n.d.b). In game and practice, visibility operates less as a luxury than a strategic asset whose marginal value rises steeply when the environment is volatile.

The nuance the games’ mechanic add is in how transparency is obtained. Visibility is earned: every new tile of map data has an explicit opportunity cost, forcing players to weigh reconnaissance against competing upgrades. By contrast, real-world dashboards often present visibility as a binary deliverable once the software license is paid. The collected data suggest that decision-makers benefit from experiencing the trade-off curve directly. Embedding “visibility-for-resources” mechanics, in effect, a gamified ROI calculator inside digital-twin interfaces, could sharpen managers’ intuition about where incremental data spend truly pays off. Thus, the empirical findings support the literature’s emphasis on transparency while enriching it with a behavioural insight: visibility is valuable precisely because it is scarce and has to be prioritised.

5.3.2 Capability Building & Strategic Planning

The questionnaire data suggests that technology development was pivotal to strategy. Fully 88.3% of respondents (330/374) rated researching new technologies as important or very important to enjoyment and success (Q4). A combined 81% sharp (303/374) reported that they either always or generally devise an initial research path before the game begins (Q5), confirming a maturity-model mindset. Adaptability also featured strongly: 38% (143/374) claimed to change research plans often or very often in response to unforeseen events (Q6). Section 5.2.2 documented how these choices crystallise at discrete Decision Points in the tech tree: opting for resource-efficiency upgrades delays defensive technologies, and vice versa.

This pattern closely reflects Lockamy & McCormack's (2004) staged-capability model, in which firms advance sequentially from ad-hoc to optimised processes. The tech tree visualises that staircase: prerequisite nodes must be unlocked before higher-order capabilities are available. Moreover, the trade-off between rapid economic output and defensive redundancy maps onto the well-established efficiency-resilience dilemma in SCM (Pettit, Fiksel & Croxton 2010). Players who maximised early throughput suffered disproportionately when ambushed, illustrating empirically the risk of overly lean configurations. Each branch of the tech tree is a living "future-state lane" in value-stream-mapping terms: it captures flow, inventory posture, and enabling technologies in a single glyph, translating VSM's static icons into an interactive roadmap (Tyagi & Vadrevu 2015; CreateASoft n.d.; Azaletskiy 2024).

Conceptualising a "decision-points based" SCM focus tree (Figure 7) foregrounds path dependence more vividly than traditional maturity grids or ROI spreadsheets. Each node in the diagram represents a capability gate; a solid arrow indicates the chosen branch, while the dashed arrow shows a now-locked alternative, visually signalling the opportunity cost of that decision. Once a deep branch is chosen, alternative branches become cost-prohibitive for several turns; the same is true when a firm selects, for example, a single-sourcing philosophy that later constrains multi-sourcing agility. Embedding tech-tree-style roadmaps into digital-twin toolchains would allow people within the industry to see how committing capital expenditure to automation today pre-configures tomorrow's strategic options. In essence, the empirical findings both validate and operationalise the literature by confirming staged development and trade-off theory while demonstrating a tangible interface that could improve strategic foresight.

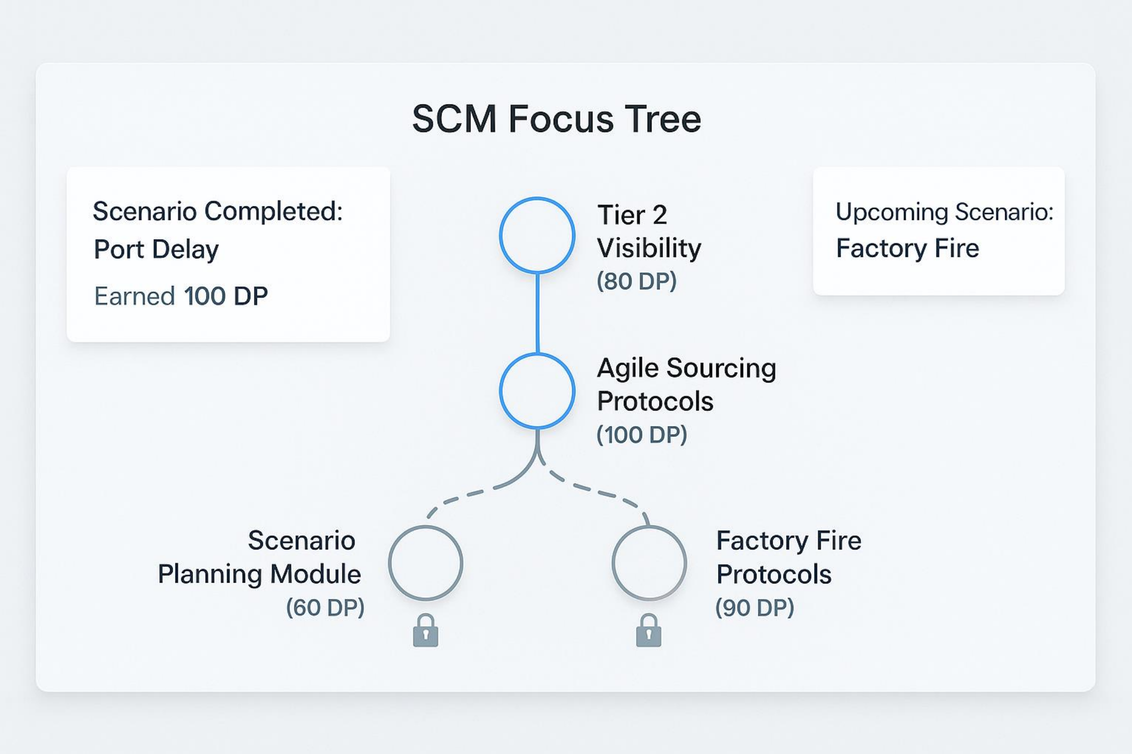

Figure 7. SCM Focus Tree

5.3.3 Engagement & Learning

Players' behavioural metrics underscore the pedagogical power of complex mechanics. High levels of engagement were evident, with over 50% of respondents averaging over one thousand hours (Annex 5). This significant investment of time suggests deep immersion in the games' systems. Furthermore, the gameplay intrinsically presented complex trade-offs analogous to those in supply chains, albeit not straightforwardly, allowing players to experientially learn the consequences of decisions, such as the costs associated with late visibility or the ripple effects stemming from mis-sequenced research, through direct feedback and outcomes within the games themselves.

These outcomes resonate with Self-Determination Theory and contemporary gamification research (Werbach & Hunter 2012; Hamari, Koivisto & Sarsa 2014), which argue that competence, autonomy and relatedness drive sustained engagement. Chapter 2.1 mentioned analogous performance gains from Deloitte's Leadership Academy, while Chapter 2.2 documented morale boosts from Amazon's Fulfilment-Center games (Joy 2018; Wollenhaupt 2021). Most importantly, the key takeaway is that advanced game mechanics, such as those dealing with uncertainty or staged upgrades, allow players to engage with (like managing uncertainty or staged upgrades) supply chain concepts to become part of the motivating gameplay itself. This means users are not just engaged, but are also genuinely learning.

5.3.4 Synthesis

The table summarises the key alignments and extensions presented, linking the foundational concepts from Chapter 2, the empirical evidence from the survey and game analysis (Chapters 5.1-5.2).

Theoretical pillar	Proof from Chapters 5.1-5.2	Theoretical Contribution
Visibility & Mapping tools	62% prioritise early exploration; 86.6% invest resources for data.	Confirms the strategic value of transparency Introduces “earned visibility” as a concept, highlighting explicit ROI trade-offs for information.
Staged Capability & Resilience trade-offs	81% of players pre-plan research paths; game mechanics enforcing path dependence and lean-vs-buffer tensions were observed.	Empirically illustrates principles analogous to Lockamy & McCormack’s (2004) staged development and the Pettit, Fiksel & Croxton (2010) efficiency-resilience trade-off.
Gamification motivation & learning	High engagement evident (>50% of players with over 1000 hours playtime). Gameplay intrinsically presented SCM-analogous trade-offs, facilitating experiential learning of consequences.	Reinforces findings from gamification research such as Werbach & Hunter (2012) and Hamari et al. (2014) on motivation. Demonstrates complex game mechanics can convey systems thinking relevant to SCM, potentially surpassing benefits of simpler reward-based schemes.

Overall, the data support the central claims of Chapter 2 while extending them in two respects: (1) visibility is most persuasive when its acquisition cost is palpable, and (2) capability evolution is more intelligible when rendered as branching, each carrying significant implications. These insights suggest that next-generation supply-chain decision platforms should integrate earned-visibility and decision-point mechanics alongside traditional analytics, thereby aligning behavioural engagement with optimisation, which is an integration explored further in Chapter 6.

6 DISCUSSION

6.1 Addressing Supply Chain Disruptions

This section aims to connect the Fog of War and Technology Tree findings to the thesis's central question: "How can gamified mapping tools improve decision-making to reduce risk in global supply chains?". Building on the conceptual framework of section 3.4, the game analyses are examined through two complementary lenses. First, the potential for improved information management and uncertainty handling, drawing from the Fog of War analysis; and second, the enhancement of strategic capability planning and resilience building, informed by the Technology Tree analysis. In essence, this is done by exploring how "earned visibility" and "tiered progression", which are two game-inspired ideas, map onto a layered supply chain model (Core-Middle-Shell) to address disruptions systematically. The following discussion applies these lenses to three common supply chain shocks (resource shortages, route delays, geopolitical risks) and shows how each leads to better decisions and mitigates risk.

6.1.1 Enhancing Decision-Making through Visibility and Uncertainty Management (Fog of War)

Chapter 5's player survey and game analysis underscored that visibility is valued as a strategic asset. For example, over 60% of respondents rated early exploration of unknown regions as important (Appendix 12), and an even greater majority willingly invested resources (scouting, sensors, data tools) to reduce information gaps (Appendix 15). Contrarily, nearly one-third reported that missing information had frequently harmed their in-game decisions (Appendix 13). These findings suggest that players react strongly to uncertainty. Players treat missing data as a penalty and see active intelligence gathering as essential. In supply chain terms, this maps directly onto the "Fog of War" idea: incomplete visibility forces cautious, suboptimal choices, whereas earned information unlocks better options.

- **Resource shortages.** The Fog of War concept implies that hidden supplier or inventory details can blindside a manager facing a shortage. A gamified map might initially obscure second-tier suppliers or alternate materials. As the user engages, the map gradually reveals hidden nodes. In practice, this means that tackling a raw material shortage would unlock deeper supplier-network visibility. Managers would uncover alternative vendors or substitute resources that were previously "under fog". This earned visibility parallels the way strategy-game players unlock map regions by investing in scouting, as described in Chapter 4.3.1 and analysed in Chapter 5.2.1, teaching that proactive information-seeking can pre-empt stockouts. In the Core-Middle-Shell model, the Core is the actual supply network (with its unknown bottlenecks), the Middle (digital twin layer) applies a Fog of War overlay to highlight blind spots, and the Gamification Shell motivates the user to "lift" the fog. By rewarding exploration, the gamified tool turns visibility into a reward mechanism, ultimately leading to more informed sourcing decisions and fewer unanticipated shortages.

- **Route optimisation.** When primary shipping lanes become congested or disrupted, the Fog of War mechanic encourages users to explore alternatives. In a gamified map, for example, a major port closure or highway delay might appear as a grey or obscured region until the player actively investigates. As the player reroutes or "scouts" new paths, the interface reveals secondary routes (e.g. smaller ports, rail links, or cross-border corridors) that were initially hidden. This mirrors how HOI4 or EU4 players dispatch scouts to reveal terrain under fog. For supply chains, this means a logistics manager can simulate a blocked route and gradually uncover less obvious, but faster or more resilient corridors. According to the conceptual framework, the Middle digital twin layer provides this interactive routing sandbox, and the Gamification Shell incentivises testing alternatives. The clear insight is that by forcing the player (manager) to deal with limited visibility and actively seek information, the "game" teaches flexibility. This means better routes become visible only through exploration, leading to smarter rerouting decisions in real operations.

- **Geopolitical risk.** Sudden political events or regional instability often hit without warning, much like an enemy army emerging from unexplored territory on a strategy map. The Fog of War analogy suggests that until an area is "mapped" or monitored, its risks are unknown. A gamified tool could initially blur out politically volatile regions of a supplier map. If the player invests in geopolitical "intel" (analogous to building spies or radar in the game), new data flows in, such as local supplier statuses, tariff changes, or conflict alerts appear. For instance, diversifying production into a new region might require uncovering hidden infrastructure or regulatory details. By modelling this as a Fog of War layer, the simulation rewards early diversification and reconnaissance actions with better foresight. This aligns with Chapter 3.4's notion that the Mapping Layer activates systems thinking: as users expand visibility, they link core processes (Plan, Source, Deliver) across regions. Ultimately, by reducing uncertainty through earned visibility, the manager can hedge geopolitical risk, making decisions based on fuller information and thus reducing exposure to surprise disruptions.

By integrating these aspects, the Fog of War approach can improve real-world decision-making. In the Core-Middle-Shell conceptualization, the Core (the real supply chain data) provides the truth that must be visualised; the Middle (digital twin) uses a Fog of War interface to translate hidden dynamics into an actionable model; and the Shell (gamification layer) encourages the user to reveal more of the map over time. This synergy means managers learn to value information. They face "foggy" scenarios in the simulation and receive feedback as they clear the fog. As a result, when a disruption occurs, people in the position of making decisions are better prepared (having already practised under uncertainty) and make choices that proactively reduce risk.

6.1.2 Strengthening Risk Mitigation through Strategic Capability Planning (Technology Tree)

The analysis done in Chapter 5 similarly showed that players treat long-term progression as crucial. Nearly 90% of respondents rated strategic technology research as important (Appendix 7), indicating they view capability development as the prime lever of success in the game. Moreover, most players approached the tech tree with a general plan but remained flexible: about 80% had at least a loose research strategy (Appendix 8), and many frequently revised it; more precisely, 38% changed plans often (Appendix 9). These findings illustrate a clear, forward-looking mindset. Gamers balance immediate gains with unlocking future capabilities, which is a lesson that directly parallels corporate strategic planning under uncertainty.

- **Resource shortages.** The Technology Tree suggests planning for redundancy before a crisis hits. In practice, this could mean investing in backup inventory systems or flexible manufacturing technology ahead of a shortage. A gamified map might emulate this by unlocking an upgrade (e.g. a “secondary supply module”) after the player reaches a certain level or earns enough points. This mirrors games where a tech unlock provides alternative production or storage capacity. For example, if a simulated factory experiences a stockout, the user could use previously unlocked “redundancy tech” to maintain supply. The branching structure, as exemplified in Figure 7, where choosing one path would make another temporarily inaccessible, illustrates how making a strategic choice, such as investing in a hypothetical “secondary supply module”, locks in certain redundancies before a shortage occurs. In a real SCM context, this encourages decision-makers to allocate budget now (in the simulation) to open future options (like extra suppliers or modular equipment). Within the Core-Middle-Shell model, the Core process (Sourcing, Inventory) is strengthened by new capabilities, the Middle digital twin models these upgrades (e.g. showing how safety stock cushions outages), and the Shell layers on the reward of unlocked redundancy. Thus, Tech Tree planning teaches proactive investment: by investing “tech points” (“Decision points”) early, managers can mitigate future resource shortages.

- **Route optimisation.** Tech unlocks in the game can represent advanced logistics solutions in real life. For example, as the player progresses, they might unlock an “AI routing algorithm” or access to additional ports. These correspond to a manager expanding analytics or diversifying infrastructure. In a gamified map, using earned “tech points” (“Decision points”) could activate features like automated route optimisation or real-time traffic forecasting. If a disruption blocks a major route, an unlocked capability might instantly reveal alternative paths or optimise remaining ones. Applying this to global logistics, firms might sequentially invest in digital twin enhancements (e.g. live sensor networks, predictive algorithms), which are exactly the kind of upgrades modelled by tech-tree progression. Conceptually, the Middle layer would simulate how an AI tool improves delivery planning, while the Shell provides the structured unlock mechanism that guides the user to build such tools over time. The key insight is that strategic "tech" planning allows one to pre-emptively diversify routing options, making the supply chain more robust against future delays.

- **Geopolitical risk.** Branching out into new regions often requires building local capabilities. In the tech-tree analogy, the player might unlock region-specific upgrades (e.g. cross-border logistics, local warehousing) after committing to a research path. This encourages preparing for geopolitical shifts by investing in alternative hubs or distributed networks. For instance, a manager using the simulation might unlock the ability to stock products closer to unstable markets or to source locally as a reward. In SCM terms, these are analogous to developing regional supplier bases or dual sourcing strategies. The conceptual framework ties in here: the Core supply chain gains built-in redundancy (e.g. multiple regional nodes), the Middle twin shows how those redundancies dampen geopolitical shocks, and the Shell motivates building them through visible progress bars or scorecards. Ultimately, tech-tree driven planning teaches that building capacity in advance is valuable, even if not immediately used. The game rewards delayed gratification with more options later, just as real companies can deal with political disruptions by having prior investments in alternate regions.

By reinforcing strategic planning, the Tech Tree mechanic can enhance long-term resilience. Under the Core-Middle-Shell model, gamified mapping directs the user's attention to capability development (shell), simulates the impact of those capabilities on operations (middle), and aligns them with core performance metrics. The result is improved readiness. Supply chain professionals learn to view budget or time spent on "upgrades" not as a cost, but as unlocking strategic options. In concrete terms, a manager who has practised unlocking redundant plants or analytics tools in the game will be inclined to support similar investments in real life. Thus, tech tree planning in the simulation can lead to actual firms building the process redundancies and flexibility that mitigate disruptions, closing critical gaps before they become crises.

6.1.3 Synthesis

Game-Inspired Lens	Key SCM Benefit Derived	Alignment with Core-Middle-Shell Model	Impact on SCM Decision-Making & Risk Management
Fog of War Lens	Improved situational awareness through earned, interactive visibility.	Shell motivates engagement with Middle for Core visibility.	Faster, more informed decisions under uncertainty; increased agility.
Technology Tree Lens	Strategic foresight and proactive investment in resilience and innovation.	Shell guides capability development in Middle impacting Core.	Better preparedness for disruptions through preemptive capability building; clearer understanding of strategic trade-offs.
Combined Insights	Enhanced SCM preparedness, agility, and informed decision-making.	Shell motivates deeper engagement with Middle layer, improving understanding and management of the Core.	More effective risk mitigation and response through improved information and strengthened capabilities.

6.2 Integration of Gamified Mapping into SCM Workflows

Building upon the insights from Chapter 6.1, which highlighted how Fog of War and Technology Tree mechanics can address supply chain disruptions, this section concentrates on the practical integration of gamified mapping tools into standard SCM workflows. Utilizing the Core-Middle-Shell model from Chapter 3.4 as a guide, the subsequent discussion examines how these tools can become part of the daily toolkit for SCM professionals. This directly addresses the remaining aspects of the main research question, meaning the improving decision-making and reducing risk in ongoing operations, alongside how game features enhance predictions (SQ1) and how tools can be customized for specific risks (SQ2).

The Core-Middle-Shell framework ties together three layers in a reinforcing loop. The Core layer represents the factual supply chain data (data truth), the Middle layer provides a dynamic digital twin of the supply chain (living model), and the Shell layer adds game-like motivational elements (playful motivator). In practice, the Shell's design, whether it is through points, challenges, feedback, etc., encourages the user to return frequently to the Middle layer's interactive map. That map continuously reflects the true state of the Core data, so each interaction is grounded in reality. In effect, the Shell motivates the user to engage with the Middle model over and over, and the Middle presents the Core's data in a hands-on format. This synergy ensures that sustained engagement is always linked back to actual supply-chain information, creating the foundation for the benefits of integrating such a tool into SCM workflows.

Integrating the aforementioned framework into an SCM workflow can enhance decisions by turning routine system interaction into a rewarding one. The Shell layer's gamified incentives motivate users to engage regularly with the Middle's supply-chain model, which in turn is continuously fed by the Core data. Frequent interaction builds familiarity with both the structure of the model and the underlying data. By framing supply-chain forecasting as a sequence of interactive challenges, individuals can experiment and learn without consequence. In effect, each game round serves as a mini experiment in which users set parameters (e.g. inventory levels, routing decisions), run the model, and then immediately see the results. This rapid feedback loop, which is common in games, can translate into more informed decision-making in the tool. Moreover, this familiarity is critical, as survey and game-analysis results showed that users highly value early data exploration and actively seek information. In other words, a gamified interface taps into natural human preference for information, so users learn to check the system often. As a result, managers using the tool become more aware of emerging risks and can mitigate them proactively.

6.2.1 Enhanced Predictive Capability (SQ1)

The enhanced predictive capability (SQ1) is strengthened by the framework, enabling interactive “what if?” scenario testing. The Shell’s game interface invites users to experiment with hypothetical events. In the Middle’s live model is linked to the Core data. This hands-on simulation trains planners to anticipate complex effects that are hard to see in static reports. Indeed, the Middle’s digital twin is explicitly designed to run thousands of hypothetical scenarios rapidly, showing projected impacts on metrics like service level or cost. By trying out scenarios and seeing the outcomes in real time, users internalise how the system behaves. For example, a user might simulate a sudden spike in regional demand and observe the resulting inventory shortages in the Middle’s model, helping the team to forecast the needed safety stock in advance. Over time, this experiential learning improves forecasting accuracy and confidence.

Real-time decision scenarios are also a key ingredient. In a gamified tool, the Core layer of the framework continuously ingests live data while the Middle layer runs a dynamic simulation to compute outcomes. The Shell layer then presents these outcomes as interactive feedback, with the possibility of further exploration. This cycle mimics the “flight simulator” approach: players make a choice, see its effect (queue length, stockout, cost change), and then choose again (Sterman 2014). Additional academic research shows this kind of iterative challenge loop helps users internalise complex dynamics (Arias-Vargas, Sanchis & Poler 2024). As outlined in Chapter 2.2, a long tradition of simulation games has provided learners with a risk-free setting in which to master core supply-chain concepts.

Furthermore, the concepts derived from the game analysis directly support enhanced prediction. The “earned visibility” inspired by the Fog of War mechanic, analysed in 5.2.1, suggests that predictive accuracy improves as users gain deeper insights into the system by successfully navigating challenges and actively seeking information. This is a behaviour mirrored in the survey, where 86.6% of players reported actively investing resources to gain visibility (Appendix 15). Similarly, the staged progression analogous to Technology Trees (Chapter 5.2.2) allows users to unlock more sophisticated predictive tools or analytics within the simulation as their competence grows. This aligns with the survey finding that exploration feedback frequently influences subsequent capability investment (Appendix 10), linking information gain to improved future planning tools. For example, simulating a demand spike (Middle layer) might not only help forecast safety stock but could also reveal vulnerabilities, previously under “fog” or highlight the benefit of an unlocked analytical capability, a “tech tree” style upgrade.

Utilising these elements which have been drawn directly from the game mechanics analysed (Chapter 5.2) and supported by observed player behaviours (Chapter 5.1), the gamified mapping tool leverages real-time data (Core), dynamic simulation (Middle), and engaging, feedback-driven interaction (Shell) to enhance predictions (SQ1). Instead of relying solely on static spreadsheets, planners engage with an evolving digital model, uncovering hidden trade-offs and refining strategies through simulation. Essentially, the tool encourages exploration of alternatives, exposes risks early, and thus strengthens supply-chain predictions.

6.2.2 Customization for Regional Risks (SQ2)

Supply chains span diverse geographies, each with its own set of risk factors. Chapter 5 introduced the concept of an SCM Focus Tree (Figure 7), a branching decision roadmap inspired by the analysed grand strategy games. This tree can be used to customise content by region. For instance, the focus tree could have a branch for “Expand Operations”. If the player chooses to expand in a region with high political risk, the next nodes might unlock a risk dashboard showing stability indices and simulate scenarios like strikes or sanctions. By contrast, in a low-risk region, the user might proceed without interruption. In effect, each branch can represent a region-specific scenario or tool.

Concretising this, the following factors can be taken as examples:

- **Political instability.** In regions prone to unrest, the tool could make available a “Geopolitical Risk” node. Unlocking it might reveal a crisis-simulation mini-game (e.g. a labour strike or border closure) that the player must manage. The map interface could display a special overlay (e.g. heatmap of protest probabilities) and metrics (lead-time volatility, cost surges). This branching feature ensures that when operating in that region, planners are immediately aware of the local threat and have specialised data available.

- **Weak infrastructure.** For areas with poor roads or unreliable power, another branch might introduce alternate logistics options. For example, choosing a “Build Local Network” focus could unlock tooltips or scenarios about using smaller trucks or temporary depots. The gamified map might then visually highlight alternate routes or modes that become available. This teaches players that they need to invest in infrastructure workarounds when going down that particular path.

In both cases, a “fog of war” case can be implemented. Initially, low-confidence areas on the map might be greyed out or hidden, forcing the user to decide whether to gather more information or invest resources. As in the games, taking certain actions (e.g. paying for satellite data or local liaisons) can gradually reveal these unknowns. This incentivises exploration and models real uncertainty in places such as emerging markets.

These customisations fit into the Core-Middle-Shell model as follows. The Core layer will incorporate region-specific risk data. For example, indices of political stability, weather forecasts, and infrastructure quality. This data can come from external feeds (news, satellites, risk-rating services). The Middle layer then simulates region-specific disruptions: for instance, a queue model might stall if a road is blocked or a pricing model might spike if tariffs change. Finally, the Shell exposes these effects through the focus tree decision points and map interface. In other words, the tree's branches become interactive menus: selecting a particular branch triggers the corresponding simulation scenario in the Middle and shows tailored results to the user.

By layering regional data into the Core and branching outcomes in the Shell, the tool inherently answers SQ2. It allows supply chain managers to tailor their strategy to local conditions. Rather than a one-size-fits-all map, the game adapts itself: new capabilities and visualisations appear only when relevant. The result is a mapping tool that not only displays data but narrates a region's story through its gameplay. This approach aligns with best practices in risk management, such as the ISO 28000:2022, which emphasises local context and thus ensures that gamified mapping is useful across diverse geographies (DNV 2023).

6.3 Limitations of Gamified Mapping

After exploring the potential benefits of gamified supply-chain mapping in Chapter 6.2, several limitations need to be addressed. This section has the scope to identify the major real-world challenges, costs, and constraints in implementing such a system, complementing the methodological limitations discussed in Chapter 4.5. Examining the heavy infrastructure and financial demands, obstacles to user uptake, design pitfalls, and ethical concerns that could hinder the deployment of a gamified mapping platform.

6.3.1 Foundational Cost and Infrastructure Barriers

Developing a complex platform that involves gamified mapping tools, particularly one that incorporates a "living model" layer based on digital twin technology, involves significant foundational barriers related to cost and infrastructure. Integrating the necessary complex software, data management systems, and the digital twin itself inevitably imposes a tremendous financial obligation on adopting businesses. Studies focusing on digital twin adoption highlight that these systems necessitate a hefty initial investment, identifying "investment difficulties" as a primary construction-enterprise-related barrier. Furthermore, significant technology-related hurdles exist, such as ones in connecting disparate systems, ensuring different data platforms can work together (interoperability), and navigating the complexities of storing, processing, and analysing large datasets The problems stemming from the maintenance of these programmes also contribute to ongoing expenses, further complicating the adoption landscape. These combined financial and technical requirements represent substantial overhead for implementing advanced digital twin-based systems. (Opoku et al. 2023; West & Blackburn 2017; Madni, Madni & Lucero 2019; Rafsanjani & Nabizadeh 2021; Greif, Stein & Flath 2020; Boje, Guerriero, Kubicki & Rezgui 2020)

A prime example of a failed digital twin implementation was Google's Sidewalk Labs, which planned on creating a smart city twin for Toronto, which would later be implemented in real life. That failure underscored how technical, regulatory and cost challenges can derail advanced digital-twin initiatives. As a result, the need for extensive data collection, modelling expertise, proper computing infrastructure is crucial for the success of such an initiative. (Jacobs 2022)

6.3.2 User Adoption: Generational Considerations and Resistance

The survey data (Appendix 3) show that most participants (81.8%) were under 34, implying a heavy representation of Millennials, Gen Z, and even Gen Alpha. Younger professionals tend to welcome game-like tools, whereas older, experienced supply-chain managers may be wary of them. Empirical studies confirm this generational gap: one large corporate study found that generational differences in the workplace indicate that younger staff, notably those in Generation Z and Millennials, exhibit a stronger preference for gamification techniques than older employees and are much more likely to engage with a gamified app at work (Caserman et al. 2024). In contrast, older managers often view such tools with skepticism or discomfort. Resistance typically stems from a fear of change and uncertainty about relevance. For example, implementing gamified systems requires process changes and can cause anxiety and fear among those used to traditional workflows. Moreover, a lack of prior gaming or digital experience can lead some workers to dismiss the new interface as a gimmick. Overcoming these barriers will demand careful training and change management. In addition to teaching the supply-chain logic (inventory policies, lead times, etc.), organisations must train users on the game mechanics themselves (rules, goals, and controls). Without clear demonstrations of how game rewards tie to real performance, older staff in particular may be slow to adopt or may misuse the system. Basically, bridging generational attitudes is a fundamental challenge in any workplace gamification effort. (Panda 2024; Zizo n.d.)

6.3.3 Design, Effectiveness and Alignment Challenges & Ethical Aspects

Ethical issues arise when tracking and rewarding employee performance. Over-competition and constant scoring can increase stress or pressure. Gamification experts warn that excessively competitive systems often create a toxic atmosphere: if employees race each other for points, it can generate stress, burnout, and even unsportsmanlike conduct (Steele 2023). Employees may feel they are under constant surveillance, since every action is logged and scored, which raises privacy concerns. Certain reward designs are close to being manipulative by conditioning behaviour without the subject's awareness, similar to Pavlov's Classical Conditioning.

Daniel Pink's (2009, 34-52) work on motivation is a prime example of this case. If employees learn to seek points instead of focusing on core tasks, they may risk encouraging people to focus on maximising external rewards instead of developing intrinsic motivation from accomplishing the task itself. In practice, this means participants might chase high scores or leaderboards even when that conflicts with actual supply-chain goals. As a result, gamification elements must be tightly tied to genuine KPIs; otherwise, the "game" can drive users off-target, undermining the intended supply-chain improvements.

To address this, organisations must build safeguards in place. They should be transparent about what data is collected, allow opt-in participation, and ensure performance data is used responsibly. Failing to do so could erode trust or even violate data protection norms, making an otherwise promising tool ethically problematic.

6.4 Theoretical Implications

This section articulates the theoretical contributions of this research, centred on the Core-Middle-Shell framework as an analytical lens for gamified mapping in supply chain management. As developed in Chapter 3.4 (Figure 1), the framework layers real supply chain data (Core), an interactive digital twin (Middle), and a gamification outer layer (Shell) into a unified model. By explicitly linking game elements to decision-support models, it offers a new perspective on how motivation, learning, and performance interact. In this view, gamified mapping becomes more than a visualization tool. Rather, it becomes a structured environment where user engagement (motivated by game mechanics) drives exploration of the digital twin, which in turn yields insights into real SCM processes and KPIs.

6.4.1 The Framework as a Theoretical Contribution

The Core-Middle-Shell framework itself is a key theoretical contribution. Chapter 3.4 introduced this conceptual model for "gamified mapping", synthesizing gamification theory and SCM principles. On the gamification side, it draws on models such as the one illustrated by Hamari et al. (2014) that decompose gamification into implemented affordances, psychological outcomes, and behavioural outcomes. On the SCM side, it aligns with process-oriented models like SCOR by tying game goals to supply chain objectives, like reducing lead time, improving service level, cutting costs. The framework posits that if game-like features (Shell) are embedded in a comprehensive supply chain visualization (Middle), they can elevate user engagement and learning, which should translate into better strategic decisions in the Core (real supply chain).

In essence, it provides a formal structure: the Shell's motivational design (points, challenges, feedback) produces positive psychological outcomes, the Middle's digital twin activates systems thinking by visualizing interdependencies, and the Core layer ensures all gamified activities are grounded in actual logistics data. By uniting these layers, the model extends gamification theory into the context of SCM decision-making, and conversely enriches SCM theory with human-centred, motivational elements. This hybrid framework therefore advances theory by showing how user behaviour, simulation environments, and supply chain KPIs interconnect in a gamified context.

6.4.2 Measuring Impact (SQ3)

The proposed framework in Chapter 3.4, shows a structured approach to measuring the impact of a gamified mapping tool at three levels: (1) Shell (User Engagement); (2) Middle (Decision Quality and Learning); (3) Core (Supply Chain Outcomes).

At the first level, that layer is intended to boost motivation and engagement. Its impact can be measured by user-centric metrics such as frequency of use, time on task, completion of challenges, or survey scales of engagement and enjoyment. These correspond to the psychological outcomes in the gamification model. Thus, high engagement would indicate that the gamified affordances are effectively motivating users.

Then at the second level, The Middle layer is the digital twin simulation. Its impact is seen in decision quality and learning outcomes. This can be measured by performance in simulated scenarios. For instance, improvements in forecast accuracy, more optimal routing choices, or higher scores in scenario challenges. The theoretical rationale is that the Shell's challenges and feedback should induce deeper exploration of the model, leading to better informed and more strategic choices. One could measure changes in decision accuracy or strategy sophistication after repeated interaction with the tool, reflecting learning.

Finally, in the last level, the Core involves real SCM performance metrics. The framework connects game objectives to real KPIs (e.g. minimizing cost or delays, forecast accuracy, asset turns etc.). Meaning that the ultimate impact measures are operational outcomes: lead times, service levels, cost efficiency, risk exposure, etc. These could be evaluated through the simulation or real-world pilots. The framework predicts that by increasing visibility and training strategic thinking, the gamified tool should improve these Core metrics. For example, unlocking alternate suppliers in the game should map to fewer real stockouts. In summary, the three-level measurement approach nests engagement metrics (Shell), decision performance (Middle), and SCM KPIs (Core) into a coherent evaluation method.

6.4.3 Broader Theoretical Implications

The Core-Middle-Shell framework suggests a new direction for decision-support theory in SCM. By coupling a gamified front end with a live digital-twin back end, the model meshes naturally with established notions such as control-tower visibility and real-time analytics, yet it adds a motivational layer that keeps people interacting with the system on a routine basis. In practice, the digital twin becomes a “living model” whose dynamics are shaped not only by data streams and optimisation routines, but also by patterns of user exploration and learning. Recognising these behavioural influences encourages future SCM theory to treat interactive visualisation and feedback loops as integral enablers of systems thinking and resilience, rather than peripheral user-interface concerns.

Seen from the lens of gamification research, the same framework shows how game mechanics can be mapped systematically onto complex, data-rich decision processes. Drafting the Shell, Middle, and Core as distinct yet interlocking layers supplies a blueprint for assigning each mechanic a clear functional role: points motivate continued use, branching challenges steer strategic choices, and earned visibility reveals additional data that matters for KPIs. This layered design demonstrates that principles originally developed for morale or micro-task engagement can scale to enterprise-level simulations that move organisational KPIs. A finding that may guide future work in other complex contexts, such as healthcare planning, energy management, where the model’s emphasis on linking motivational design to systemic outcomes is likewise valuable.

By specifying how to measure effects at each layer and by validating the model through the Fog of War and Tech Tree findings, the framework strengthens both academic understanding and practical development of gamified SCM tools. Ultimately, it shows that embedding game design in digital twins can turn motivation into measurable improvements in supply chain decision-making, thereby advancing theory at the intersection of human-computer interaction and logistics management.

7 RECOMMENDATIONS

7.1 For SCM professionals

Building on the empirical findings and the conceptual framework developed in this thesis, several actionable recommendations can guide SCM professionals who wish to leverage gamified mapping for stronger, more resilient decision making.

1. **Promote simulation game**s. Seeing the “Living Model” described in Chapter 3.4 as a practice field. A short, game-style run-through of next quarter’s demand spike or a port closure lets people see cause-and-effect in real time. Thus, creating a situation in which thirty minutes in a guided scenario will teach more about system bottlenecks than three hours of slide review.

2. **Reward people for chasing visibility, not just for reporting on it**. The Fog of War results (sections 5.3.1 and 6.1.1) show that users dig deeper when extra information has to be earned. By setting up a control tower so that additional tier-two data, lane-level risk scores or alternative routings only appear after an analyst validates or enriches the baseline, curiosity will rise, and so will data quality.

3. **Map capability building like a tech tree**. By borrowing the logic behind the “SCM Focus Tree” (Figure 7), lay out in a set time frame the possible initiatives (e.g. dual sourcing, inventory segmentation, carbon tracking, etc.) as nodes that unlock only when prerequisites are met. This makes trade-offs explicit, allowing for enhancing strategic clarity and prioritization.

4. **Use game mechanics to bring every generation along**. Younger staff see progress bars and badges as normal feedback; senior staff want to know which KPIs moved. Good gamified can tools do both. Pair digital natives with experienced planners during experiments, so they can complement and learn from one another. The result is faster adoption and a

culture that treats continuous improvement as engaging rather than mandatory.

Collectively, these recommendations translate the Core-Middle-Shell framework into managerial practice. They encourage supply-chain professionals to view gamified mapping not as entertainment, but as an extension of decision-support theory.

7.2 For Software Developers and Tool Designers

Developers are encouraged to incorporate advanced game structures, such as progressive information access ("earned visibility") and branching capability roadmaps, into mapping applications. The Fog-of-War metaphor analysed in Chapters 5.2.1 and 6.1.1 shows that users willingly "work" for data when discovery is embedded in play; similarly, the Focus-Tree prototype (Figure 7) illustrates how decision nodes can visualise strategic trade-offs in capability building. Embedding these mechanics can transform abstract supply-chain constructs into concrete, navigable choices without compromising the analytical side.

Designing for intrinsic motivation is also key. Empirical work on Self-Determination Theory (Chapter 3.1) suggests that competence, autonomy and relatedness drive sustained tool use. Interfaces should therefore privilege clear feedback, meaningful choices and challenge levels calibrated to professional expertise. Extrinsic rewards (points, badges or leaderboards) remain useful, but only if they track authentic supply-chain outcomes (e.g. lead-time variance reduced, forecast error narrowed), rather than superficial activity counts.

The simulation engine (Middle layer) should operate as a low-risk sandbox in which planners can rehearse disruptions such as route closures, tariff shocks or capacity outages. Providing immediate, model-based feedback supports the predictive reasoning highlighted in Chapter 6.2.1, enabling professionals to internalise system behaviour rather than memorise static "rules of thumb".

Drawing from other real-life examples, complex systems often acquire new uses in the hands of committed communities. A pertinent analogy is CCP Games' decision to release an official Microsoft Excel add-in for EVE Online, after players had long exported data to spreadsheets to optimise in-game economies (Stanton 2023). Developers of SCM tools should likewise treat unexpected workflows as signals of unmet analytical demand, integrating popular "sidecar" practices into the formal interface rather than resisting them. For instance, the persistent use of ad-hoc spreadsheet models highlights this; a significant portion of SCM professionals report using tools like Microsoft Excel more frequently than any other specialised SCM software (Lopez 2018). Thus, suggesting that the accessibility and flexibility of basic spreadsheets often overshadow dedicated SCM systems for certain analytical tasks

For practical impact, the gamified tool must be grounded in real data (the Core layer). This means it should connect to live or historical supply-chain systems (ERP, IoT sensors, logistics databases) so that scenarios reflect actual constraints and metrics. However, implementing a "living" digital twin is technically challenging. As discussed in Chapter 6.3, detailed further in section 6.3.1, building a platform with a persistent simulation layer requires significant investment. Integrating diverse software and data sources entails substantial cost: studies note a heavy financial burden for the required infrastructure and data management. In practice, developers must plan for issues like system interoperability, large-scale data storage/processing, and ongoing maintenance, all of which add overhead. A pragmatic approach may be to start with limited pilots: for instance, link the tool to one or two key data feeds (such as order and transit data) before scaling up. Acknowledging these costs upfront and designing the tool to operate with partial data, while keeping it expandable, can help manage the technical burden of full integration.

Lastly, survey data (Appendix 3) and empirical data from studies such as the Caserman et al. (2024) confirm that younger individuals are comfortable with game-like interactions, yet experienced managers may prefer traditional dashboards. Dual onboarding pathways, such as guided tutorials for novices and expert shortcuts for veterans, can mitigate resistance identified in section 6.3 without diluting the motivational advantages of playful design.

7.3 For Future Research

The current research demonstrates that integrating Fog of War and Technology Tree mechanics within a dynamic digital twin environment has the potential to enhance engagement and strategic thinking in supply chain management. However, these two mechanics represent only a subset of the gamification elements available to system designers. A logical progression for future research involves testing a broader array of mechanics that continue to support the Shell-Middle-Core framework, the efficacy of which was indicated in Chapters 5 and 6. Potential mechanics for investigation include:

- **Adaptive Difficulty Loops:** These could dynamically adjust the intensity of scenario-based difficulties, thereby extending the optimal challenge levels observed in the Fog of War experiments.

- **Cooperative Quests:** In these scenarios, multiple planners or stakeholders would need to undertake joint actions to unlock new data layers or insights, reflecting an extension of the “earned visibility” dynamic discussed in section 5.3.1.

- **Time-Constrained Decision Rounds:** Introducing time pressure could compel rapid triage and decision-making, which is particularly useful for simulating real-world bottleneck situations where operational minutes are critical.

- **Outcome-Weighted Leaderboards:** To mitigate the risk of superficial “points-chasing” behaviour identified in Chapter 6.3, leaderboards could be designed to weight rankings based on the quality of decision outcomes rather than mere activity volume.

Each of these proposed mechanics could be evaluated using the engagement, decision quality, and operational impact metrics outlined within the framework presented in this thesis.

7.3.1 Cross-Domain Framework Implementation

Beyond expanding the range of mechanics within SCM, future research can also explore the applicability of the Core-Middle-Shell framework in diverse contexts. The fundamental principles of gamified interaction with digital twins may offer benefits in other fields. Some examples include:

- **Cold-Chain Healthcare Logistics:** Also known as hospital digital twins have the chance to benefit from the framework's adaptive difficulty features. They can be employed to simulate critical incidents such as vaccine spoilage shocks within a hospital's cold chain.

- **Smart City Mobility and Energy Planning:** Digital twins for cities are becoming more common place. However, only a small number are fully operational globally (Ferré-Bigorra et al. 2022). Such a municipal tool can integrate data from traffic systems, public transportation networks, and micro-grid energy distribution could serve as a platform for testing cooperative quest scenarios (e.g. inter-departmental sharing of sensor coverage for enhanced city-wide visibility) or branching narrative exercises (e.g. evaluating the long-term systemic impacts of investing in mass transit versus electric vehicle charging infrastructure). The challenges encountered in prior initiatives, such as the Toronto Sidewalk Labs project regarding data governance and significant cost hurdles, represent critical variables that the framework could assist in systematically identifying and addressing.

Further research across different domains can contribute to a deeper understanding of how gamified digital twin environments can be deployed to enhance decision-making, learning, and operational performance in more fields than just SCM.

7.3.2 Prototyping and Assessment via Game Mods

Creating a simple game mod for established grand-strategy titles, such as Hearts of Iron IV or Europa Universalis IV, represents a low-cost, low-risk test bed for the Core-Middle-Shell framework. These games already simulate complex logistics, trade and capability building, attract tens of thousands of active players and support via Steam Workshop distribution, giving researchers an instant, instrumented sandbox and a ready pool of players.

Because the vanilla rulesets contain mechanics that mirror key SCM constructs (Fog of War for visibility gaps and Technology Trees for staged capability growth), a minimalist mod can layer the thesis' original ideas on top rather than reinventing them. For instance:

- **SCM Focus Tree.** Branch choices in production or transport upgrades, mapped to realistic trade-offs (e.g. investing political power to unlock "Intermodal Freight Hubs").

- **Earned Visibility Toggle.** Dynamic reveal of in-game supply flows when players hit efficiency milestones, operationalising the "visibility as a reward" concept proposed in Chapter 4.

- **Behavioural Variables.** Simple scripts that impose convoy fatigue (attrition rising with overused sea lanes) or random embargo shocks, forcing players to re-route and exposing how they prioritise resilience vs speed.

Telemetry from such mods can log decision paths, response times and KPI deltas, lining up naturally with the Shell (engagement), Middle (simulation results) and Core (operational outcomes) metrics. Importantly, the grand strategy communities are already accustomed and eager for participation in similar projects, as the survey in this thesis has shown. Furthermore, that survey also successfully gathered several SCM-relevant insights from this audience, indicating that recruiting play testers and collecting mixed-method data will be straightforward.

In essence, a mod for one of those titles serves as an inexpensive "wind tunnel" for the framework. It would allow researchers to observe human behaviour under uncertainty, iterate on mechanic tuning in days rather than quarters, and de-risk subsequent full-scale digital-twin deployments. Data from such a test would strengthen the external validity of the model before a capital-intensive roll-out.

8 CONCLUSION

8.1 Summary of Key Findings

This research was guided by one main research question and three supporting questions, seeking to understand how gamified mapping tools can enhance decision-making and reduce risk in global supply chains. Survey data from 374 experienced grand-strategy players, alongside qualitative game analysis, provide convergent evidence. The results indicate that these tools can sharpen supply-chain decision-making by foregrounding information visibility through mechanics like the Fog of War, scaffolding strategic capability investment via systems similar to Technology Trees, and sustaining user engagement in crucial scenario exploration.

The main research question asked is: “How can gamified mapping tools improve decision-making to reduce risk in global supply chains?”. The findings suggest that by coupling uncertainty-management mechanics like Fog of War with staged capability progression akin to Technology Trees within an interactive map, users are effectively nudged to acquire missing data proactively, rehearse disruption scenarios, and strategically invest in resilience before shocks occur. For instance, the study found that the Fog of War mechanic successfully internalises the cost-benefit of information in risk mitigation, as evidenced by two-thirds of survey respondents (62%) rating early exploration of hidden zones (Appendix 12) as important and a significant 86.6% (Appendix 15) actively spending in-game resources to gain extra visibility.

Addressing the first supporting question, “How can video-game features like real-time decisions and challenges improve supply-chain predictions?”, the research found that the Fog of War challenge makes missing data particularly of value. Nearly a third of players (29.9%) reported that information gaps “frequently” harmed their plans (Appendix 13), and a majority (69.3%) chose to act immediately or hedge their positions rather than pause indefinitely when faced with uncertainty (Appendix 14). In a supply chain planning context, this observed player behaviour, a proactive response to incomplete information, maps to more rigorous hypothetical scenario testing and potentially faster, more adaptive forecast revisions, thereby strengthening predictive capabilities.

Regarding the second supporting question, “How can gamified mapping tools be customised to fit different regional risks, such as political instability or weak infrastructure?”, the study demonstrated that a branching SCM Focus Tree (Figure 7), inspired by game design, allows the simulation to inject region-specific stressors like political-risk events or infrastructure bottlenecks. This approach still rewards and leverages the same visibility-first behaviour observed in players. The survey highlighted a high readiness among players to tackle such bespoke regional modules, as 86.6% already choose to trade current resources for information (Appendix 15), suggesting they would willingly engage with and invest in uncovering information within modules that frame local risk as “fog” to be cleared.

Finally, the third supporting question asked: “What are the best ways to measure the impact of gamified mapping tools on supply-chain operations?”. As detailed in Chapter 6.4.2, a measurement scheme on three levels is proposed. This includes: (1) engagement metrics (e.g. repeat sessions, scenario completion rates); (2) decision-quality metrics within the digital twin (e.g. scenario scores, forecast accuracy in simulations); (3) operational KPIs in the live supply chain (e.g. lead-time reliability, inventory turns). Survey evidence on player habits, such as 81% of players starting with at least a loose research path for capability development (Appendix 8) and 38.3% revising these plans often in response to new information (Appendix 9), provides examples of behaviours that could be logged as decision-quality indicators within such a measurement framework in a future pilot.

Several cross-cutting insights emerge from these findings. Firstly, information visibility is highly valued by experienced players; 62% place high importance on uncovering the map early, 29.9% feel a frequent penalty when critical data are missing, and an overwhelming 86.6% will explicitly invest in-game resources for intelligence gathering. Secondly, capability planning is a habitual behaviour; a combined 81% of respondents formulate either a specific (25.9%) or general (55.1%)

multi-stage upgrade plan, indicating anticipatory strategic thinking, with 38% adjusting these plans “often” or “very often” as new data becomes available. Thirdly, sustained engagement supports learning; over half of the surveyed players have logged more than 1000 hours in the analysed game titles, demonstrating deep and prolonged interaction with complex, uncertainty rich environments. This level of engagement backs the potential of game mechanics to keep supply-chain professionals actively iterating on disruption scenarios and internalising complex system dynamics.

These empirically grounded findings confirm that the proposed Core-Middle-Shell design framework has the possibility to convert digital-twin dashboards from passive displays into interactive “decision dashboards”. Such a transformation encourages managers toward earlier data acquisition, more structured capability building, and risk-aware, iterative planning, all of which are key levers for reducing global supply-chain vulnerability and improve resilience (Mhaskey 2024).

8.2 Contribution to the Field

This paper makes valuable contributions to supply chain management theory and practice by utilising gamification insights and applying them to supply chain decision-making. Theoretically, it introduces and applies a novel conceptual framework (Core-Middle-Shell) that links specific gamification mechanics to key dimensions of supply chain decision-making. This model bridges game design elements such as Fog of War and Technology Trees with key supply chain concepts: information visibility, strategic capability building, and stakeholder involvement. By formally connecting these domains, the study expands existing supply chain management theory to account for how information availability and capability development (analogous to unlocking new “technologies” in a game) can shape decision quality. Thus, it offers a structured lens to understand how layered game mechanics, when mapped onto supply chain processes, help explain and improve decision-making under uncertainty while sustaining stakeholder participation during complex planning tasks.

Methodologically, the study employs an interdisciplinary methodology that combines quantitative analysis, qualitative insight, and scenario-based modelling. It integrates survey data from 374 respondents with a structured analysis of game mechanics and maps concepts from grand-strategy games into realistic supply chain scenarios. This blended method allowed for cross-validation of ideas. For instance, the questionnaire data gauged perceptions and impacts of gamified elements, while game-derived scenario mapping provided illustrative cases of how those elements function in practice. Such a mixed-method approach is rather new in supply chain research, borrowing analytical tools from game studies to complement conventional data analysis and yielding greater understanding of decision behaviours.

From a managerial perspective, the findings translate directly into practical design principles for supply chain optimisation tools and processes. The study shows that features like “earned visibility”, “capability planning via upgrade paths”, and “interactive feedback loops”, which have all been inspired by game mechanics, can be implemented in real-world supply chain systems to enhance performance. In practice, this means information is gradually revealed as certain conditions are met (echoing Fog of War), companies develop capabilities in staged increments (similar to a tech tree progression), and managers receive continuous, interactive feedback during decision-making (mirroring game feedback loops). The potential for these elements to support better decision quality and reduce risk is a key finding of this research (explored throughout Chapter 5 and 6), and section 6.4.2 specifically further details how this impact can be effectively measured. By demonstrating the potential of these game-inspired mechanisms to improve outcomes in a supply chain context, the research provides actionable guidance for managers with concrete examples of how to design more engaging and informative decision-support environments. Ultimately, this managerial contribution shows that complex global supply chain decisions can be supported by tools that not only analyse data but also motivate and guide human decision-makers, leading to more resilient operations.

In summary, the contributions of this research are threefold: (1) it enriches supply chain management theory with a new gamification-based framework; (2) it employs an innovative mixed-method approach for studying decision-making; (3) it delivers practical insights that can be applied to enhance supply chain decision making in real life. Together, these contributions demonstrate the value of gamified mapping for global supply chain optimisation, effectively bridging the gap between interactive game design principles and effective SCM practices.

8.3 Final Thoughts

This study was driven by a practical personal question: “Could the motivational logic of commercial strategy games strengthen supply-chain decision making?” The evidence proved it can. Questionnaire data and a structured mechanics analysis show that two familiar game devices, managing information scarcity (Fog of War) and sequencing capability upgrades (Technology Trees), reshape strategic behaviour when mapped onto supply-chain tasks. Participants consistently prioritised early data acquisition and staged resilience investment, mirroring best-practice risk-mitigation principles.

The inquiry also highlights a striking implementation gap. While aerospace and city planning sectors already operate comprehensive digital twins, many supply-chain teams still play with multi-billion dollar flows in spreadsheet environments. The contrast is notable given that leading logistics brands such as Maersk and DHL actively sponsor eSports tournaments, signalling cultural readiness for more interactive decision tools. Yet, comprehensive, gamified SCM platforms remain the exception rather than the rule.

The Core-Middle-Shell model developed here demonstrates how game-derived mechanics can be embedded in supply-chain mapping to convert passive dashboards into engaging “risk laboratories”. Features such as earned visibility unlocks and tiered capability paths make complex networks more transparent and actionable for a digitally native workforce, while reinforcing disciplined data gathering and planning. Integrating these elements promises a double reward: sharper operational insight and sustained user engagement. In an era of escalating volatility, supply-chain resilience will depend as much on the inherent nature of human curiosity and adaptability as on algorithmic power; gamified mapping offers a practical bridge between the two.

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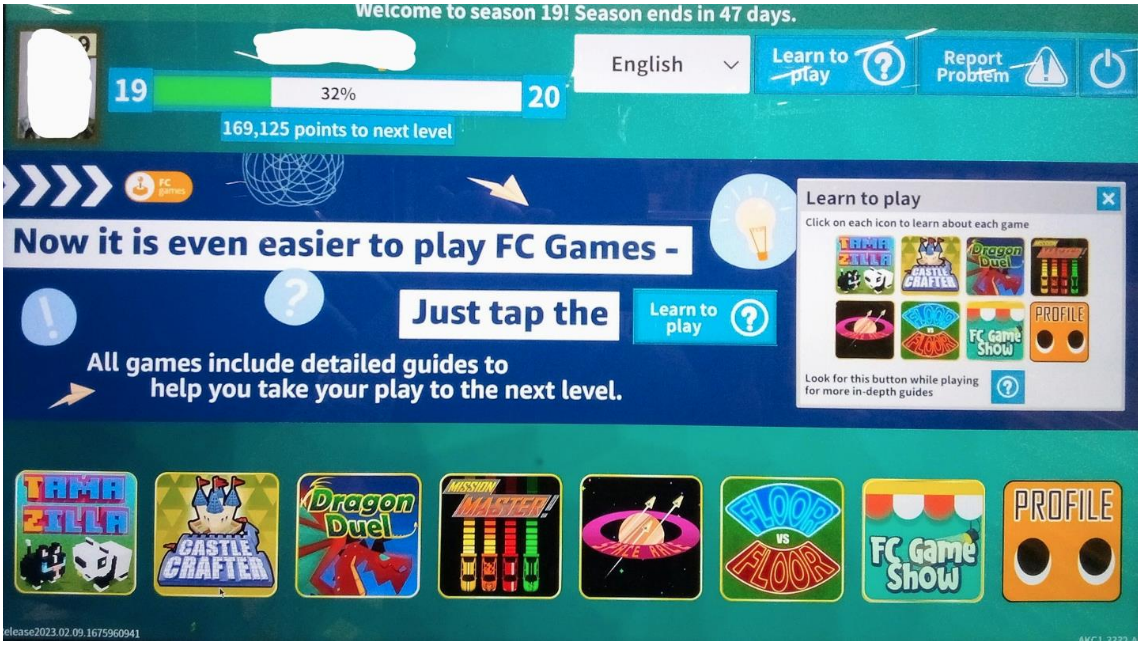
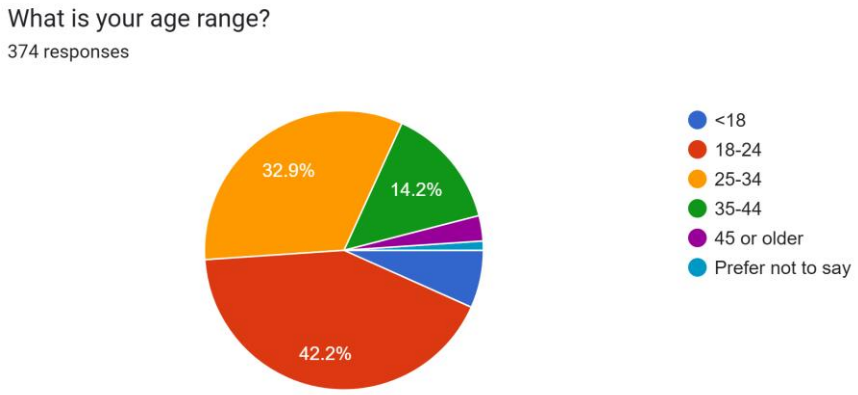
APPENDICES

Appendix 1. Amazon FC Leaderboard interface (u/yenedakine 2023)

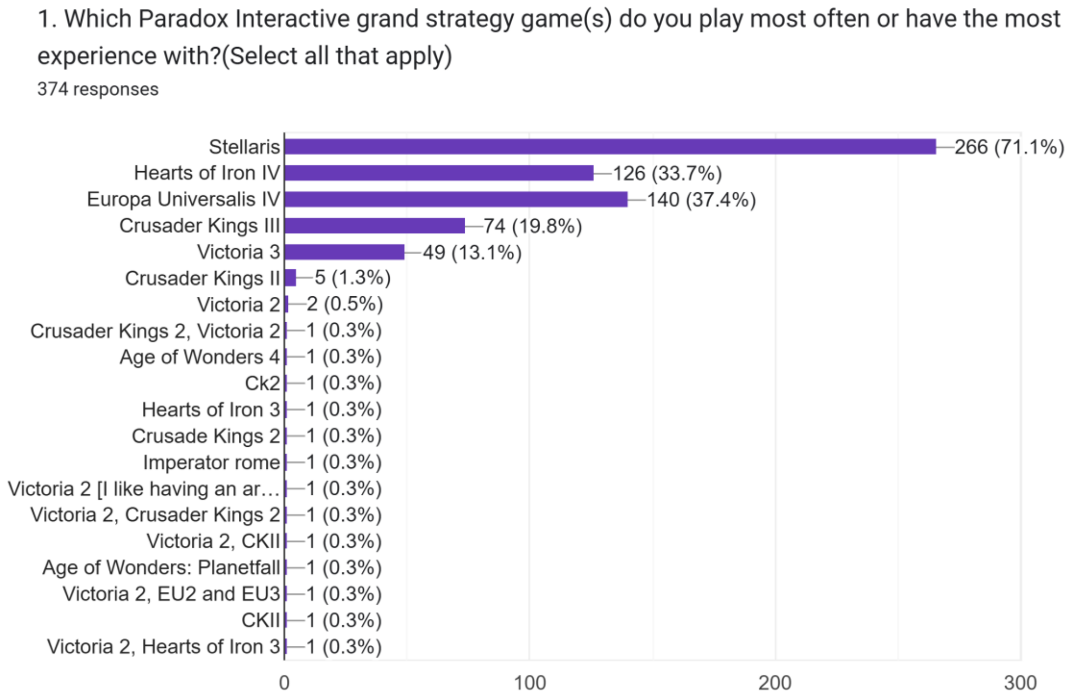
Appendix 2. Amazon FC Main Menu Interface (Atari365 2023)



Appendix 3. Age Distribution

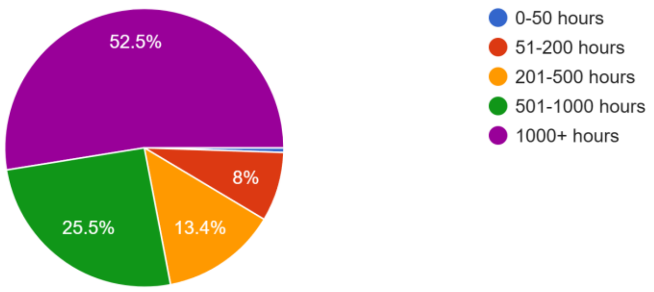


Appendix 4. Gaming Experience - Q1

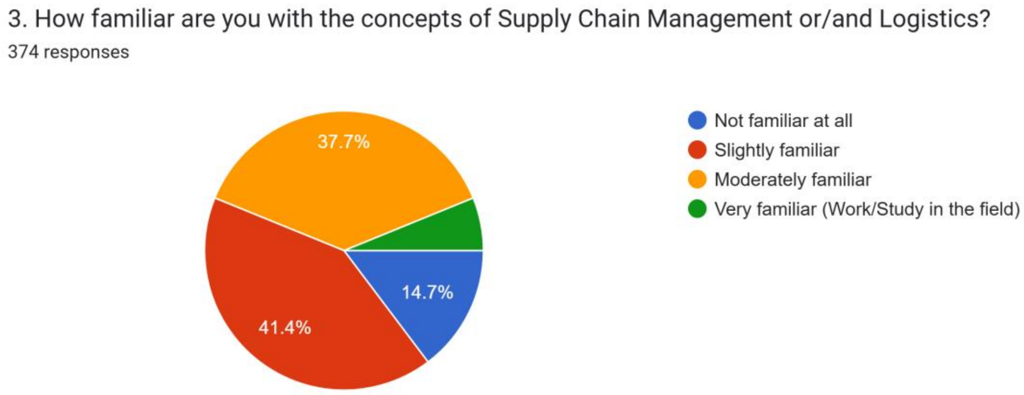


Appendix 5. Gaming Experience - Q2

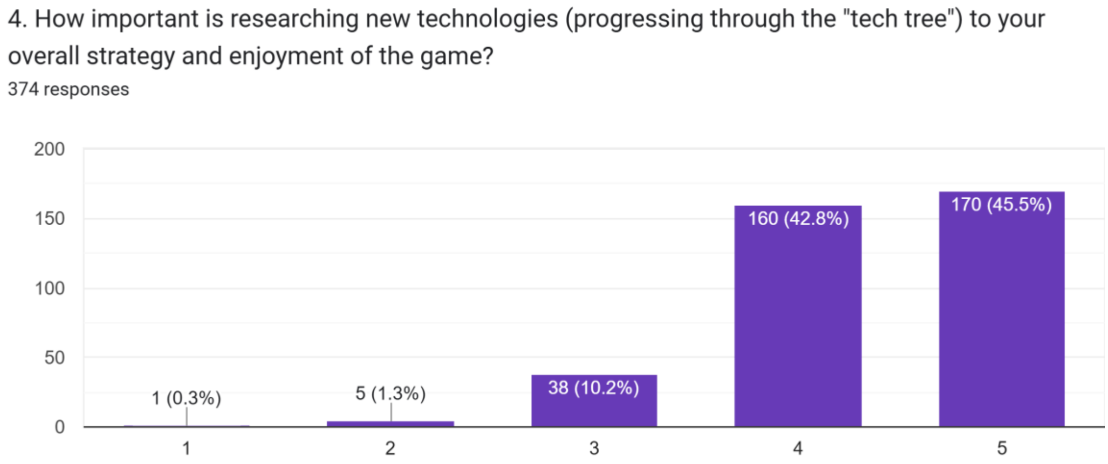
2. Approximately how many hours have you spent playing your Paradox game(s) listed above?
373 responses



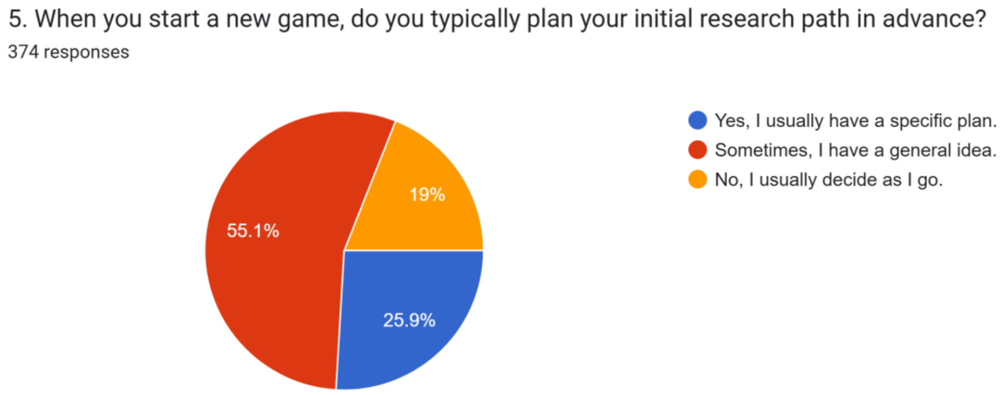
Appendix 6. Gaming Experience - Q3



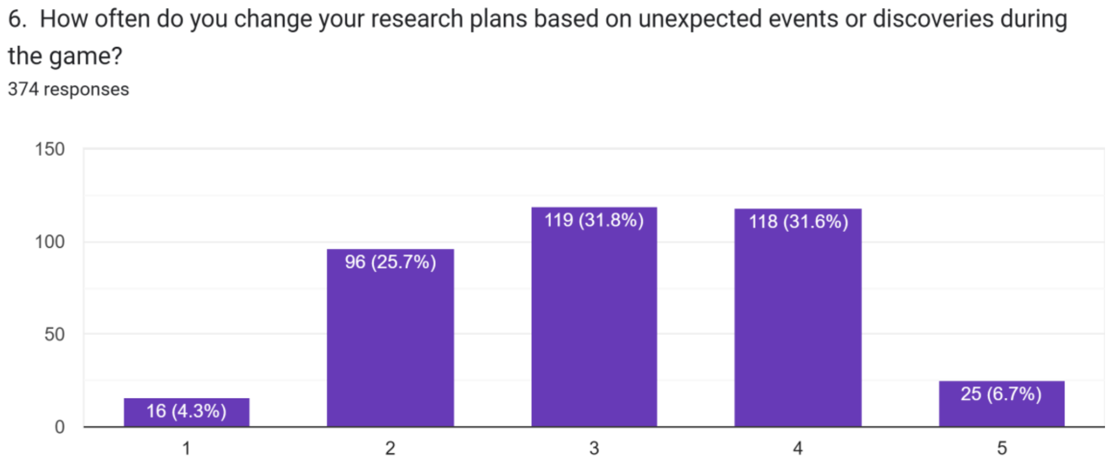
Appendix 7. Technology & Capability Building (Tech Trees) - Q4



Appendix 8. Technology & Capability Building (Tech Trees) - Q5



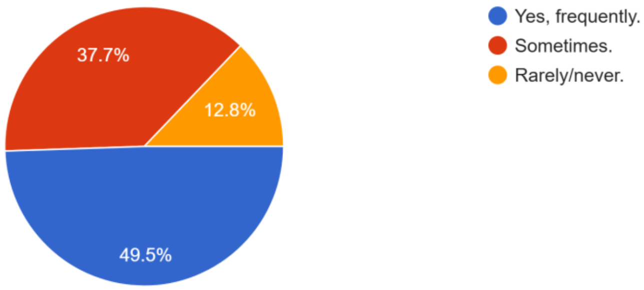
Appendix 9. Technology & Capability Building (Tech Trees) - Q6



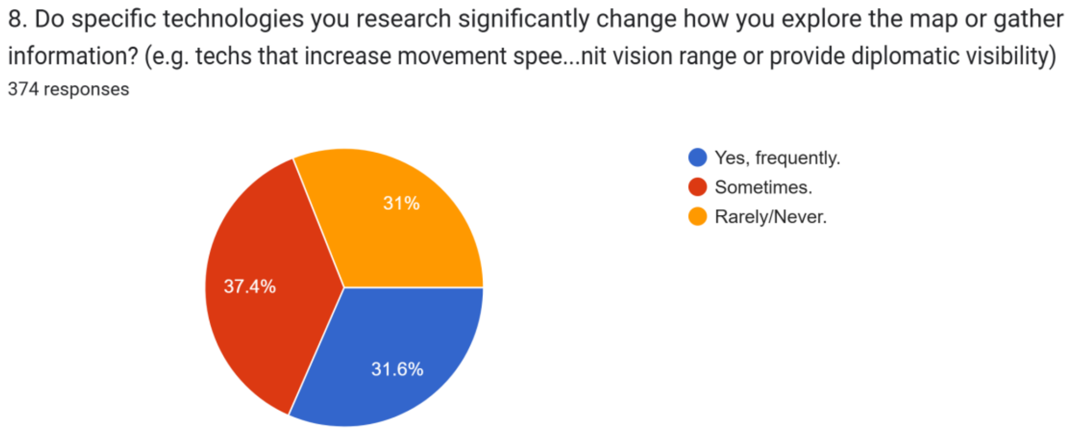
Appendix 10. Technology & Capability Building (Tech Trees) - Q7

7. Do discoveries made while exploring (e.g. finding a specific resource, encountering a strong rival) often directly influence which technologies you decide to research next?

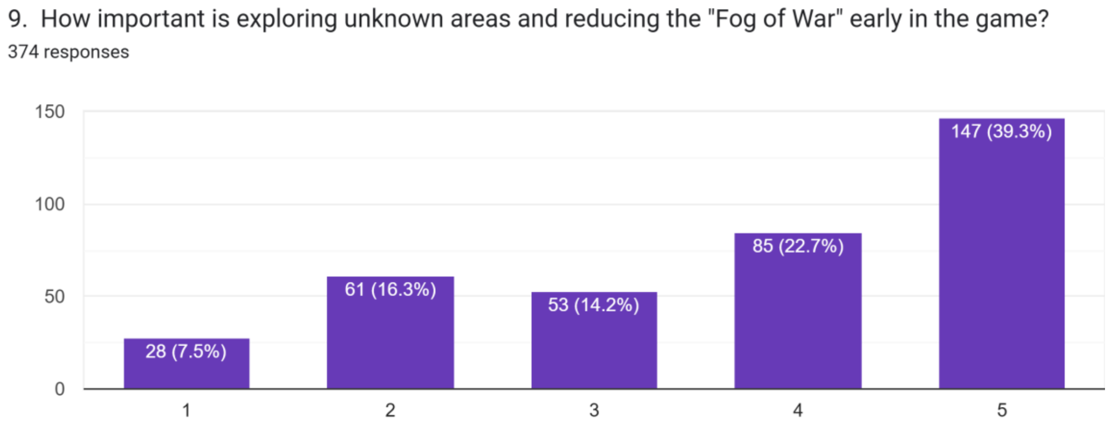
374 responses



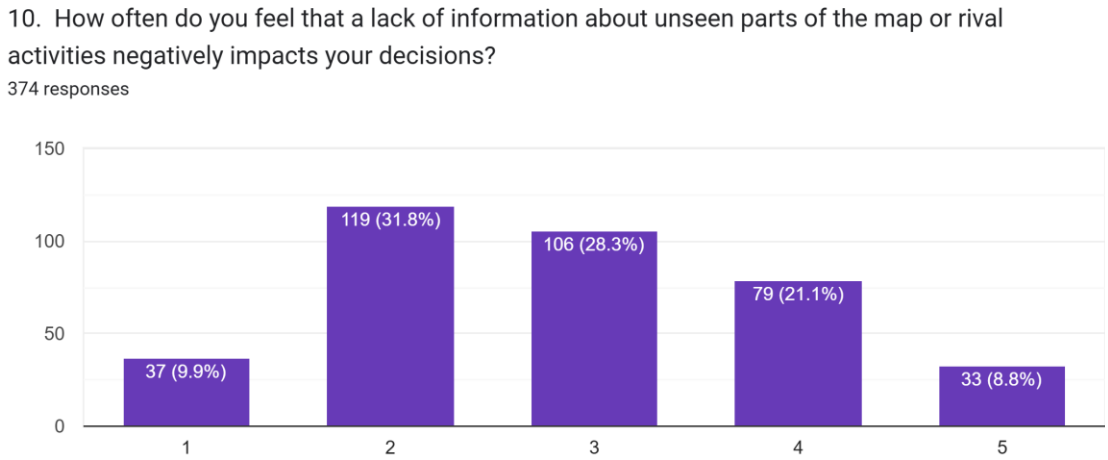
Appendix 11. Technology & Capability Building (Tech Trees) - Q8



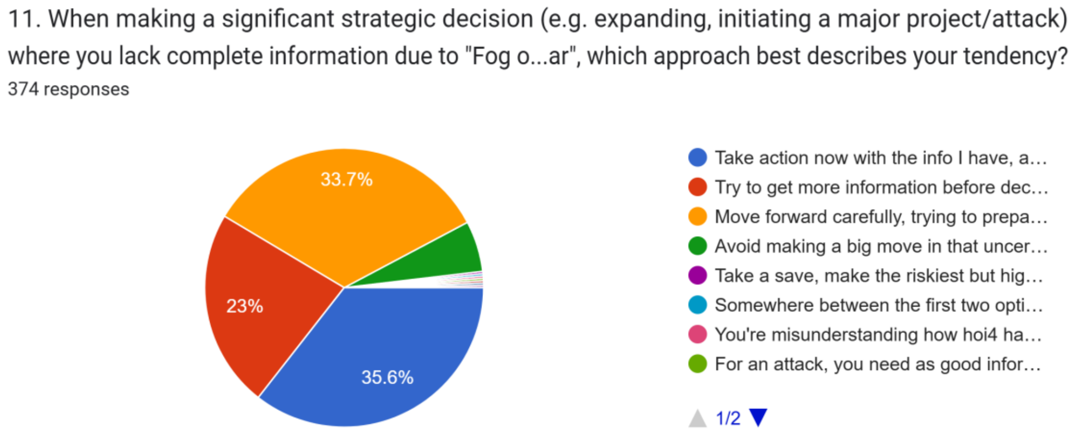
Appendix 12. Exploration & Information Management (Fog of War) - Q9



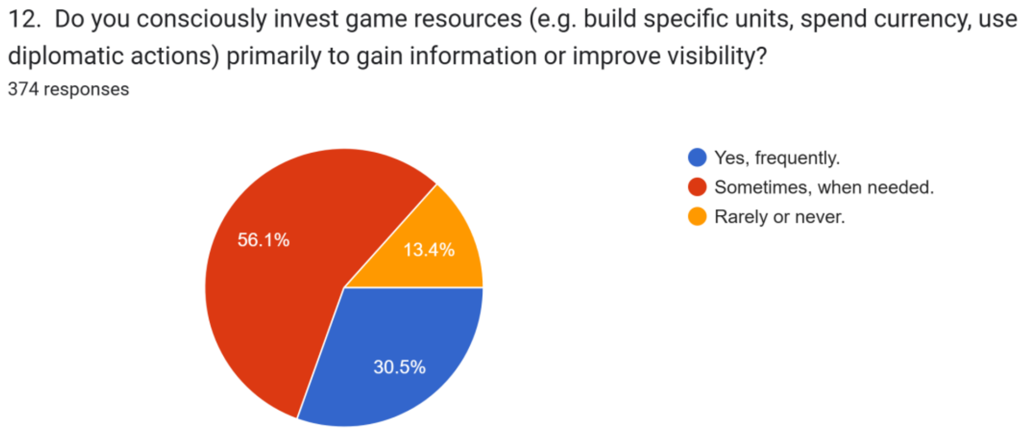
Appendix 13. Exploration & Information Management (Fog of War) - Q10



Appendix 14. Exploration & Information Management (Fog of War) - Q11



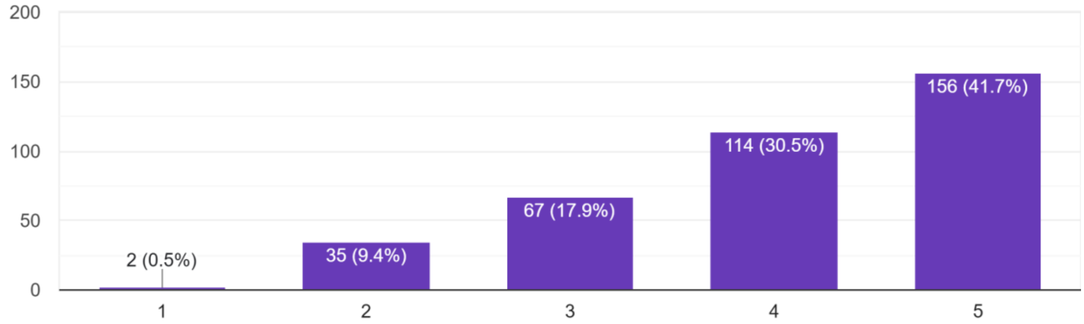
Appendix 15. Exploration & Information Management (Fog of War) - Q12



Appendix 16. Exploration & Information Management (Fog of War) - Q13

13. How valuable is it to gain specific information about your rivals (e.g. their location, army size/composition, tech level)?

374 responses



Appendix 17. Fog Cross-tab

Both High (Q9&Q10)	High Q9 only	Overlap
97	232	0.42
Formula used: =COUNTIFS(L2:L375,">=4", M2:M375,">=4")	**Formula used**: =COUNTIF(L2:L375,">=4")	**Formula used**: =COUNTIFS(L2:L375,">=4", M2:M375,">=4") / COUNTIF(L2:L375,">=4")

Appendix 18. Yu-kai Chou's Octalysis Model (Chou n.d.)