# An Analysis of Coordination Mechanisms to Address Drought and Heatwave Climate Risks in the Beer Industry - A Heineken Case Study

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# Preface

As my time at TU Delft draws to a close, I find myself reflecting on the enlightening journey that began with my Masters in Complex Systems Engineering and Management following the Transport and Logistics (T&L) Track under the program. Diving deep into the intricacies of the transport and logistics track, I found a particular fascination with supply chain modules. 'Supply chain gaming' was not just a course; it became an enlightening experience that enhanced my appreciation for the complexities of stakeholder viewpoints and the nuanced intricacies that come with it.

A pivotal turning point was my association with Royal HaskoningDHV for the JIP Project, which enriched my understanding of climate change's profound implications. I wish to express my profound gratitude to Royal HaskoningDHV for their invaluable resources and unwavering support throughout the project. A special note of gratitude goes to Mr. Djeevan from Royal HaskoningDHV. His innovative insights and thought-provoking discussions were nothing short of inspirational. Working with him not only honed my interests but also carved out a path for me towards sustainable supply chains. Fortuitously, our collaboration extended to my thesis, delving deep into climate change and devising adaptation strategies for supply chains. My appreciation extends to all the participants who graciously shared their time and expertise, enriching the scope and depth of my investigation.

I owe immense gratitude to my thesis supervisors. Dr. Amineh, who also graciously assumed the role of my chair, has been a beacon of support throughout this journey. Her unwavering encouragement, accessibility, and accommodating nature ensured I never felt adrift, no matter how challenging the seas. Dr. Nihit, with his incisive feedback and directional insights, played an indispensable role in refining my thoughts and sculpting the direction of my research.

My parents, my unwavering pillars, deserve all the gratitude in the world. Their unwavering belief in me has been my stronghold throughout. To my close-knit family and friends, your persistent support, encouragement, and faith have been the wind beneath my wings, driving me forward. To the subtle glow guiding me in moments of introspection – my 'Diya' in the dark – thank you for lighting up my path.

As I present this work, I hope it mirrors the dedication, passion, and collaborations that shaped its creation.

**Arjun Santhosh**
Delft, August 2023

# Executive Summary

In the face of escalating climate change, the urgency to understand its impacts on various sectors is paramount. Among these sectors, the beer industry stands out due to its reliance on specific agricultural inputs like barley and hops, which are directly affected by changing weather patterns. The quality and quantity of these ingredients can be compromised by the unpredictability of climate change, influencing not only the taste but also the availability of the end product. This research centers on the growing challenges that the beer industry encounters as it negotiates with the threats and uncertainties brought about by climate change. It specifically focuses on the supply chains within the beer industry, which often stretch across regions that are highly susceptible to the impacts of climate change. In turn, this exposes companies within the sector to significant physical risks, including water scarcity, crop failures, heat stress on equipment, and transportation disruptions, albeit indirectly. The research zeroes in on investigating effective coordination measures as potential tools to bolster the resilience of companies within the beer supply chain against climatic adversities.

The importance of this research lies not only in its immediate relevance to the beer industry but also in its broader implications for the business sector. Climate hazards such as drought and extreme heat pose significant threats to supply chains across various industries. These threats are particularly pronounced in sectors like the beer industry, where supply chains often traverse regions that are vulnerable to these hazards. Multiple studies and industry reports have consistently highlighted that poor coordination is a recurring challenge for companies across sectors, leading to inefficiencies and vulnerabilities when disruptions, including those driven by climate change, arise. In this context, the research aims to alleviate these threats by specifically addressing poor coordination within supply chains. By investigating this challenge in the beer industry, the study offers insights and strategies that can be beneficial for other industries grappling with similar issues.

The signs of poor coordination are manifold and multifaceted, ranging from inconsistent communication between actors and delays in response time to climate-induced disruptions, to a lack of transparency in supply chain activities and misalignment of adaptive measures across the supply chain. In recognizing these issues, the research posits that effective coordination measures could significantly enhance the resilience of companies in the face of climate-related threats.

To achieve the research objectives and address the primary research question, 'What effective coordination measures can beverage (beer) supply chain companies adopt to minimize their vulnerability to drought and heatwave risks and enhance their climate resilience?', the study employs an inductive and qualitative approach. This method involves the collection of primary data through semi-structured interviews, complemented by secondary data from industry reports and academic publications. These interviews aim to shed light on the operational dynamics, challenges, and strategies that companies within the beer industry and its supply chain use to navigate climate-related vulnerabilities. By comparing the findings from these interviews with secondary data, the study offers an insightful and comprehensive understanding of the structure of the supply chain and the challenges it presently faces.

Subsequently, the research undertakes a sectorial study to delve deeper into the relationships between the various actors within the beer supply chain. This is pivotal to

understanding the complexities and intricacies that characterize these relationships and, by extension, the supply chain as a whole. Following data collection, a thorough analysis is carried out to unpack the nature and extent of these relationships, the potential for establishing effective coordination mechanisms, and the influence these mechanisms can have on mitigating climate change vulnerability.

Heineken, a global giant in the beer market, serves as a pivotal case study in this investigation, providing real-world context and grounding for the research. The Institutional Analysis and Development (IAD) framework is employed to systematically dissect the research problem, as it provides a structured lens through which institutional arrangements and their impact can be understood. Concurrently, action situation analysis is utilized to assess Heineken's strategic case studies.

The research anticipates that its findings will provide valuable insights into the adaptation strategies adopted by companies within the beer sector. These insights are expected to emphasize the dual need for collaboration and proactivity as companies navigate the ramifications of climate change on their supply chains. Central to this study is the application of Ostrom's design principles. Originated by Elinor Ostrom, these principles present a set of guidelines devised to manage common-pool resources effectively. They emphasize the importance of clear boundaries, congruence between rules and local conditions, and accountable governance, among other aspects. Given their foundational nature in managing shared challenges, the study aspires to demonstrate how these principles can serve as a pragmatic guide for the beer industry, aiding in the design and formulation of robust coordination mechanisms.

In light of the research findings, it is recommended that the beer industry adopt Ostrom's design principles as a blueprint for action. These principles offer a robust framework for establishing coordination mechanisms that could prove critical in navigating shared environmental challenges. Implementing these mechanisms could engender a more resilient, sustainable supply chain capable of mitigating climate risks effectively. This recommendation is not just crucial for companies striving to ensure business continuity and competitiveness but also instrumental in fostering sustainability and resilience in the face of climate change.

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# 1 Introduction

## 1.1 Problem Background

Climate change is rampant and multi-dimensional in nature, affecting different systems around the world [1]. It is a slow-moving crisis that is going to last for a very long time, hence some fundamental changes are required to be made in every industry. Companies in various industries are recognizing the urgency of the issue and investing in solutions to protect the planet and economy from climate change impacts [2]. They're adopting sustainable practices and reducing carbon footprint, driven by demand from stakeholders [2].

Extreme weather conditions like heat waves, floods, storms, and droughts are events linked to climate change. As such events become more frequent and impactful, it also increases the likelihood of supply chain disruptions. Supply chains often move through parts of the world that are most vulnerable to the impact of climate change. Due to this, firms in a similar sector might be indirectly exposed to physical risks due to their suppliers [3]. The risk of disruption in recent times has increased as supply chains have become optimized for efficiency rather than resiliency [4].

Inherently, supply chains are interconnected entities, where a hiccup in one segment can potentially send shockwaves throughout the system [5].
The COVID-19 pandemic is a real-life example of how disruptions in one part of the supply chain can lead to system-wide shocks. The pandemic caused a surge in demand for certain goods, such as medical supplies and personal protective equipment, which put pressure on global supply chains. As countries implemented lockdowns and closed borders to contain the spread of the virus, transportation and logistics were also severely impacted, leading to delays and disruptions in the delivery of goods [6]. These disruptions affected not only the healthcare industry, but also other industries such as manufacturing and retail, highlighting the interconnectedness of global supply chains and the need for resilience and adaptability in the face of unforeseen events.

Addressing these multifaceted challenges mandates a comprehensive understanding of supply chain design and its inherent resilience or vulnerability to climate-induced disruptions. Such understanding is instrumental both for preemptive risk management and for post-disruption reconfiguration towards more climate-resilient supply chains [7].

Climate change exerts a pervasive influence that necessitates a united effort, stretching from individual enterprises to the vast intricacies of global supply chains [8]. Yet, the market doesn't inherently ensure this coordinated approach [8]. An effective response to climate change requires a comprehensive understanding of issues across multiple scales and a thorough assessment of the associated feedback mechanisms. Harnessing these

feedback mechanisms, both internal and external, becomes pivotal in shaping a robust and effective strategy [8].

Hence, it is crucial for companies to understand their vulnerabilities to climate risks and identify potential adaptation strategies to mitigate the impact of these risks on their supply chain. Therefore, it is necessary to conduct a thorough analysis of the potential climate risks faced by companies and their supply networks to facilitate the development of effective adaptation strategies.

## 1.2 Literature Study

A systematic literature review was followed for evaluating and interpreting all relevant research on the topic. The research papers analysed in the review are referred to as secondary studies [9]. The findings from the secondary studies can be valuable in offering insights, identifying patterns and knowledge gaps for the primary studies.

The primary topics which were looked at in depth for literature were:

- Impacts of climate change on specific industries, commodities, global trade and logistics.
- Climate risk assessment and management for supply chain operations.
- Development of resilience and adaptation strategies for supply chain infrastructure and logistics.
- The role of sustainability and collaboration in supply chain adaptation to climate change.
- Coordination mechanisms facilitating collaborations within supply networks to address climate risks.

For these topics, relevant research papers are found to identify the knowledge gap in this domain.

### 1.2.1 Literature Search Query

A variety of methods were used to identify relevant research articles for literature. Primarily, a manual computer search using a combination of search strings and Boolean logic (AND, OR) was constructed using keywords and attempted on multiple electronic databases.

**Search Strings** The following Search strings with different combinations of keywords based on the research focus using Boolean logic were used.

- ("Supply Chain" OR "Industries") AND "Climate change"
- ("Supply Chain" OR "Industries") AND "Climate resilience OR "Climate Adaptation"
- ("Supply Chain" OR "Industries") AND ("Vulnerability" AND "Climate risk")
- "Supply Chain" AND ("Collaboration" AND "Coordination mechanisms")

**Electronic Databases** A variety of electronic databases were used for searching the literature articles. The list of electronic databases used are:

- Google Scholar
- Scopus
- ScienceDirect
- ResearchGate
- SSRN
- Emerald Insight
- Connected Papers

The first 6 electronic databases were searched using the keywords and search strings listed in Section 1.2.1 to find relevant published papers (journals, reports, etc.). These articles were then analyzed using Connected Papers, a visual tool that helps researchers explore related papers in their field of study. The process helped map out related papers and the list was refined by narrowing down the scope. The selected articles were also checked for cited sources.

**Selection Procedure** After removing duplicate search results, the articles were screened to include only papers published from 2015 onwards. This was done to ensure that the research is up-to-date and relevant, considering that prior to 2015, limited research was available on the coordination efforts between supply chains towards climate resilience. This approach also ensures consistency with the most recent developments and trends in the field. The articles from this list were further screened to exclude articles which were not accessible or retrievable, only contained quantitative reports, lacked insights about data collection, focused on climate change causes or only contained mitigation strategies.

The articles relating to supply chain vulnerabilities, climate resilience, and case studies on climate adaptation were set as the eligibility criteria during the title screening of the papers. The articles after abstract screening were further narrowed down, which along with the inclusion of recommended articles from experts/supervisors and other citations, were used in the literature review.

### 1.2.2 Literature Synthesis Flowchart

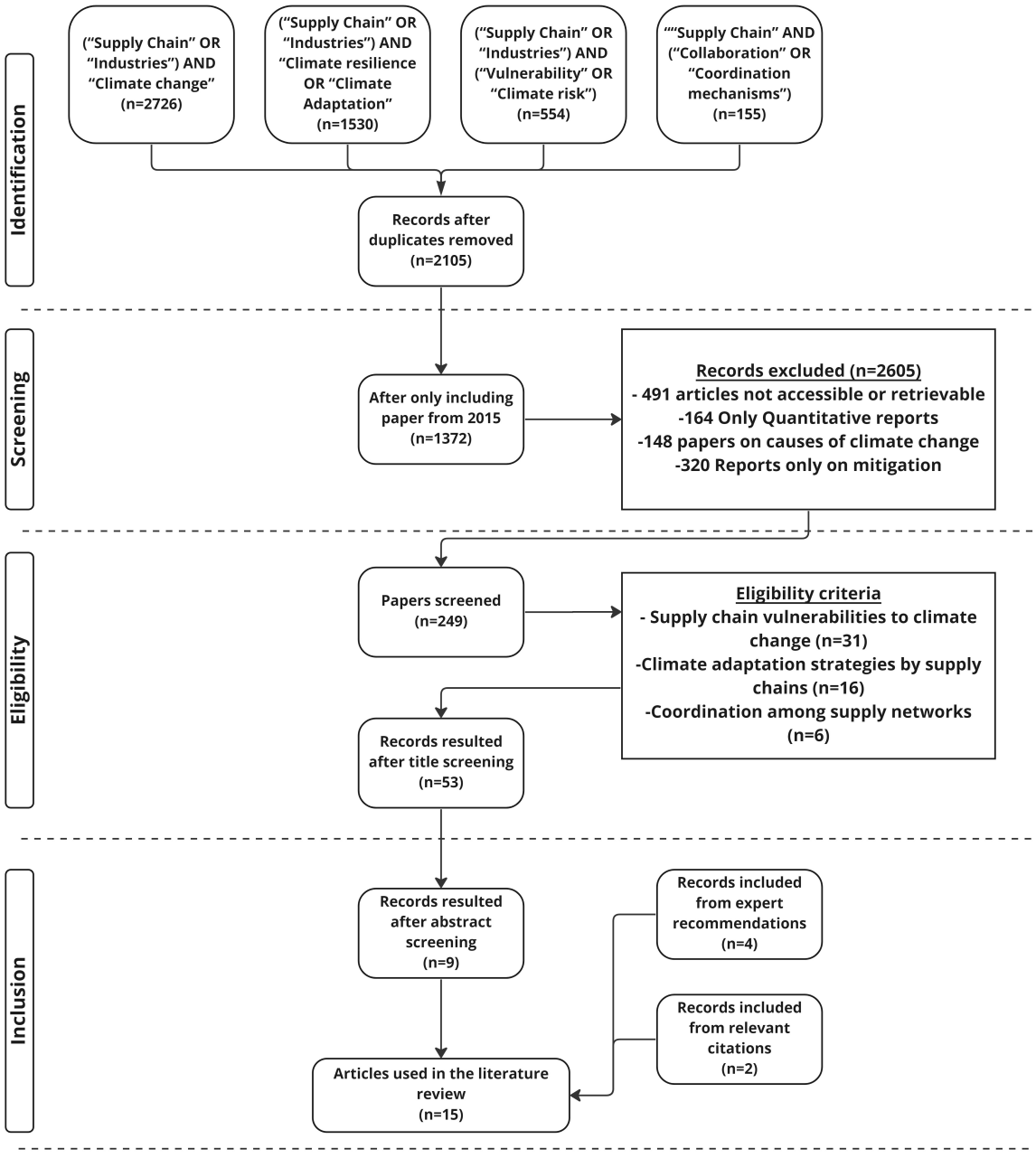


Figure 1: Literature Synthesis Flowchart

### 1.2.3 Analysis

The effects of climate change on supply chains have emerged as a critical research area. Various scholars have dissected this multifaceted issue, providing insights into supply chain complexities, vulnerabilities across sectors, adaptation strategies, and overarching theoretical frameworks. The following review systematically delves into these facets:

Lim-Camacho (2017) highlighted the resilience inherently borne out of supply chains that boast high levels of complexity, marked by a dense network of intermediaries and a robust system of vertical integration [7]. It's essential to note, though, that this resilience is as much a product of complexity as it is of the supply chain's level of dependency on affected resources [7].

Shifting our gaze to specific industries, Nakano (2021) underlined the pronounced vulnerabilities in the automotive sector, particularly in regions like the US, Japan, and Germany, where an economic reliance on imports or low-cost labor heightens the risk of climate-related disruptions [10]. Such vulnerabilities aren't confined to the automotive realm. Malek (2022) alerts us to the profound impact that climatic extremes, such as droughts and heatwaves, are poised to have on the supply chains of agricultural commodities, advocating for a nuanced, location-specific approach to build resilience [11].

In this age of uncertainty, adaptation is not a mere afterthought but a crucial cornerstone. Godde (2021) articulates the urgency of transformative adaptation in the livestock domain, pushing for a holistic assessment of potential impacts [12]. Levermann (2014) echoes this sentiment, emphasizing that merely localized adaptation efforts might crumble under severe global climatic events [13]. However, the journey of adaptation is riddled with challenges, as Hermann (2017) elaborates on the numerous organizational roadblocks faced during strategy implementation [14].

Peeling back the layers on businesses' adaptative strategies, Canevari-Luzardo (2019) elucidates the pivotal role of business networks, praising the merits of collective problem-solving [15]. This spirit of collaboration is also championed by Tenggren (2019), who emphasizes the interconnected risks threaded through supply chains and the necessity for a concerted effort among stakeholders [16].

Rahman (2022) paints a picture of the staggering economic repercussions that climate extremities can unleash on food supply chains, while Ghadge (2019) offers a bird's eye view through the lens of systems theory, signaling that certain sectors might demand a more granular research approach [17].

Stepping into the realm of theoretical explorations, researchers like Huntjens (2012) and York (2021) furnish the academic world with frameworks and propositions for a deeper understanding of climate-related challenges [18, 8]. Huntjens (2012) champions polycentric governance systems tailored for water governance, while York's (2021) approach is firmly rooted in dissecting climate-linked decision-making processes. In the urban context, Tyler

(2012) carves out a path centered on shared learning and planning [19], whereas Kangogo (2020) spotlights the bridge between farm resilience and farmer adaptability [20].

Navigating the comprehensive array of research, a narrative surfaces, highlighting the significance of integrated approaches, the strength inherent in collaboration, and the potential of innovative strategies. The challenges of climate change demand more than mere comprehension; they call for the unified endeavors of industries and relevant stakeholders to bolster supply chain resilience.

### 1.2.4 Knowledge Gap

The literature identifies a series of knowledge gaps, especially regarding the policy alternatives and adaptation options tailored for diverse supply chains. Factors such as geographical differences, specific conditions, and the precise phasing of the measures can influence the costs and benefits of climate adaptation options [21].

Due to the large and complex nature of supply chains, there is a lack of understanding of the interactions between supply networks and climate impacts [22]. Though supply chain vulnerabilities with respect to market fluctuations, infrastructure and quality control, has been evaluated in-depth, there are limited data and metrics currently to assess and monitor supply chain vulnerability with respect to climate change [17]. There is also insufficient knowledge and inadequate training for supply chain managers of effective adaptation strategies and technologies for reducing the impact of climate change on supply chains [13]. A limited amount of study is done on adaptation strategies for supply chains, compared to mitigation. Adaptation strategies can be beneficial to implement in short-term planning compared to mitigation measures, which often require significant investments and long-term planning [14]. Limited collaboration between organizations and lack of knowledge or information sharing between supply chain stakeholders is another key factor acting as a hindrance in making supply chains more climate resilient [15].

In addition to the knowledge gaps mentioned above, it is worth noting that while several studies have looked at the policy alternatives and adaptation options for supply chains to cope with climate change, there has been limited research from a collective action perspective. Specifically, there is a lack of understanding of how different coordination mechanisms or collaboration between the supply networks can enhance the resilience of supply chains within a sector. The study by Kangogo [20] highlights the importance of farmer organizations and farmer-buyer relationships in influencing farmer adaptive capacity and enhancing farm resilience. These aspects of collective action could be further explored and evaluated in the context of supply chain resilience to climate change impacts.

The current state of knowledge highlights the necessity for further research into the vulnerability of supply networks in sectors expected to be impacted by climate change. Additionally, evaluating the effectiveness of various coordination strategies in mitigating these vulnerabilities is crucial for enhancing the resilience of supply chains [13] [16] [15].

Moreover, there's a conspicuous lack of studies that utilize frameworks to dissect supply chains within industries and to delineate strategies. Such an analytical tool could be pivotal in offering structured insights and actionable strategies [23].

Building upon the knowledge gaps identified from the literature, the research aim is to explore effective coordination measures that supply chain companies can adopt to minimize their vulnerability to climate change risks and enhance their climate resilience. The rationale for specifically focusing on coordination measures is twofold. Firstly, while climate change risks are an area of increasing concern for all sectors, their impacts are particularly potent and complex in the supply chain context, necessitating a specific focus. Secondly, coordination measures, by facilitating improved communication and collaboration between supply chain partners, have shown significant potential in other sectors to mitigate the impacts of other types of risks [20].

The study will focus on a specific sector, and investigate the different levels and key components of the supply chain, the impacts and vulnerabilities of the focused climate change hazards, the roles and responsibilities of the actors involved, the nature of relationships between them, and potential coordination mechanisms that could facilitate effective collaboration. The research aims to provide practical recommendations for improving the resilience of supply chains to climate change risks by utilizing theoretical frameworks.

### 1.2.5 Industry Focus: Beverage Sector (Beer) in the Food and Beverage Industry

The food and beverage industry has been chosen as the central theme for this thesis primarily because of its profound academic merits, given its pivotal role in influencing the global economy and daily lives of individuals. Additionally, the selection was informed by the accessibility of resources from Royal HaskoningDHV, the collaborating entity.

As a primary need, food and beverage industry is certainly in great demand and the market size of global food and beverage sector is expected to grow to $8.9 trillion by 2026 at a compound annual growth rate of 8.7% [24]. The F&B sector plays a crucial role in building resilience across the food supply chain, with the potential to make a significant impact at every stage. There is increasing interest from companies to take action on sustainability and disclose their progress, as demonstrated by the rise of corporate social responsibility reporting. To achieve sustainability goals and support climate-resilient practices, it's important to understand the risks and challenges faced by different actors in the food supply chain, including processors, distributors, aggregators, and producers [25].

In order to narrow down the scope of the thesis, the supply chain of the beverage subsector, specifically the beer supply chain is focus of the study. This main reasons for focusing on this sub-sector are:

- The beer beverage industry offers insights into complex supply chains, changing consumer dynamics, and sustainability challenges [26]. While the association with RHDHV enriches the study through its industry ties, notably with giants like Heineken, the primary focus is on the sector's intrinsic academic value, its implications for broader market trends and economic studies.

- The beer beverage supply chain's intricacy, driven by factors such as beer's perishability, temperature-control demands, and stringent regulations, makes it an intriguing subject of study [26]. These inherent challenges not only heighten logistical and compliance demands but also present unique operational dynamics unseen in other F&B segments. This complexity, coupled with the sector's broad economic implications, positions it as a compelling focus for academic research and exploration.

- From a climate resilience perspective, the beer supply chain stands out due to its deep-rooted reliance on natural resources like water, barley, and hops, which are notably sensitive to climatic variances [26]. Changes in rainfall patterns, temperature fluctuations, and extreme weather events can drastically impact the quality and availability of these primary ingredients, thereby affecting production capabilities and costs [26]. Delving into these intricacies provides valuable insights for sectors that similarly lean heavily on natural resource dependence and showcases adaptive measures that can be translated across industries.

**Climate Risks Focused: Drought and Heatwave Hazard**

Beer is one of the most popular and a highly demanded alcoholic beverage, and to meet its growing demand, a stable supply of its primary ingredients, including clean water, barley, and hops, is essential. Nevertheless, climate change brings about distinct risks to each of these components [27].

- Beer production has a high water footprint, with an average of 44 gallons of water required for a pint [27]. Climate change affects the quality and quantity of freshwater, leading to limited water supplies for brewing due to reduced snowpack and groundwater depletion. As a result, competition for water resources in drought-prone regions could pose a significant challenge to the beer industry [27].

- Barley, which is the primary grain used in brewing beer and serves as the primary source of sugars that are later converted into alcohol, is highly vulnerable to extreme heat and drought, rendering it susceptible to climate change impacts [27].

Therefore, in the context of this thesis to furthur narrow down the scope, the primary focus will be on droughts and extreme heatwaves as the main climate hazards. These hazards present a significant risk to the reliability of the beer supply chain network, leaving it vulnerable to disruption.

## 1.3 Research Question

The following main research question will guide the investigation process and help to gain deeper insight into this topic.

### 1.3.1 Main Research Question

*"What effective coordination measures can beverage (beer) supply chain companies adopt to minimize their vulnerability to drought and heatwave risks and enhance their climate resilience?"*

### 1.3.2 Sub-Research Questions

Utilizing the Institutional Analysis and Development (IAD) framework as the theoretical framework, the following sub-research questions are formulated. They are further broken down into descriptive and relational sub-questions.

**Descriptive sub-research questions**
These sub-questions are aimed to mainly guide in the data collection and analysis process.

1. What are the different levels and the key components of the beverage (beer) supply chain?
2. What are the impacts and vulnerabilities of drought and heatwave hazards on the beer supply network?
3. What are the key roles and responsibilities of the actors involved in the beer supply chain?

**Relational sub-research questions**
These sub-questions are aimed to provide a more in-depth understanding of the relations between variables or concepts to identify the underlying mechanism.

1. How do the nature and depth of relationships among various actors in the beer supply chain intersect with and shape existing coordination mechanisms?
2. To what extent are the existing mechanisms or strategies in the beer supply chain effective in enhancing climate resilience?
3. How do coordination mechanisms in the beer supply chain contribute to enhancing climate resilience, and what improvements can further bolster this resilience?

# 2 Methodology

## 2.1 Theoretical Framework

Theoretical frameworks provide the overarching structure for a research study. They can provide a comprehensive structure for identifying and examining the essential elements of institutions, as well as the relationships that exist among these elements [23]. By providing a well-defined set of variables, they facilitate systematic analysis of diverse phenomena, not just those related to institutional arrangements. [23].

### 2.1.1 IAD Framework

The Institutional Analysis and Development (IAD) framework, developed to systematically study the structure and performance of governance systems [23], will be utilized as the theoretical basis for dissecting the beer beverage supply chain and addressing the research questions. At its core, the IAD framework offers a comprehensive lens to examine how diverse actors interact within institutional settings and how these interactions influence outcomes [28].

The rationale for utilizing the IAD framework as a reference for addressing the research problem is because:

- IAD framework offers a structured approach to analyzing the complex relationships and coordination mechanisms between actors within an institutional setting [23], making it an ideal tool for breaking down the beer beverage supply chain and understanding the vulnerabilities and resilience strategies of companies within this sector.
- The IAD framework recognizes that institutions are not static but rather evolve over time through the actions of their constituent actors [28]. This is important in the context of climate change, as companies within the beer supply chain will need to adapt and evolve their supply chain strategies to remain resilient in the face of changing climate hazards.
- The IAD framework emphasizes the importance of collaboration and collective action among actors within an institutional setting [29]. This is particularly relevant for the research problem at hand, as companies within the beer supply chain will need to work together to identify and implement effective coordination mechanisms that enhance their climate resilience.

This framework facilitates the breakdown of the research problem into research questions by offering a structured approach to comprehend actor interactions within a specific

institutional setting. It can also be useful for analyzing the coordination mechanisms and relationships among actors in the beer supply chain [23].

### Application of IAD Framework

The Institutional Analysis and Development (IAD) framework is a multi-tier conceptual map used to identify the major types of structural variables present in different institutional arrangements. The framework focuses on the action situation leading to interactions and outcomes. By opening up the action situation and analyzing its component parts, one can specify how to analyze the actors involved at that level [23].

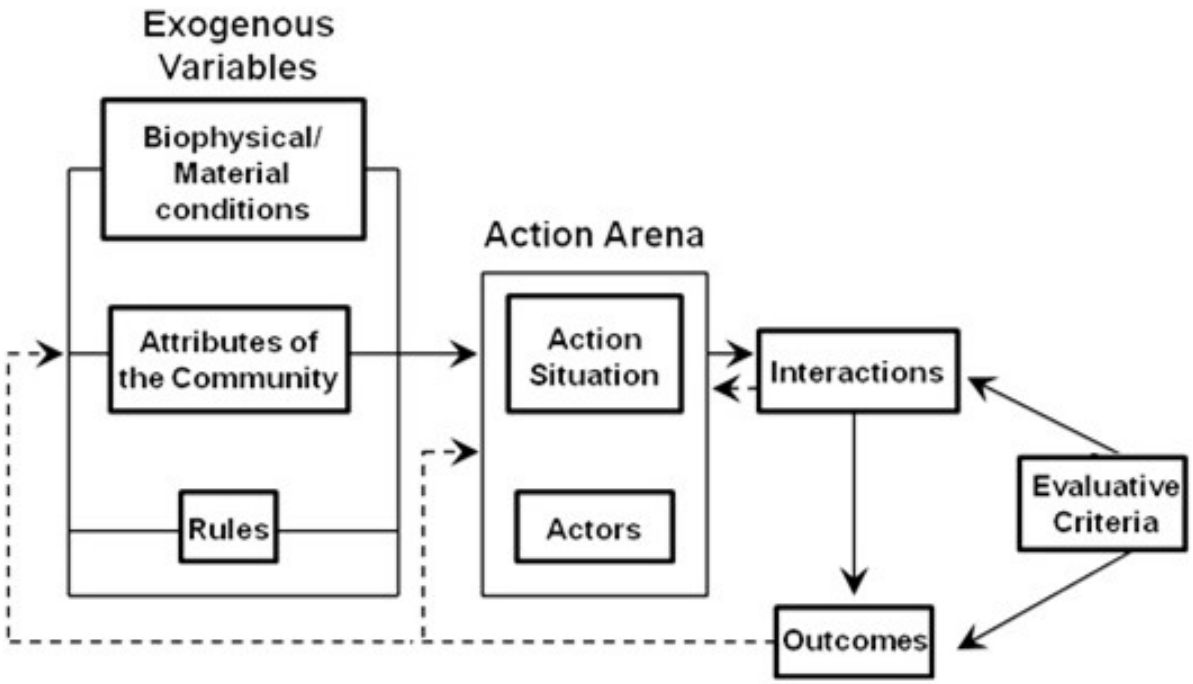


Figure 2: IAD Framework. Source: Adapted from E.Ostrom [23]

An approach of defining an objective and applying the IAD framework involving socio-economic activity and then working forward through the framework is selected. For instance, for the objective to investigate the climate resilience of the beer supply chain companies to minimize their vulnerability to climate hazards, we would begin by describing the physical and material attributes of the beer supply chain, such as the suppliers, logistics, and production processes, and proceed through the community attributes, rules-in-use, a detailed analysis of the action arena, patterns of interaction, and outcomes. This approach is best suited to policy tasks that involve developing new policy initiatives or comparing alternative policy designs [30] for enhancing the climate resilience of beer supply chains.

**Physical/Material Conditions:** The physical and material conditions play a crucial role in shaping policy action situations and institutional arrangements [30]. These condi-

tions encompass the physical and human resources, capabilities necessary for producing and providing goods and services, including production inputs, financing sources, and distribution channels. To determine the physical and material conditions associated with the beer supply chain, the economic nature of the activity, how the beer is provided and produced, required resources, technologies, storage, distribution requirements, and the scale and scope of the production and provision activities needs to be considered.

This research question addresses this variable: i.e.
***What are the different levels and the key components of the beverage (beer) supply chain?***

**Community Attributes:** The attributes of a beer supply chain community that affect policy action situations include demographics, accepted norms, shared knowledge, and homogeneity of values, beliefs, and preferences [30]. The nature of relationships between actors within the beer supply chain and their interactions with one another are important considerations for analyzing and designing policies. It is essential to understand the ways in which different actors, such as suppliers, manufacturers, distributors, and retailers, interact with one another, their roles and how these interactions impact the overall functioning of the supply chain.

This research question addresses this variable: i.e.
***What are the key roles and responsibilities of the actors involved in the beer supply chain?***

**Rules-in-Use** The IAD framework introduces a concept termed "Rules-in-Use" that centers on elements crucial to understanding an action situation within any institutional setting. While the term "rules" is used, it's imperative to differentiate between what's conventionally understood as rules and strategies. In the context of the IAD framework, these "rules" are foundational structures that guide actions, interactions, and results [30]. The seven types of "rules" we emphasize are: Position, Boundary, Authority, Aggregation, Scope, Information, and Payoff [30].

For instance, Position rules in the beer supply chain delineate roles that actors occupy, emphasizing the diversity and categorization of participants [30]. Boundary rules, akin to guidelines, illustrate how actors engage with or disengage from these roles. Authority rules underscore permissible actions, while Aggregation rules outline decision-making protocols. Scope rules convey the extent of impact and its permanence. Information rules affect data accessibility, and Payoff rules illustrate the distribution of costs and benefits [30].

It's pivotal to distinguish between these inherent "rules" and the more fluid concept of strategies, especially when focusing on adaptation. Rules provide a foundational structure [23], whereas strategies are agile and modifiable, aimed at fulfilling specific objectives

within these foundational guidelines [31]. Within the beer supply chain, adaptation strategies encompass the methods by which diverse actors interact with, leverage, or modify these rules to ensure resilience, especially when confronted by evolving challenges like climate change.

This research question addresses this variable: i.e.
***What are the impacts and vulnerabilities of drought and heatwave hazards on the beer supply network?***

**Action Arena** The action arena encapsulates a designated conceptual space wherein actors engage in diverse activities: from acquiring knowledge, appraising varied courses of action, finalizing decisions, to executing the chosen initiatives and ultimately observing their effects. This multifaceted arena doesn't exist in isolation; it is intricately shaped by elements like the tangible physical realm, the surrounding community's attributes, and the overarching rules-in-use [30]. These elements not only craft the arena's atmosphere but also delineate the spectrum of roles that the actors assume within it [30]. Comprehending these dynamics is pivotal, especially when seeking to dissect the existing action situation of strategies. Such understanding allows for a seamless integration of the IAD policy analysis, facilitating the formulation of tailored strategies. These strategies, once anchored in a profound understanding, can holistically cater to the interests of every entity within the beer supply chain.

This research question addresses this variable: i.e.
***To what extent are the existing mechanisms or strategies in the beer supply chain effective in enhancing climate resilience?***

**Patterns of Interactions** Analyzing the behaviour of actors in the beer supply chain from the constraints of the physical world, community attributes, and rules-in-use will help to determine determine the patterns of interaction among the actors in the action arena [30]. In tightly constrained situations, there is scope limited strategies, hence stronger predictions about likely behavior patterns is observed [30]. However, most situations are less predictable such as the effects of climate change on the supply chain and the approaches in such cases can be influenced by industry norms and stakeholder interactions [30]. In these situations, participants have a broader range of strategies that can change over time.

This research question addresses this variable: i.e.
***How do the nature and depth of relationships among various actors in the beer supply chain intersect with and shape existing coordination mechanisms?***

**Evaluation Criteria** An objective standard or principle of comparison is needed to analyze the outcomes in a beer supply chain, since the overall performance of the supply chain is considered. Policy design for a climate resilient beer supply chain must frequently consider how alternative policies affect actors incentives to produce efficiently while maintaining climate resilience. Evaluation criteria can help identify areas where strategies need to be improved, adjusted, or revised [30]. It can also help stakeholders make informed decisions about the allocation of resources and identify the most effective approaches to tackle climate change [30]. Navigating this context, the focus should seek to bridge the evaluation criteria with actionable strategies, positioning them as intertwined facets of the overarching goal to improve the resilience of the beer supply chain amidst evolving climate challenges.

This research question addresses this variable: i.e.
***How do coordination mechanisms in the beer supply chain contribute to enhancing climate resilience, and what improvements can further bolster this resilience?***

**Outcome** This research focuses on developing robust coordination mechanisms for companies within the beer beverage sector, given the mounting climate change challenges. Its objective is to encourage a more collaborative and proactive approach to manage climate change adaptation strategies in the sector. These measures, evolved through comprehensive analysis, are aimed at reinforcing the resilience of the beer beverage sector against climate change-induced disruptions.

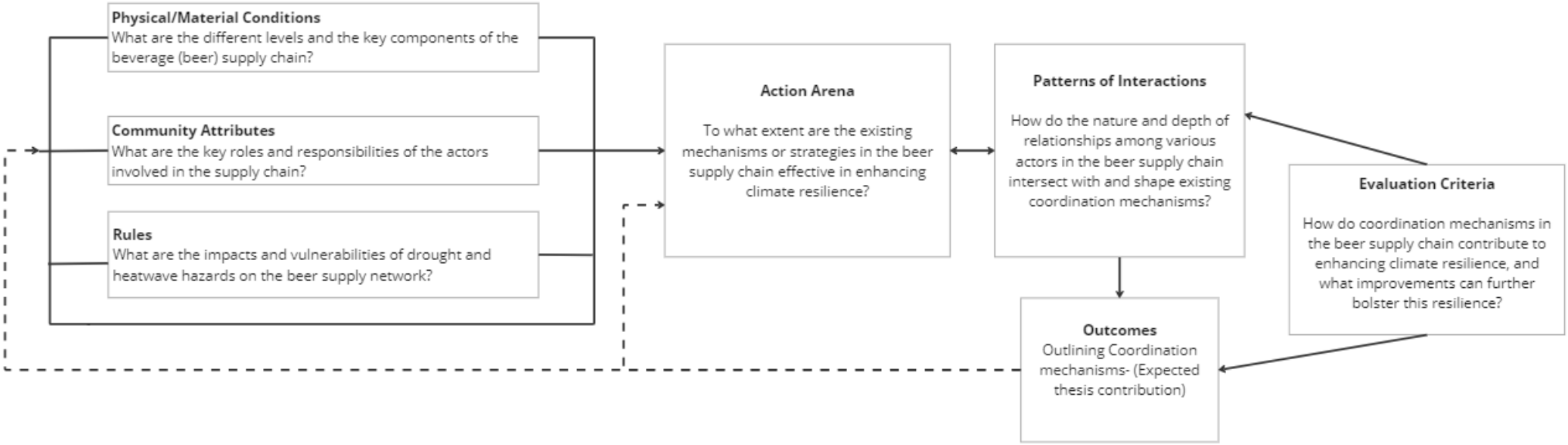


Figure 3: Research breakdown using IAD Framework.

### 2.1.2 Action Situation Framework

The Institutional Analysis and Development (IAD) framework, initially employed to systematically dissect the beer beverage supply chain, forms the foundational theoretical base of this research. Building on this, the Action Situation framework, conceptualized by Elinor Ostrom, emerges as an integral extension of the IAD. This tool is tailored to examine the behaviors and interplays of actors within an institutional context [23], further refining our understanding of the subject. Comprising variables such as participants, positions, potential outcomes, and the interlinkages therein, this framework delves deeper into the nuances of actor interactions, control dynamics, information dissemination, and the subsequent costs and benefits [23].

This thesis delves into the strategic measures implemented by Heineken, an international brewery, to fortify resilience within its supply chain. Emphasis is laid on the evaluation of Heineken's response mechanisms to contemporary climate-related hazards. Action component of the Institutional Analysis and Development (IAD) Framework is used as a tool in analysing the methods and approaches Heineken employs to manage its supply chain amidst climate-induced challenges. Applying this method to Heineken's climate response strategies can provide a comprehensive understanding of how the company operates and reacts under potential climate related disruptions. Further, it allows the identification of potential gaps or areas where Heineken's strategies can be improved or refined. Together, the IAD and the Action Situation framework synergize, offering a robust analytical toolkit for this research.

#### Application of the Action Situation

In the IAD framework, an action situation is an arena where participants with diverse positions interact, exchange goods and services, solve problems, dominate one another, or fight. The primary focus is on the patterns of interaction among the actors [23].

The IAD framework's relevance becomes even more pronounced when delving into relational sub-question 2, which inquires about the effectiveness of existing mechanisms or strategies in the beer supply chain in enhancing climate resilience. The Action Situation component of the framework is pivotal for dissecting Heineken's strategies and understanding their interactions with the challenges posed by climate change. By analyzing the intricate patterns of interaction among the actors, it becomes feasible to gauge the effectiveness of these mechanisms in bolstering resilience. Moreover, the framework aids in identifying gaps, potential redundancies, or inefficiencies within the strategies [23], paving the way for recommendations on improvements or introductions of new, more robust mechanisms.

The application of the Action Situation framework to Heineken's supply chain strategy yields an extensive analysis of the company's interactions with climate change ramifications. This framework provides a comprehensive lens to observe the following integral

components:

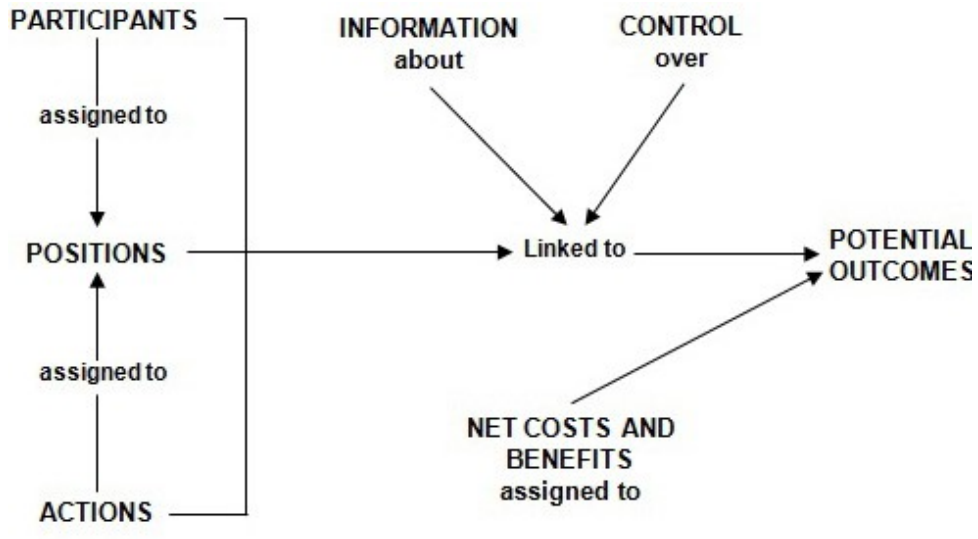


Figure 4: The action situation of the IAD Framework. Adapted from Ostrom[23]

**Identifying Participants and Positions:** This step involves distinguishing all the key actors involved in Heineken's supply chain - from raw material providers, to the top-tier management involved in the strategic formulation. These actors each have distinct roles and responsibilities, and understanding these roles is pivotal to recognizing how actions at every level reverberate through the entire system [32].

**Understanding Potential Outcomes and Action-Outcome Linkages:** Every action has potential outcomes, and understanding this link is crucial to predict the impact of any decision made within the system [32]. For instance, to analyze the potential outcome of an investment in sustainable farming techniques based on the yield quantity and quality during extreme weather conditions.

**Examining Actor Control and Information Accessibility:** An integral part of this analysis involves understanding the amount of control different actors have over their actions and the extent of information available to them [32]. For instance, analysing the influence of different actors in sustainable farming techniques and the gaps in information flow or control.

**Assessing Costs and Benefits:** Finally, assessing the costs and benefits of actions and outcomes is crucial. It isn't merely a financial evaluation but includes environmental, social, and long-term resilience factors [32]. For instance, analysing if the costs of implementing sustainable farming practices outweigh the benefits of a reliable supply of raw materials.

### 2.1.3 Coordination Problems and Ostrom's design principles

#### Coordination Problems

Collective action refers to the joint efforts made by two or more parties aimed at addressing a shared concern. This often involves situations such as formulating and enforcing regulations for the use of a commonly shared natural resource [33].

Collective action problems pertain to situations in which the overall welfare of a group, community, or society could be improved through cooperation [34]. Solving collective action problems is often a complex process that necessitates some level of regulation, cooperation, or coordination [34]. Understanding of these collective action problems can significantly inform strategies for enhancing coordination and cooperation within complex systems such as supply chains [35].

Game theory classifies collective action problems into three types: coordination, cooperation, and division problems [36]. Coordination problems arise when actors jointly produce or exchange goods or services, requiring effective coordination for successful outcomes [36]. Division problems manifest when the benefits or gains are distributed unequally among the parties, leading to disagreements on the distribution of costs or rewards associated with their joint effort [36]. Cooperation problems surface when actors have divergent goals and are incentivized to act opportunistically [36].

Among these, coordination problems offer the most pertinent focus for this research for the following reasons:

- Supply chains inherently demand coordination among various actors to function efficiently. The introduction of new uncertainties and risks by climate change can disrupt this coordination, underscoring the need for enhanced resilience strategies [37].
- The impacts of climate change are not restricted to a single entity or supplier within the chain. Rather, they present a collective challenge that necessitates a collaborative response from all supply chain participants [38]. The efficient and effective addressal of these challenges calls for improved coordination mechanisms.
- Coordination issues in the context of supply chains often stem from communication gaps, misalignment of incentives, and a lack of clarity in defining roles and responsibilities. These areas present opportunities for meaningful enhancements that could improve the climate resilience of beer supply chains [39].

In the context of climate-related risks, the challenge isn't solely about sharing resources or collaborating. It's about ensuring that each actor in the supply chain can anticipate, react to, and recover from disruptions in a manner that doesn't compromise the overall functioning of the entire chain [15]. For instance, if a barley supplier is hit by a drought

and fails to supply in time, it's not just a distribution issue of how much barley gets to the brewery, nor solely a cooperation issue of the supplier's willingness to help. It becomes a coordination issue of how every subsequent actor in the chain adjusts to this disruption to maintain the supply chain's efficiency. Therefore, while cooperation and distribution are indeed important aspects to consider, the primary challenge in enhancing climate resilience in the beer supply chain lies in coordination - ensuring that all actors work in tandem, synchronizing their responses to external shocks, and maintaining the integrity and efficiency of the entire supply process [26].

Coordination is an essential aspect of any supply chain, and effective coordination can lead to improved performance and greater resilience to external shocks such as climate-related risks [15]. The beer supply chain involves multiple actors with differing roles, interests, and objectives, making coordination a complex task [26]. Therefore, understanding the mechanisms that facilitate effective coordination is crucial for enhancing the climate resilience of beer supply chain companies. Coordination theories provide a framework for analyzing these factors that influence coordination among actors and identifying strategies that can improve coordination.

### Ostrom's Design Principles

Elinor Ostrom's design principles offer a comprehensive and practical framework for addressing coordination problems, particularly in shared resource contexts [40] like supply chains. By incorporating Ostrom's principles into this study, it allows for a systematic, theoretical approach to analyze and enhance the coordination processes in the supply chain management under the impact of climate change [41].

Elinor Ostrom's eight design principles provide a valuable framework for understanding how to manage common-pool resources effectively. These principles emerged from Ostrom's extensive research on different communities worldwide and their varied success in managing shared resources [42].

Ostrom's design principles is the idea that for a shared resource system to be durable and efficient, it must be fair and responsive to the people who use and manage it [40]. Ostrom identified eight key principles found common in long-enduring, successful common resource management:

1. Clearly defined boundaries: Ostrom's first principle focuses on defining clear boundaries for who has rights to the shared resource and the resource itself. This is crucial for managing resource usage and promoting cooperation among users [42].

2. Congruence between rules and local conditions: Rules and regulations governing resource usage must align with local needs and conditions. This congruence fosters greater compliance and respect for the system [42].

3. Collective-choice arrangements: All resource users should have the opportunity to

participate in the decision-making processes that determine the rules governing the resource. This ensures their buy-in and commitment [42].

4. Monitoring: Regular monitoring of resource conditions and user behavior is essential. Effective monitoring deters rule violations and ensures the resource is not depleted or damaged [42].

5. Graduated sanctions: When users violate community rules, they should face sanctions that are proportionate to the severity and context of their infractions. This dissuades misuse and promotes fair and equitable treatment [42].

6. Conflict-resolution mechanisms: Low-cost, accessible mechanisms should be in place to resolve conflicts among users or between users and authorities. Quick resolution of disputes maintains trust and cooperation among the community [42].

7. Recognition of rights to organize: The rights of users to devise their own institutions must not be challenged by external governmental authorities. This fosters a sense of ownership and encourages users to protect and sustain their resources [42].

8. Nested enterprises: In larger common-pool resources, governance activities should be organized in multiple nested layers. This allows for more effective management and caters to the complexity and diversity of large systems [42].

They provide a valuable framework for evaluating and designing institutions and collaboration mechanisms across various sectors [43], including complex supply chains like that of the beer industry. They offer guidance on how to structure relationships and interactions among different actors for effective, sustainable management of shared resources [40].

The relevance of Ostrom's principles in defining new coordination mechanisms is particularly pronounced in the face of climate change. With the increasing need for industries to adapt to changing environmental conditions [2], these principles can guide the beer industry in developing robust, flexible strategies to mitigate climate risks.

Hence, Ostrom's design principles could serve as a practical guide for the beer industry to structure and outline efforts in managing shared environmental challenges. It can provide a framework for collaboration, mutual accountability, and adaptability for developing new, effective coordination mechanisms in the face of climate change.

## 2.2 Research Approach

Literature shows inductive, deductive and abductive as the three most commonly used approaches in a research process [21] [44]. Since the supply chain's adaptation to climate change is relatively a novice topic, an inductive approach is preferred due to its flexible nature [45].

The research approach chosen for this study is inductive, which involves the collection and analysis of data to develop insights[46]. This approach aligns with the research questions that aim to gain a deeper understanding of effective coordination measures that can enhance the climate resilience of beer supply chain companies. The study will begin with the collection of data through interviews and literature, and other methods to address the descriptive sub-research questions that explore the different components and actors in the beer supply chain, as well as the impacts and vulnerabilities of drought and heatwave hazards. The data collected will then be analyzed to identify relationships and underlying mechanisms to answer the relational sub-research questions that explore the nature and extent of relationships between actors in the beer supply chain, potential coordination mechanisms, and their positive influence on climate change vulnerability.

Using an inductive research approach, the first aim would be to observe and gather empirical information on the working of different supply networks of organizations within the same sector and their impact due to climate change. The information gained could help to identify the vulnerability points in the supply chain resulting from climate change and to analyse what kind of hazards or non-hazard data needs to be monitored over time.

To accommodate the available data from literature and provided by Royal HaskoningDHV, a two-part research approach utilizing an inductive method is proposed. This approach will involve a descriptive study to guide the data collection and analysis process, and a sectorial study to provide a more in-depth understanding of the relationships between variables or concepts and identify underlying mechanisms.

### 2.2.1 Descriptive study

This approach is mainly used to answer the descriptive sub-questions. This research approach focuses on using descriptive studies namely case reports, case series, cross-sectional studies, business reports, case studies and other forms of literature to look into the existing public data available along with the data available from the company to demonstrate the relationships existing within the supply chains [46]. This is an observational study approach where information is collected without changing the environment. This study will explore the impacts and vulnerabilities of drought and heatwave hazards on the beer supply network. This approach would be useful to study what elements in the supply chain could be manipulated or changed for making them more climate resilient.

### 2.2.2 Sectorial study

This approach is mainly used to answer the relational sub-questions. The research approach would be to broadly study a group of supply chains in a sector. This would require the extensive use of a set of tailored interview questionnaires which is useful in gathering large amounts of data from sizeable sample volumes. These tools are particularly effec-

tive for measuring subject behaviour, intentions, attitudes and opinions [46]. The data collected will be analyzed to identify relationships and underlying mechanisms to explore the nature and extent of relationships between actors in the beer supply chain, outlining potential coordination mechanisms, and their positive influence on climate change vulnerability.

## 2.3 Research Methodology

### 2.3.1 Qualitative Research

The thesis is done in collaboration with Royal HaskoningDHV. A qualitative research methodology using case studies and semi-structured interviews with experts and companies in the beer beverage sector would be used to gather a comprehensive understanding of their supply chain vulnerabilities and existing climate adaptation capabilities. The causes of climate change and research on future climate projections are scoped out. The main scope is on the effective coordination strategies against climate risk under the assumption that climate change is occurring, and that future climate projections are broadly correct.

Studies suggest an interpretivism research paradigm favouring methodologies such as ethnography and case studies and use methods such as interviews and focus groups are preferred by researchers to gain an extensive knowledge of the primary objective for an inductive type of research approach [47]. Qualitative studies have been used in a wide range of domains. The objective of the qualitative methodology is to produce in-depth and illustrative information in order to understand the various dimensions of the problem under analysis [48]. Qualitative research is also more versatile as it is much easier for researchers to adapt to circumstances or changes in the environment [49] making it suitable for this research.

### 2.3.2 Theoretical Frameworks

In the quest to methodically understand the complexities associated with the beer supply chain and its interaction with climate resilience, this research employs three pivotal theoretical frameworks. Each of these frameworks offers a unique lens through which the research questions are developed,explored, and subsequently analyzed.

1. **Institutional Analysis and Development (IAD) Framework:** The IAD framework offers a structured modality to dissect actor interactions within specific institutional settings [23]. Applied to this study, the IAD framework facilitates the structured breakdown of the overarching research problem into detailed sub research questions. Specifically, it provides a valuable tool for scrutinizing coordination mechanisms and relationships among actors in the beer supply chain. By doing so, it ensures a holistic understanding, making it indispensable for this research.

2. **Action Situation Component of the IAD:** Diving deeper into the IAD, the Action Situation framework becomes particularly crucial when dissecting Heineken's strategies against climate change challenges. It lends itself to a granular analysis, offering insights into how different actors interact, both internally and externally, and their ensuing implications [30]. Directly connecting to relational sub-question two, it equips the research with the tools to gauge the effectiveness of existing mechanisms or strategies in bolstering climate resilience within the beer supply chain using Heineken as a case study.

3. **Ostrom's Design Principles:** Elinor Ostrom's design principles for managing common-pool resources have proven seminal in understanding shared challenges and their governance [40]. Transposing these principles to the context of the beer industry's shared challenges posed by climate change, they can offer a structured blueprint. These principles can help the industry in crafting a collaborative, adaptable, and mutually accountable approach towards these challenges. Moreover, in relation to relational sub-question three, Ostrom's principles outline the pathways to devise, evaluate, and enhance coordination mechanisms that fortify climate resilience.

These theoretical frameworks not only shape the methodology but are also instrumental during the analysis phase. They provide a systematic lens to interpret the gathered data, ensuring that conclusions drawn are rooted in robust academic structures.

### 2.3.3 Data Collection

Interviews provide a rich source of data as they allow for a detailed exploration of the experiences, perspectives and attitudes of participants. Having a semi-structured type of interview provides flexibility to allow the interviewee to elaborate and discuss the topics more in depth apart from the set of pre-determinined questions [50]. It can provide context and background information that may not be available from other sources [50].

In the data collection phase of the research methodology, the focus will be on two primary sources of data to enrich the analysis and contextual understanding of the beer beverage industry, with a special focus on Heineken as a case study.

- The first pool of data will be collected from interviews with supply chain experts, particularly those who are intimately familiar with or directly involved in the beverage sector. This will provide a broad perspective on the industry trends, common practices, challenges, and unique attributes of the beverage supply chain.

- The second pool of data will be drawn from interviews conducted with personnel from Heineken or associated with Heineken projects. These interviews will offer

an in-depth exploration of the company's unique supply chain structure, its specific challenges, its strategies to cope with climate hazards such as droughts and heatwaves, and its coordination measures to enhance climate resilience.

Even though a qualitative methodology is predominantly used, quantitative data such as climate datasets, climate reports, hazard data and company financial figures could also be evaluated to identify patterns and relationships in the data in order to achieve a valuable result.

**Interview Sample**

The choice of an interview sample should be driven by the research questions and objectives of the study [51].

In line with the objectives of this research, the unit of analysis will be companies operating within the beverage supply chain, including those involved in the production, distribution, and retailing of beer sector. The population of interest for the study encompasses individuals who bear responsibility for managing and operating these beer supply chains, as well as experts in the field who bring a depth of experience and knowledge to the understanding of the issues at hand.

To focus on the analysis, Heineken will be the sampling population. Heineken, as a global leader in the beer industry with a complex and expansive supply chain, offers an ideal context for the investigation. The study aims to unearth insights that are relevant not only to Heineken but also to other actors in the industry facing similar challenges.

The method of sampling to be used in this study is convenience sampling. Bhattacherjee discusses convenience sampling as a type of non-probability sampling technique where subjects are selected because of their convenient accessibility and proximity to the researcher [51]. This is selected primarily due to the practical considerations of access and availability of respondents. While this non-probability sampling method may introduce some bias, it is worth noting that the depth and specificity of information obtained from targeted respondents at Heineken, coupled with the industry-wide expertise, are likely to provide rich and valuable data for the study.

## 2.4 Research Flow Diagram

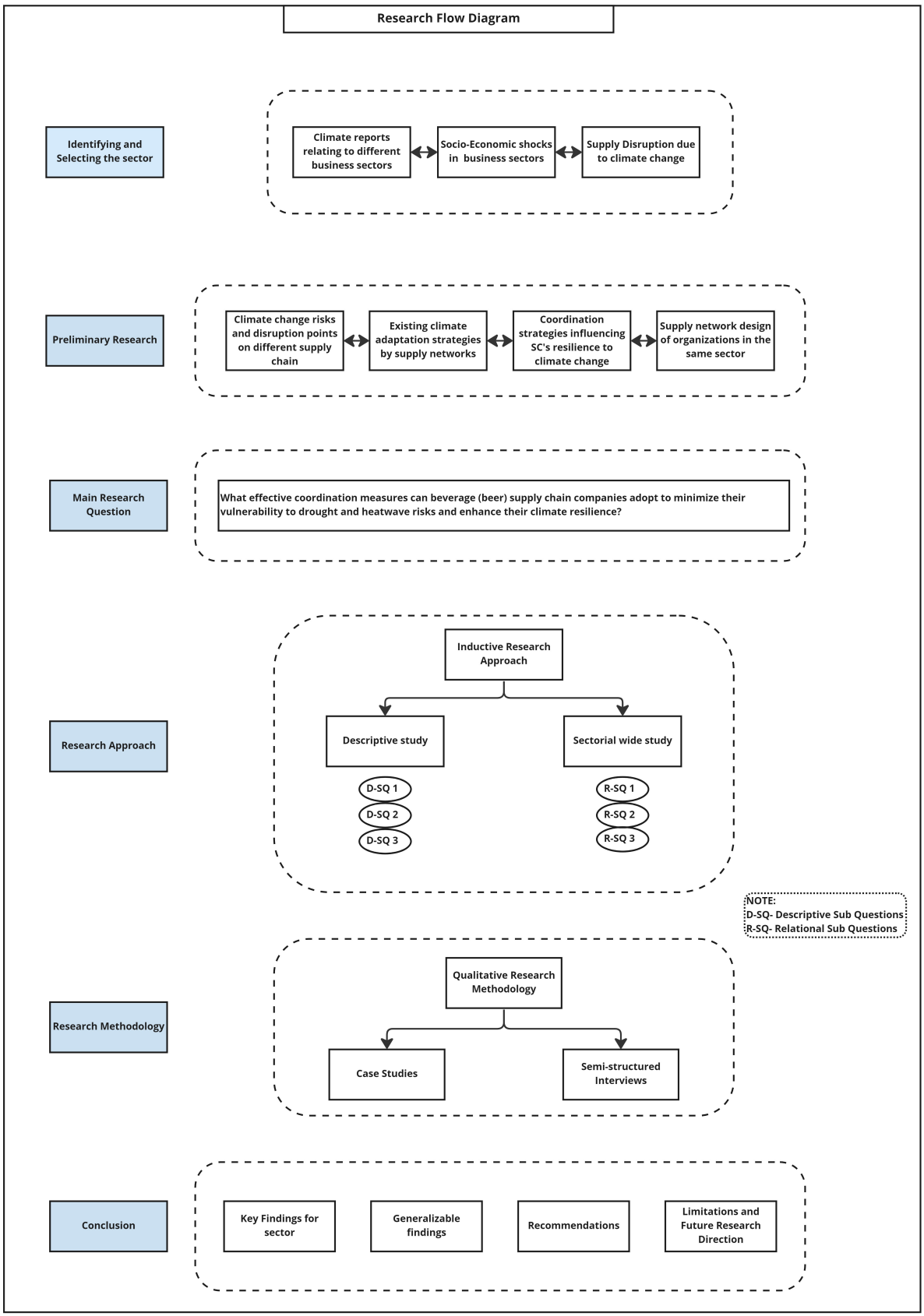


Figure 5: Research Flow Diagram

# 3 Industry Overview: Beer Beverage Supply Chain

## 3.1 Food and Beverage Sector Introduction

As a primary need, food and beverage industry is in great demand and the market size of global food and beverage sector is expected to grow to $8.9 trillion by 2026 at a compound annual growth rate of 8.7% [24]. To achieve sustainability goals, it is essential to understand the risks and challenges faced by different actors in the food supply chain, including processors, distributors, aggregators, and producers [25]. The F&B sector plays a crucial role in building resilience across the food supply chain, with the potential to make a significant impact at every stage. There is increasing interest from companies to take action on sustainability and disclose their progress, as demonstrated by the rise of corporate social responsibility reporting [25].

Due to factors such as resource allocation, inventory management, climate disruptions, and sustainability, the food and beverage supply chain can be complex [52]. The efficiency of food and beverage SMEs is influenced by their supply chain, which has a significant impact on their performance. Early supplier involvement and collaboration can positively impact supply chain performance in food and beverage processing companies [52]. Overall, understanding the complexities of the food and beverage industry's supply chain is vital for effective supply chain management, sustainability, and business success.

The food and beverage industry is quite broad and diverse in nature. The major subsectors within this sector are Dairy products, Confectionery, Meat and poultry, Seafood, Fruits and vegetables, Beverages (alcoholic and non-alcoholic), Snack food, Bakery products, Sauces, dressings and condiments, Processed foods, Natural and organic foods [24] [53].

While the supply chains of different sub-sectors within the food and beverage industry share similarities, they also have unique characteristics that distinguish them from one another [54]. For instance, the supply chain of the meat and poultry sector involves specific requirements for storage and transportation to ensure food safety and maintain product quality. In contrast, the supply chain of the beverage sector requires specialized packaging and handling to prevent spoilage and maintain freshness. Thus, while the food and beverage industry shares a common supply chain framework, the unique requirements of each sub-sector necessitate tailored supply chain strategies to ensure product quality, safety, efficiency and resiliency [54].

## 3.2 Beverage (Beer) Supply Chain

The beverage industry is a vast and diverse sector that includes the production and distribution of a variety of non-alcoholic and alcoholic drinks. Non-alcoholic beverages include soft drinks, juices, energy drinks, sports drinks, bottled water, tea, and coffee,

while alcoholic beverages include beer, wine, spirits, and other fermented beverages [55].

The beer industry is composed of a wide range of companies, from small craft breweries to large multinational corporations, and includes both traditional beer-making methods and innovative techniques. The beer industry is dominated by a few large multinational corporations such as Anheuser-Busch InBev, Heineken, and Carlsberg, which account for a significant portion of global beer production and sales [56]. However, there has been a recent trend towards the growth of smaller craft breweries that produce high-quality, unique beer products that cater to specific consumer tastes. Despite the varying sizes of companies, the industry is heavily regulated by governments, particularly in terms of alcohol content, labeling, and advertising [56].

Beer is one of the most popular and a highly demanded alcoholic beverage, and to meet its growing demand, a stable supply of its primary ingredients, including clean water, barley, and hops, is essential [57]. Hence, its supply chain is complex and interrelated, beginning with the procurement of specialized raw materials such as malt, hops, and yeast, and continuing through the brewing process to produce finished beer products.

However, climate change poses significant threats to the availability and quality of these raw materials, with changes in temperature and precipitation patterns and extreme weather events such as droughts and floods potentially affecting crop yields and quality, leading to supply chain disruptions and increased costs for breweries [58].

In response to these challenges, many companies in the beer industry are taking steps to improve their climate resilience. This includes efforts to reduce greenhouse gas emissions from their operations, as well as investments in sustainable agriculture practices and research into new varieties of barley and hops that are more resistant to climate-related stressors [59]. Additionally, better collaboration strategies among stakeholders along the beer supply chain, such as suppliers, distributors, and retailers, is also expected to enhance the industry's climate resilience and minimize the impact of climate-related disruptions [60].

## 3.3 Levels and Components of the Beer Supply Chain

The supply chain can be defined as a network of interconnected and independent entities involved in various business processes that result in the production and delivery of physical products or services to customers [57]. For the beer industry, the supply chain includes both upstream, downstream links, and comprises a series of activities that organizations undertake to deliver value to their customers. It can be in the form of a product, service, or a combination of both (Interviewee 1). In addition, the supply chain can be seen as the integration of materials and information flow between the customer, manufacturer, and supplier [61]. The beer supply chain involves a complex series of processes and activities that span from the procurement of raw materials to the distribution and delivery of finished products to consumers.

To gain a comprehensive understanding of the beer supply chain, it is beneficial to break it down into four key subparts: Upstream, Work-in-Progress, Downstream, and Supply Chain Flows (Interviewee 2). This approach helps to provide a clear and structured view of the various processes and activities involved in the beer supply chain. By examining each subpart in detail, stakeholders could identify potential areas for improvement and develop strategies to enhance supply chain collaboration, thereby potentially improving supply chain resiliency to climate change.

### 3.3.1 Upstream

The upstream supply chain refers to the processes and activities that occur prior to a product reaching the manufacturing or assembly stage, involving the sourcing, transportation, and management of raw materials, semi-finished goods, and other necessary elements required to produce a final product [62]. The primary objective of the upstream supply chain is to ensure that the right quantity and quality of raw materials are available to meet the manufacturing requirements of the organization [62].

In the beer industry, this entails identifying and establishing relationships with suppliers of essential beer ingredients, such as malt, hops, yeast, and water, as well as suppliers for packaging materials like bottles, and cans (Interviewee 6). Procuring high-quality malt, hops, yeast strains, and water sources is crucial, as these ingredients must meet the specific requirements for brewing different types of beer [57].

For understanding the upstream supply chain in depth, each of these crucial beer ingredients—malt, hops, yeast, and water as well as packaging materials i.e. glass and aluminium cans will be explored in depth to identify its role and procurement options in the upstream supply chain.

**Malt** Malt is the result of the germination process of grains, commonly barley, where the grains are allowed to sprout and then dried and it plays a central role in beer production [57]. It provides the essential sugars needed for fermentation, which contribute to the beer's flavor, color, and alcoholic content [57].

Sourcing or procuring of Malt for brewing is done in multiple ways:

- **Purchasing from Maltsters/Malting Co-operations:** Maltsters are professionals who specialize in the production of malt from grains, usually barley. They handle the entire malting process, which includes steeping, germination, and kilning. This process converts the starches in the barley into fermentable sugars, which are essential for the brewing process [63]. Purchasing malt directly from maltsters or malting co-operations is common because it saves breweries the time, equipment, and expertise needed to malt barley themselves (Interviewee 6).

- **In-house Malting:** Some breweries choose to malt their barley in-house. This gives them complete control over the malting process, allowing them to tailor the malt's characteristics to their specific needs (Interviewee 6). In-house malting requires significant investment in equipment and expertise, but it can lead to unique flavors and a strong selling point for craft breweries and locally-produced beers [64].
- **Locally Sourced Barley:** Choosing to source locally grown barley has several advantages. It supports local farmers and the local economy, and it can also reduce transportation emissions, contributing to a lower carbon footprint [65].
- **Imported Barley:** Sourcing specific barley varieties from around the world allows breweries to experiment with unique flavors and characteristics. Different regions and climates can produce barley with different properties, and breweries might import these specialty grains to create unique beers or replicate traditional styles from different regions [66].

**Hops** Hops are the cone-shaped flowers of the hop plant, used primarily in brewing beer [57]. Hops hold a place of critical importance in the process of beer manufacturing, significantly contributing to the character, taste, and preservation of the final product [57]. Furthermore, in the modern craft beer scene, hops are central to product differentiation, allowing brewers to innovate and create new styles [57].

Sourcing or procuring of Hops for brewing is done in multiple ways:

- **Direct Purchase from Hop Growers or Dealers:** Most breweries obtain their hops by purchasing directly from growers or dealers (Interviewee 6). These specialists are responsible for the cultivation, harvest, and processing of the hops, which are typically dried and converted into forms suitable for brewing, such as pellets. This method is preferred because it eliminates the need for breweries to invest in the infrastructure and expertise required to grow and process hops themselves [67].
- **In-house Hop Growing:** While less common, some breweries, particularly small craft breweries, opt to grow their hops in-house [68]. This approach allows for total control over the growth and harvest processes, and can contribute to a unique flavor profile that sets the brewery's products apart. However, in-house hop cultivation requires significant land, equipment, and horticultural expertise [68].
- **Local Sourcing:** Local sourcing is an option favored by many breweries for its dual benefits of supporting local agriculture and reducing transportation-related emissions (Interviewee 6). The locally grown hops can give the beer a unique flavor profile. This method can also be beneficial from a marketing perspective, as consumers are increasingly interested in locally-sourced products [66].

- **Importing:** The climate and soil conditions in different regions can produce hops with varied properties, and brewers might import these specialty hops to create distinctive beers or to replicate traditional styles from those regions [69].
- **Contracting:** Breweries often enter contracts with growers or suppliers to ensure a consistent supply of hops. These contracts typically specify a certain quantity of hops to be delivered at a future date, and at an agreed-upon price [67]. This can provide stability in terms of both supply and price, but it requires breweries to accurately forecast their future needs [70].
- **Spot Market Purchasing:** Some breweries buy hops from the spot market, which means purchasing hops as needed without a prior contract [70]. This approach can be beneficial when there's a surplus of hops, leading to lower prices. However, it also leaves breweries vulnerable to price volatility and potential supply shortages [70].
- **Sustainability Initiatives:** Increasingly, breweries are looking to source hops from growers who employ sustainable farming practices [71]. This might involve using less water, reducing the use of pesticides, or promoting biodiversity. These initiatives align with a growing consumer preference for environmentally-friendly products [71].

**Yeast** Yeast procurement for beer manufacturing is an essential aspect of the brewing process because yeast is the microorganism responsible for fermentation, the process that turns the sugar extracted from malt into alcohol and carbon dioxide. Yeast also contributes to the beer's flavor and aroma profile [57].

Sourcing or procuring of Yeast for brewing is done in multiple ways:

- **Purchasing from Yeast Laboratories or Suppliers:** Many breweries source their yeast from specialized yeast laboratories or suppliers who provide a wide variety of yeast strains, each imparting a different flavor and aroma profile to the beer [57]. These suppliers often provide the yeast in a ready-to-pitch form, meaning it's in a healthy and active state, ready for fermentation. This is the most common method as it saves breweries from the complex and time-consuming process of yeast propagation and maintenance [57].
- **In-house Yeast Propagation and Maintenance:** Some breweries, particularly larger ones or those with a strong focus on unique beer styles, may choose to propagate and maintain their yeast strains in-house (Interviewee 6). While this method requires significant expertise and resources, it gives the brewery complete control over the yeast strains used and allows for the development of proprietary strains that can create unique and distinctive beers [64].

- **Local Sourcing:** While not as common, some breweries may choose to source yeast locally, particularly for styles such as wild or spontaneous fermentation beers. In these cases, the yeast is often captured from the local environment, leading to unique flavor profiles that are strongly tied to the brewery's location [67].
- **Yeast Banks:** Yeast banks are another source of yeast for breweries. These banks store a wide variety of yeast strains, including many that are rare or unusual. Breweries can access these banks to find unique strains that can help them create distinctive beers [72].
- **Yeast Reuse:** Many breweries practice yeast reuse, where yeast from one fermentation is harvested and used in subsequent fermentations. This practice requires careful management to ensure the yeast remains healthy and free from contamination over multiple generations, but it can be a cost-effective method of yeast management [69].

**Water** Water is absolutely vital in beer manufacturing. Constituting about 90-95% of the final product, it significantly influences beer's volume, taste, and quality [27]. Water characteristics can dictate beer styles and, as a resource-intensive industry, breweries must manage their water usage responsibly for sustainability [57].

Sourcing and managing of Water for brewing is done in multiple ways:

- **Local Water Sources:** Many breweries source their water locally, either from municipal water supplies or from natural sources like wells, rivers, or springs (Interviewee 6). The mineral content and pH of the water can greatly affect the beer's taste and the efficiency of the brewing process [68].
- **Water Treatment:** Because water quality is crucial for brewing, many breweries invest in water treatment systems to purify and adjust the water used in their brewing processes [73]. This can involve processes like reverse osmosis, deionization, or filtration to remove impurities, and the addition of salts or minerals to adjust the water's profile to suit the style of beer being brewed. This gives breweries the ability to consistently produce high-quality beer, regardless of the inherent variability in their local water supply [73].
- **Water Conservation:** Water usage in breweries goes beyond just the beer itself; it's also used extensively in the cleaning and cooling processes. Therefore, many breweries have started to implement water conservation strategies to reduce their environmental impact and save on water costs [69]. This can involve practices like reusing water from the cooling process in cleaning, capturing and reusing steam from the brewing process, and investing in more water-efficient equipment [73].

**Aluminium Can** Aluminum cans play a crucial role in the beer manufacturing industry due to their ability to preserve product quality by providing an impermeable barrier to light and oxygen, both of which can degrade beer over time [74]. Their lightweight and durable nature reduces transportation costs and minimizes product loss, making them an economically appealing packaging option. Notably, their recyclability and high recycle rate contribute to the sustainability goals of many beer manufacturers, enabling them to lower their environmental footprint while delivering their product in a form that is both convenient and appealing to consumers [74].

The procurement of aluminum cans for beer manufacturing can be conceptualized into a multi-tier supply chain:

- **Tier 1 - Aluminum Can Manufacturers:** These are the direct suppliers to the breweries. They purchase aluminum sheets, form them into cans, label them according to the breweries' specifications, and apply internal coatings to prevent the beer from reacting with the aluminum [75].
- **Tier 2 - Aluminum Producers:** They smelt raw aluminum from processed bauxite (alumina) and form it into sheets. These sheets are then sold to can manufacturers. This stage is energy-intensive and requires proximity to inexpensive power sources [74].
- **Tier 3 - Bauxite Mining and Alumina Refining:** The supply chain begins here, with companies mining bauxite, primarily in countries like Australia, Guinea, and Brazil [76]. The mined bauxite is then refined to produce alumina, which is sold to aluminum producers [74].

**Glass Bottles** Glass bottles are essential in beer manufacturing for their ability to preserve beer's quality, contribute to product differentiation through unique designs, and for their recyclability. However it also has challenges such as higher shipping costs and breakage risk [77].

The procurement of glass bottles for beer manufacturing involves multiple tiers of suppliers:

- **Tier 1 - Bottle Customization Suppliers:** This tier involves suppliers who customize the glass bottles to meet the brewery's specific requirements. This could involve the design and application of labels, the embossing or engraving of branding elements on the bottle, or the addition of any other distinctive features [78]. This step is critical in ensuring the brewery's product stands out on the shelves.
- **Tier 2 - Glass Manufacturers:** Glass manufacturers receive the raw materials and undertake the glass-making process. This involves melting the raw materials

at high temperatures to form a uniform liquid, which is then molded into the shape of beer bottles [77].

- **Tier 3 - Raw Material Suppliers** These suppliers mine and provide the fundamental raw materials necessary for glass production. The primary ingredients for glass include silica (sand), soda ash, and limestone. These raw materials are extracted and processed to meet the purity requirements for glass production [77].

### 3.3.2 Work-in-Progress

The "work-in-progress" (WIP) section of the beer supply chain mainly refers to the breweries and encompasses a number of critical stages, namely production, warehousing, and packaging (Interviewee 1). This segment constitutes the transformation of raw materials into a finished product that is ready for distribution and sale.

#### Production

- **Raw Material Handling:** This involves the procurement, inspection, and storage of raw materials that are used in brewing beer, including water, malt, hops, and yeast. Efficient management of these resources is critical to ensure the consistency and quality of the final product [79]. It is necessary to properly store these materials to prevent spoilage or damage and maintain their quality. This might involve refrigeration for certain types of hops and yeast or proper humidity and temperature control for storing malt [57]. Good supplier relationships are also important at this stage to ensure the timely delivery of quality raw materials (Interviewee 7).

- **Brew-house Operations:** The brewing process begins after the raw materials are managed. This occurs in the brewhouse and involves several stages, including milling, boiling, and fermenting. Each of these stages requires careful control of variables like temperature and time to ensure the consistent quality of the beer [79]. Modern breweries use automated systems to control these variables precisely, but skilled brewers also play a crucial role in monitoring the process and making necessary adjustments [79].

- **Blending:** Blending is the process of combining different batches of beer to achieve a consistent flavor, aroma, and color across all units. This is particularly important for large breweries that distribute their products widely and need to ensure a uniform product regardless of when or where the beer is purchased [79].

### Warehousing

- **Inventory Management:** After production, beers are stored in a warehouse before they're distributed to retailers or consumers (Interviewee 6). Effective inventory management is critical at this stage. Breweries must track the quantity and location of each product within the warehouse to ensure they can meet demand and deliver fresh product [80]. Furthermore, because beer has a limited shelf life, breweries often follow a first-in-first-out inventory policy to ensure older stock is sold first. This requires an organized warehouse and a reliable inventory tracking system, often using barcodes or RFID tags [80].

- **Logistics Management:** This involves the coordination of transportation and delivery of the beer from the warehouse to retail outlets, bars, restaurants, or directly to consumers (Interviewee 6). Depending on the scale of the brewery, this might involve managing a fleet of delivery trucks or coordinating with third-party logistics providers. Effective logistics management can reduce transportation costs and ensure speedy delivery, which is especially important for maintaining the freshness of the beer [69].

- **Order Fulfillment:** This is the process of receiving, processing, and delivering orders to customers. When an order comes in, the necessary products must be located in the warehouse, packed for delivery, and then shipped to the customer (Interviewee 5). This process needs to be accurate and efficient to ensure customer satisfaction. Mistakes in order fulfillment can lead to wrong or delayed orders, damaging the brewery's reputation [80].

### Packaging

- **Kegging:** In this process, beer is filled into kegs, which are often made of stainless steel. Kegging is usually employed for large quantities of beer destined for pubs, restaurants, and bars (Interviewee 6). The beer must be transferred from the fermenters into kegs under controlled conditions to prevent exposure to oxygen, which could cause the beer to spoil [81].

- **Bottling and Canning:** Bottling and canning are two other common methods of packaging beer. Both these methods require a high level of automation and precision to ensure consistent filling and sealing [81]. Packaging in bottles or cans makes the product more convenient for individual consumers and also allows for a wide variety of branding and marketing options [81].

- **Quality Control:** Ensuring quality is paramount in all stages of beer production and packaging is no exception. After the beer is packaged, it goes through various quality control checks (Interviewee 6). These may include inspection for proper

filling levels, correct cap or lid placement, label accuracy, and overall packaging integrity [69].

### 3.3.3 Downstream

The downstream supply chain typically refers to the activities that occur after the work-in progress phase and before the product reaches the end consumer. It includes all processes and procedures related to distribution, such as warehousing, order fulfillment, logistics management, and transportation (Interviewee 5). A key goal of the downstream supply chain is to deliver the product to the customer quickly, efficiently, and in excellent condition [82].

In the beer industry, the downstream supply chain commences once the beer is packaged and ready for delivery. It involves an intricate web of relationships and transactions that ensure the beer reaches consumers in the best condition. The initial stage, distribution, involves transporting beer from breweries to various distribution centers or directly to regional wholesalers. Wholesalers, who play a pivotal role in the beer supply chain, buy beer in bulk quantities, store it under optimal conditions, and then sell it to retail outlets like supermarkets, liquor stores, bars, and restaurants. The retailers finally bring the beer to the end consumers (Interviewee 5).

For understanding the downstream beer supply chain in depth, each of these stages distribution, regional wholesaling, retailing and end customers will be explored in depth to identify its roles and vulnerability or challenges in the downstream supply chain.

**Distribution** Within the beer industry, the distribution stage acts as a vital conduit linking the brewery to the network of wholesalers, retailers, and finally, consumers (Interviewee 6). Distributors are entrusted with the important task of transporting beer under appropriate conditions to ensure it arrives fresh and ready for consumers. Distribution also entails the management of critical information flow in the supply chain, such as order details, delivery schedules, and returns, ensuring the entire process operates in a seamless and efficient manner [83].

**Vulnerabilities and Challenges:**

- **Logistical Challenges:** Beer is a perishable product and its quality heavily depends on controlled storage conditions, particularly temperature [68]. It must be handled carefully during transport to prevent spoilage and damage to packaging. Logistical failures can lead to compromised beer quality, ultimately affecting the brand reputation [69].
- **Regulatory Compliance:** Distributors must navigate a complex landscape of alcohol beverage control regulations that vary by region, state, or country (Interviewee 4). These laws dictate who can sell, buy, and distribute beer, and violating

them can lead to serious repercussions, including fines and disruption of operations (Interviewee 4).

- **Supply Chain Disruptions:** External disruptions like natural disasters, pandemics, or socio-political changes can impact the beer supply chain, affecting the reliability and efficiency of distribution [62] (Interviewee 3). Distributors need to have contingency plans in place to manage such situations (Interviewee 3).

**Regional Wholesaling** Regional wholesalers play a key role in the beer supply chain by purchasing beer in bulk from breweries or distributors and then reselling it to various retailers such as liquor stores, bars, and restaurants (Interviewee 6). These wholesalers effectively act as intermediaries, connecting producers and retailers, and reducing the complexity for breweries in reaching numerous individual retail outlets.

**Vulnerabilities and Challenges:**

- **Market Dynamics and Demand Forecasting:** Regional wholesalers must navigate market trends and consumer preferences, which can shift rapidly, leading to fluctuations in demand. Accurate demand forecasting is crucial to maintain optimal inventory and avoid overstocking or understocking [62].
- **Supplier Relationships and Negotiations:** Wholesalers deal with multiple breweries, each potentially offering various beer styles and brands. Managing these relationships, negotiating prices, and ensuring a consistent supply can be challenging (Interviewee 4).
- **Financial Risks:** Changes in market conditions, currency fluctuations, or brewery pricing can impact the financial health of wholesalers. They need to manage these risks and ensure business profitability [68].
- **Logistics:** Wholesalers must ensure efficient logistics for delivering beer to numerous retailers, often dispersed across wide regions. This involves route planning, vehicle loading, and coordinating delivery schedules [61].

**Retailing** Retailers, including grocery stores, liquor stores, bars, restaurants, and online stores, represent the final link in the beer supply chain before the product reaches the end consumer (Interviewee 4). They are responsible for providing the physical or digital space where consumers can purchase beer. Retailers contribute to the overall customer experience through the variety of beer they offer, their pricing, and their customer service [83].

**Vulnerabilities and Challenges:**

- **Changing Consumer Preferences:** Retailers must stay attuned to changing consumer tastes and preferences, which can rapidly shift based on factors such as

seasonality, new trends, marketing campaigns, or societal changes [61]. Being slow to adapt to these changes can result in decreased sales.

- **Pricing and Profit Margins:** Retailers need to carefully set their selling prices to ensure they can cover costs and maintain profitability. This can be challenging due to factors like competition, price-sensitive customers, and fluctuations in the cost price from wholesalers or breweries [49].
- **Competition:** The retail beer market can be highly competitive, with numerous stores vying for customer attention. Retailers must find ways to differentiate themselves, whether through product variety, price, customer service, or unique shopping experiences [84].

**End Customers** The end consumer stage of the beer supply chain represents the final destination for the product. While this stage is not typically viewed as a part of the supply chain in the traditional sense, the end consumer significantly influences the dynamics of the entire chain [69]. Their purchasing decisions are driven by factors such as taste preference, brand loyalty, pricing, product availability, and marketing campaigns [69].

**Vulnerabilities and Challenges:**

- **Consumer Preferences:** The most substantial challenge at this stage is predicting and responding to changing consumer preferences (Interviewee 4). Trends in beer consumption can change quickly, driven by factors like seasonal changes, emerging health consciousness, and changing societal attitudes [84].
- **Information Asymmetry:** Consumers often rely on product labeling and marketing to inform their purchase decisions. However, these information sources may not always be accurate or comprehensive, leading to potential misinformation or misunderstanding about the product [85].
- **Price Sensitivity:** Consumers' purchasing decisions are often heavily influenced by the price of beer. Changes in the economy, such as inflation or a recession, can make consumers more price-sensitive, potentially affecting beer sales [85].
- **Sustainability Concerns:** Increasingly, consumers are interested in the environmental impact of the products they consume [69]. This includes interest in sustainable brewing practices, the environmental footprint of packaging, and the sustainability of the overall supply chain [85].

### 3.3.4 Supply Chain Flows

Supply chain flows refer to the movement or transfer of resources and information between businesses, starting from the procurement of raw materials to the delivery of the final

product to the end consumer [86]. The following are the major flows observed in the supply chain:

- **Demand Flow:** This refers to the process of transferring consumer demand information up the supply chain, from retailers to distributors to manufacturers to suppliers [86]. Demand generally flows upstream, starting with the consumer and moving back through retailers, distributors, and finally to the brewery and its suppliers (Interviewee 2).
- **Value Flow:** This involves the process of adding value to raw materials as they progress through the various stages of production and distribution [86]. The flow of value can be seen as moving downstream, from raw material suppliers through to the end consumer (Interviewee 2).
- **Material Flows:** This represents the physical movement of beer and its ingredients throughout the supply chain [87]. In the beer supply chain, the direction of material or product flow is downstream. It begins with the suppliers of raw materials, proceeds to the breweries for production, moves on to warehouses or distribution centers, then to retail outlets, and finally ends with the end consumer (Interviewee 2).
- **Information Flows:** This pertains to the exchange of information among different entities in the supply chain. It plays a crucial role in coordinating and managing the various operations in the supply chain [87]. Upstream, it may include orders or forecasts from the brewery to its suppliers, while downstream information might involve shipping notifications or invoices sent to distributors or retailers (Interviewee 2).
- **Financial Flows:** This represents the movement of financial resources across the supply chain [86]. This primarily flows upstream, as consumers pay retailers, who pay wholesalers, who then pay the manufacturer or brewery (Interviewee 2).
- **Return Flow (Reverse Logistics):** This involves the process of moving goods from their typical final destination (the customer) for the purpose of capturing value, or proper disposal [86]. In the beer industry, this could involve the return of reusable packaging like kegs, bottles, or crates from retailers back to the breweries, or the return of expired or damaged products [87]. This typically flows upstream (Interviewee 2).
- **Sustainability Flow:** This refers to the initiatives and practices implemented across the supply chain to minimize environmental impact, promote social responsibility, and ensure economic viability [88]. In the beer supply chain, this could include practices such as wastewater management at the brewing stage, carbon footprint reduction in logistics, or social responsibility in sourcing materials. This also tends to be bi-directional (Interviewee 2).

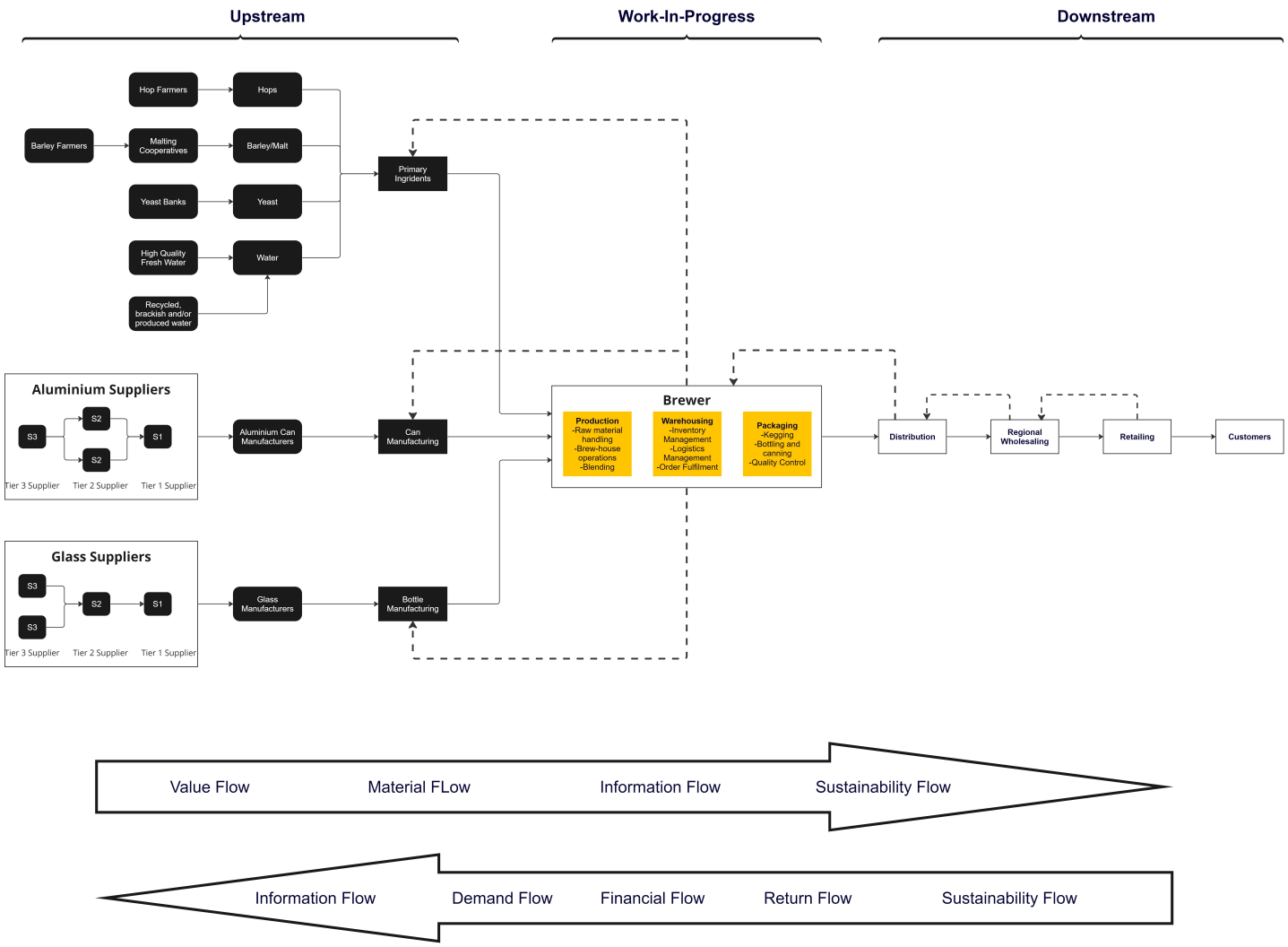


Figure 6: Beer Supply Chain Overview

# 4 Drought and Heatwave Hazards: Vulnerabilities on the beer supply chain

## 4.1 Understanding Drought and Heatwave Hazards

### 4.1.1 Definitions and Characteristics

**Drought** Drought is characterized by a lack of precipitation over an extended period, typically a season or more, leading to water deficiencies that can have substantial impacts on ecosystems and societies [89]. The identification of a drought event is usually based on the statistical comparison of precipitation deficit, where the amount of rainfall in a period is significantly lower than the historical average for that period [90]. Droughts can be characterized by their severity, duration, and geographical extent. The impacts of droughts are vast, affecting agriculture, ecosystems, water supply, and industries like beer manufacturing that rely on these resources [89].

Drought is generally classified into four main types, each presenting its own unique set of characteristics:

- **Meteorological Drought:** This is the most commonly understood type of drought, referring to a prolonged period with less than average precipitation. Meteorological drought is specific to geographical locations since average rainfall varies considerably between different regions [91].
- **Hydrological Drought:** Hydrological drought deals with the effects of these periods of precipitation shortfall on surface and subsurface water supply [91]. It manifests as reduced streamflows, lowered lake/reservoir levels, and depleted groundwater reserves, often having a lagged response to the occurrence of a meteorological drought [89].
- **Agricultural Drought:** Agricultural drought emphasizes the relationship between precipitation deficits, soil moisture levels, and the potential impact on plant life, particularly crops [91]. It affects crop yield and biomass production, posing significant challenges for farmers and agricultural industries, including the beer industry, given the dependency on crop products such as barley and hops [92].
- **Socioeconomic Drought:** This form of drought associates the supply and demand of water and related commodities with the physical water availability conditions [91]. Socioeconomic drought occurs when the demand for water or a water-dependent economic good exceeds supply as a result of a weather-induced shortfall in water availability [89].

**Heatwave** A heatwave is typically defined as a prolonged period of excessively hot weather, which may be accompanied by high humidity [93]. The World Meteorological Organization (WMO) specifies this as the daily maximum temperature of more than five consecutive days exceeding the average maximum temperature by 5°C, using the 1961-1990 period as a benchmark [94]. They pose significant challenges to various industries, including agriculture and brewing [92].

**Major characteristics of Heatwaves:**

- **Duration:** The length of a heatwave is one of its defining features. Unlike short-lived heat events, heatwaves persist for several days or even weeks. The prolonged exposure to excessively high temperatures can significantly amplify their impacts on both the environment and human health [95].
- **Intensity:** Heatwave intensity refers to how high the temperatures rise above the average for a specific location and time of year. Heatwaves can range from mild (a few degrees above average) to extreme (much higher than average), with the more intense events having more severe impacts [93].
- **Geographical Extent:** The area affected by a heatwave can range from a small region to an entire country or even span multiple countries. The severity of a heatwave can vary within its footprint, with certain areas experiencing higher temperatures or longer durations than others [93].
- **Frequency and Sequencing:** The frequency of heatwaves refers to how often they occur, while the sequence refers to the periods between heatwaves. Regions with more frequent heatwaves or sequences of heatwaves with shorter recovery periods in between can experience compounded impacts [96].

### 4.1.2 Global Trends and Predictions

**Drought** Drought hazards are rapidly evolving with the climate change and the forecast for future global trends indicates a concerning rise in both the frequency and severity of drought events. These predictions are based on several factors including temperature increases, changes in precipitation patterns, population growth, and water usage trends [93].

- **Increasing Temperatures** With the continued rise in global temperatures due to human-induced climate change, the evaporation rates are increasing, leading to drier soils. Higher temperatures can also lead to higher water consumption for agriculture, contributing to water scarcity and the risk of drought [96].
- **Precipitation Patterns:** Changes in precipitation patterns due to climate change are expected to exacerbate drought conditions in some areas. This includes shifts

in the timing and intensity of rainfall, more frequent and intense storms, and longer dry spells in between rain events [97].

- **Population Growth and Water Usage** The global population is projected to reach nearly 10 billion by 2050, and with growing populations come increased demands for water [98]. This, combined with shifts towards more water-intensive lifestyles, can put additional stress on water resources and increase the risk of drought [98].

- **Increased Drought Intensity in Wet Regions** Regions that are typically wet are likely to experience more intense and frequent droughts due to climate change. This is because warmer temperatures increase the rate of evaporation from soil and plant surfaces, leading to faster drying of the land during periods without rain. This phenomenon can lead to "flash droughts", which develop quickly and can have devastating impacts on agriculture [93].

- **Compounded Effects of Heatwaves and Drought** Heatwaves and droughts often occur simultaneously and can exacerbate each other. Predictions suggest that these events will increase in frequency and intensity by 2030 [92].

- **Socioeconomic Factors** Drought risk is also influenced by socioeconomic factors. Regions that are economically disadvantaged may have less capacity to adapt to and recover from drought. Population growth in drought-prone areas and increased demand for water due to urbanization can also contribute to increased drought risk [97].

Given these factors, it is predicted that the severity and frequency of droughts will increase in the coming decades, particularly in already drought-prone areas such as the Mediterranean, parts of Africa, Australia, and the southwestern United States [97]. Also areas not traditionally associated with drought, including parts of Northern Europe, could also see an increase in drought events [97].

**Heatwaves** Heatwave hazards are increasingly becoming a global concern due to the escalating effects of climate change. The future predictions are driven by multiple factors, including rising global temperatures, alterations in atmospheric pressure patterns, urban heat island effects, and human-induced warming [99].

- **Increased Frequency and Duration** Heatwaves are predicted to occur more frequently due to global warming. Heatwaves that previously occurred once every 20 years could happen every few years by the end of the century. Furthermore, these heatwaves are expected to last longer [99].

- **Intensification of Heatwaves** Heatwaves are also expected to be hotter where temperatures exceed historically high levels. This could have severe implications on health, agriculture, and infrastructure [100].
- **Urban Heat Island Effect** Urban areas are particularly vulnerable to heatwaves due to the urban heat island effect. This phenomenon, caused by the concentration of buildings, concrete, and human activities, can significantly increase the temperature in cities compared to surrounding rural areas [99].
- **Heatwaves and Droughts** There is a synergistic relationship between heatwaves and droughts. Prolonged periods of high temperatures lead to increased evaporation rates, intensifying drought conditions [92].

Heatwave hazards are predicted to increase globally, with particular regions expected to face more intense changes. Higher latitude regions, such as Northern Europe, Canada, and Russia, are predicted to experience a significant rise in heatwave events [99]. Additionally, densely populated regions in Asia, including India, Pakistan, and China, are likely to be severely impacted due to a combination of population density, urban heat islands, and escalating heatwave occurrences [99]. Simultaneously, arid and semi-arid regions like the Middle East, North Africa, and parts of Australia, which already endure high temperatures, are predicted to witness even more extreme heat events [101].

## 4.2 Upstream Vulnerabilities: Impact of Drought and Heatwaves on Beer Ingredient Production

The production of beer heavily depends on the primary ingredients, and its growth is particularly susceptible to drought and heatwave conditions, posing significant challenges to the beer supply chain [92].

### 4.2.1 Effects on Barley

- **Yield Decline:** Drought stands as one of the most critical environmental stressors influencing barley yield. Lack of adequate water during crucial growth stages can cause substantial disruptions in the crop's development [102]. Barley plants are notably sensitive to high temperatures, especially during their reproductive stage. Heatwaves can induce heat stress in the crop, leading to a significant reduction in grain yield. Sudden heatwaves can accelerate the barley crop's growth cycle, causing it to mature earlier than intended. This premature maturation can lead to a lower yield and poorer grain quality [103], affecting the subsequent beer production process.
- **Quality Degradation:** The effects of drought extend beyond yield, as it can also lead to a deterioration in the quality of barley. A deficiency in water content can

lead to a reduced grain size and lower weight [102]. An increase in temperature close to the harvest period can lead to pre-harvest sprouting. This severely compromises the malt quality and suitability of barley for beer production [104].

- **Geographic Shifts:** Persistent drought conditions can necessitate shifts in barley production zones. Regions historically suited for barley farming may become non-viable due to a lack of water availability. This change can lead to significant disruptions in the supply chain, requiring adaptation to new sourcing locations [102].
- **Enhanced Disease Susceptibility:** Drought-stressed barley plants are often more susceptible to diseases and pests. The water shortage weakens the plant's natural defenses, leading to an increased likelihood of infestation, which can further deteriorate yield and quality [102].

### 4.2.2 Effects on Hops

- **Water Requirement and Irrigation:** Hops are an incredibly water-intensive crop, often requiring consistent irrigation throughout the growing season. In periods of drought, the available water in soil reserves can rapidly deplete, leading to water stress in hop plants. This can cause severe wilting, stunted growth, and consequently, poor crop yield [105].
- **Heat Stress and Photosynthesis:** Hop plants are sensitive to excessive heat. Heatwaves can induce heat stress, which disrupts photosynthetic processes. High temperatures can cause damage to photosynthetic apparatus and premature maturation of hops, thereby affecting plant growth and yield [106].
- **Pest and Disease Susceptibility:** Increased susceptibility to pests and diseases is another detrimental effect of heat stress. Hop plants weakened by high temperatures become an easy target for pests and pathogens [105].
- **Increased Evapotranspiration:** High temperatures during heatwaves escalate the rate of water evaporation from the soil and transpiration from the plants, collectively known as evapotranspiration. This leads to accelerated water loss, exacerbating the effects of any concurrent water shortages and contributing to drought stress [105].

### 4.2.3 Effects on Water

- **Decreased Water Availability:** In times of drought, water levels in reservoirs, rivers, and aquifers can drop significantly, leading to severe water scarcity [73]. This directly impacts breweries that depend on these sources for their water needs.

- **Impaired Water Quality:** Drought conditions can lead to the concentration of contaminants and pollutants, as less water means pollutants are less diluted. Poor water quality can impact the flavor profile of the beer and may require breweries to invest more in water treatment processes [92].
- **Increased Water Cost:** The scarcity of water during a drought often leads to an increase in water prices [73], which adds to the overall operational costs of breweries. This can put financial pressure on breweries, especially those operating on thin margins.
- **Indirect impact on other Ingredients:** Drought can also affect the production of critical agricultural inputs like barley and hops, which need water for growth [92].

#### 4.2.4 Effects on Yeast

- **Water Scarcity and Quality:** Water is an essential input in the growth medium for yeast cultivation. During droughts, water scarcity can become a significant problem, impacting the availability of this critical input. Also, as water becomes scarce, the quality often declines. Reduced water quality, marked by higher pollutant concentration, can adversely affect the yeast's growth and fermentation capability. In extreme cases, it can even lead to complete batch failures [92].
- **Energy Constraints:** Drought can have serious implications for energy supply, particularly in regions reliant on hydropower [107]. Energy is required to maintain optimal growing conditions, process, and store the yeast. Shortfalls in energy supply or increases in energy costs due to drought can negatively affect yeast production operations [92].
- **Threat to Yeast Viability During Transportation:** High ambient temperatures pose a risk to yeast viability during transport. This is especially true for liquid yeast, which requires strictly controlled conditions to prevent over-fermentation or spoilage [92].

### 4.3 Midstream/Work-in Progress Vulnerabilities to Drought and Heatwaves

#### 4.3.1 Production

The production stage of the beer supply chain is critically dependent on the availability and quality of key resources, namely water, barley, hops, and yeast [79]. Therefore, drought and heatwave conditions pose significant vulnerabilities to this stage:

- **Water Scarcity:** Water is the most fundamental ingredient in beer production, constituting nearly 90-95% of the beer's volume [27]. Drought conditions can lead to severe water shortages, which can drastically hamper beer production. A prolonged drought can lead to stricter water usage policies by local governments, further restricting the availability of water for breweries [108]. The increasing scarcity of water could also lead to a hike in water prices, thereby inflating production costs.
- **Energy Use:** The brewing process involves boiling and cooling stages which are energy-intensive. During heatwaves, the cooling requirements increase substantially, leading to higher energy consumption. This not only increases operational costs but also puts a strain on local energy grids, possibly leading to power outages, thereby disrupting the production process [109].
- **Ingredient Availability:** Drought and heatwave conditions can have a severe impact on the growth and yield of barley and hops. This can lead to shortages in the supply of these key ingredients, affecting production schedules and possibly leading to a rise in prices due to increased demand and lower supply [92].

### 4.3.2 Warehousing

The warehousing stage of the beer supply chain is vulnerable to drought and heat due to potential disruption in climate-controlled storage conditions, which can compromise the quality of stored ingredients and products [80].

- **Storage Conditions Vulnerability:** Beer, being a perishable commodity, requires specific storage conditions to maintain its quality. The storage environment needs to be controlled for temperature and humidity. Heatwaves can jeopardize these conditions, leading to a potential deterioration in the beer's quality [108]. Moreover, temperature-sensitive craft beers can especially suffer due to heatwaves [69].
- **Energy Usage Vulnerability:** Warehouses use energy for a variety of purposes, including lighting, cooling, and running equipment. During heatwaves, the energy consumption for cooling purposes can surge significantly [109]. This increased energy demand can lead to higher operational costs and an increased carbon footprint for the brewery. If the local energy grid is unable to cope with the heightened demand, it could also lead to power outages disrupting the warehousing operations [108].
- **Inventory Management Vulnerability:** Extreme weather conditions like drought and heatwaves can disrupt transportation and logistics (Interviewee 3). These disruptions can lead to delays in inbound logistics (arrival of ingredients) and outbound logistics (distribution to retailers). This could result in stockouts or overstocking,

leading to higher inventory carrying costs and potential losses due to perishability [108].

- **Employee Health and Safety Vulnerability:** Warehouses are typically large, open spaces that can become extremely hot during heatwaves. This can create uncomfortable and even unsafe working conditions for warehouse employees [110]. There could be an increase in health-related absences, lowering the productivity of the warehouse operations [110]. Additionally, businesses may also face potential legal issues related to maintaining safe working conditions [111].

### 4.3.3 Packaging

Packaging is a pivotal phase in the beer supply chain as it not only protects the beer from external influences, but also plays a vital role in the marketing and sale of the product [81]. However, this stage is not immune to the impacts of environmental hazards such as droughts and heatwaves. These are the potential vulnerabilities in the packaging stage:

- **Material Availability and Cost:** The primary raw materials for packaging in the beer industry are glass, aluminum, and sometimes plastic, all of which need water for their production [112]. Drought conditions can lead to water scarcity, escalating production costs of packaging materials, and indirectly increasing the cost of beer packaging. This can affect the overall profit margins of breweries [81].
- **Energy Consumption:** Packaging processes require substantial energy, predominantly for heating, cooling, and running the packaging machinery. Heatwaves can exacerbate energy consumption, particularly for cooling, leading to higher operating costs and a larger carbon footprint [109].
- **Worker Health and Safety:** Heatwaves can create harsh working conditions in packaging facilities, especially for manual tasks [110]. The rise in temperature could lead to an increase in heat-related illnesses among workers, resulting in reduced productivity, increased absenteeism, and potential legal issues associated with maintaining a safe work environment [110].

## 4.4 Downstream Vulnerabilities to Drought and Heatwaves

### 4.4.1 Distribution

In the beer supply chain, the distribution stage is of particular significance as it encompasses the transfer of the finished product from the breweries to various retail points, including supermarkets, liquor stores, pubs, and restaurants [83]. The distribution stage

is a key determinant in ensuring that the beer reaches consumers in the desired condition and within the stipulated time, thereby influencing overall customer satisfaction and brand perception [82].

- **Transportation Disruption:** Drought conditions can lead to lower water levels in rivers and canals, affecting shipping routes that are often used for bulk transportation of beer [113]. Conversely, extreme heat can cause infrastructure damage, leading to service delays such as railway tracks disruption [113].
- **Refrigeration Challenges:** Beer needs to be kept at certain temperatures to maintain its quality during transport. Heatwaves can challenge the efficiency of refrigeration systems in trucks, requiring more energy to keep the products cool and increasing the risk of product spoilage [92].

### 4.4.2 Regional Wholesaling

In the downstream supply chain of beer manufacturing, the regional wholesaling stage is particularly vital, serving as the critical link between the manufacturer's distribution networks and various retail outlets [61]. However, this stage is not exempt from the potential impacts and vulnerabilities posed by drought and heatwave hazards.

- **Storage Facilities and Conditions:** During heatwaves, maintaining optimal storage temperatures for beer can become challenging. The required energy for cooling systems to maintain temperature could significantly increase, leading to higher operational costs [108]
- **Inventory Management:** In times of drought and heatwaves, beer production could potentially be disrupted due to shortage of key ingredients like barley and water, leading to lower supply from the breweries [92]. Wholesalers may have to deal with limited inventory and may need to optimize their distribution strategies to manage the reduced supply effectively [62].
- **Demand Forecasting and Management:** Drought and heatwave conditions may also lead to a change in consumer behavior [61], with potential increase in beer consumption during hot weather. This change would require wholesalers to be agile in their demand forecasting and management strategies [62].

### 4.4.3 Retailing

In the beer supply chain, the retailing stage comprises the point of sale outlets, such as liquor stores, supermarkets, convenience stores, pubs, bars, and restaurants [83]. This crucial part of the supply chain can be substantially affected by environmental hazards, such as droughts and heatwaves:

- **Impact on Inventory and Stock Management:** Droughts and heatwaves can reduce ingredient yields and water availability, leading to beer production disruption [92]. This can cause inconsistent supply, potential stock-outs at retailers, and unmet consumer demand.
- **Increased Operating Costs:** Retail stores have to maintain a controlled environment for storing beer, especially during heatwaves. The requirement of enhanced cooling can lead to an increase in energy consumption and therefore higher operational costs especially for small scale retailers [109].
- **Physical Infrastructure Impact:** The infrastructure of the retail outlets can also be affected by these environmental conditions (Interviewee 4).
- **Intensified Competition:** Drought and heatwave conditions leading to decreased beer production could spark intensified competition among retailers, which could lead to increased wholesale prices and decreased profit margins [84].

### 4.4.4 End Customer

The end consumer stage in the beer supply chain is where the product reaches the customer. Despite the consumer end being the last step in the chain, the impacts of droughts and heatwaves can still manifest significantly at this stage:

- **Impact on Affordability and Availability:** When droughts and heatwaves affect beer ingredients' production and distribution, the overall cost of beer production increases. This cost is often passed down to the consumer in the form of increased prices, impacting the beer's affordability [85].
- **Altered Consumer Behavior:** Extreme weather conditions like heatwaves can also lead to changes in consumer behavior. In periods of high temperatures, consumers might increase their consumption of cold beverages, including beer, driving up demand [84]. This surge in demand can exacerbate supply constraints, especially if the supply chain is already strained due to weather impacts on production.

# 5 Integral Actors in the Beer Supply Chain

## 5.1 Actor Roles and Responsibilities in the Beer Supply Chain

This chapter delves into the exploration of the key actors in the beer supply chain, emphasizing their distinct roles and responsibilities. It underscores the significance of each player, recognizing the profound impact their individual actions can have on the entire system's efficiency and success.

In the Upstream Supply Chain, raw materials and packaging providers play key roles, ensuring the quality and availability of necessary inputs. Within the Midstream Supply Chain, the brewery features a team of crucial actors. Supply Chain, Procurement, Production, Warehouse, and Logistics Managers each contribute to the efficient functioning and successful output of the brewery. In the Downstream Supply Chain, the roles of distributors, wholesalers, and retailers are fundamental in reaching end consumers, the final actors, whose feedback shapes the supply chain's evolution. (Interviewee 6).

### 5.1.1 Upstream Supply Chain Actors

The upstream section of the beer supply chain is primarily composed of raw material suppliers and packaging material suppliers (Interviewee 6). They form the foundation of the entire chain and are pivotal in ensuring that beer production processes operate smoothly and effectively.

In the upstream supply chain, quality control, timely delivery, and coordination with breweries are the critical responsibilities of the suppliers [62]. Any disruption in this section of the supply chain could have significant ripple effects, potentially causing delays or quality issues down the line [62]. Therefore, these actors must maintain robust relationships with breweries and have a clear understanding of their role and responsibilities in the overall supply chain.

**Raw Material Suppliers** In the beer supply chain, raw material suppliers hold significant responsibility. The quality and characteristics of the raw materials they provide directly influence the final product's quality [114]. Any disruption or delay from the raw material suppliers can significantly impact the beer production process. Raw Material Suppliers in the beer supply chain are those who provide the critical ingredients for brewing beer which include barley, hops, yeast, and water[57].

| Actor | Role | Responsibilities |
|---|---|---|
| Barley Suppliers | They provide malted barley, the primary ingredient for beer, which contributes significantly to the beer's flavor and alcohol content. | •They are responsible for ensuring high-quality barley that is grown in appropriate conditions, harvested at the right time, and processed (malted) correctly [65].<br>•They must also understand the requirements of different beer types and supply suitable barley accordingly [65]. |
| Hops Suppliers | They provide hops which contributes to the beer's bitter flavor and aroma. They may supply a range of hop varieties. | •They are responsible for growing and harvesting hops in a manner that ensures a high-quality product [57].<br>•They need to understand the different properties of various hop varieties and be able to provide the right type of hops to meet the breweries' requirements [67]. |
| Yeast Suppliers | They provide yeast, which is critical for the fermentation process in beer production [57]. | •They are responsible for cultivating and supplying yeast strains that are healthy, free of contamination, and have the right characteristics for the type of beer being produced [57]. |
| Water Suppliers | They provide water, the most abundant ingredient in beer. | •They are responsible for providing clean, high-quality water that meets the breweries' specifications [57].<br>•This may include specific mineral content or pH levels, depending on the type of beer being produced [68]. |

Table 1: Roles and Responsibilities of Upstream Actors-1

**Packaging Material Suppliers** These actors provide essential packaging materials, including bottles, cans, kegs, and labels, that help to preserve the beer's quality, facilitate transportation, and catch the consumer's eye. Packaging is an essential part of product marketing and protection; hence packaging suppliers work closely with breweries to understand their branding and packaging needs [81].

| Actor | Role | Responsibilities |
|---|---|---|
| Glass Bottle Suppliers | Supplier, Procuring raw materials for bottle production | •They produce and deliver high-quality glass bottles. They play a critical role in the aesthetics and branding of the beer products as they provide the primary packaging material [81].<br>•They also invest in developing better, more sustainable packaging solutions [81].<br>•They must understand the breweries' packaging requirements and production schedules.[81]. |
| Aluminium Can Suppliers | Supplier, Procuring raw materials for can production | •They produce and deliver high-quality aluminium cans. They too contribute to the aesthetics and branding of beer products, providing an alternative packaging solution to glass bottles [81].<br>•Their responsibility also extends to devising more efficient and eco-friendly cans [81].<br>•They need to accurately understand and respond to the breweries' demand patterns and production schedules [81]. |

Table 2: Roles and Responsibilities of Upstream Actors-2

### 5.1.2 Midtream Supply Chain Actors

**Breweries** Breweries are the heart of the beer supply chain. They are responsible for transforming raw materials like malt, hops, yeast, and water into beer through the brewing process. Their key responsibilities include managing the brewing process, maintaining the quality of beer, and ensuring that the produced beer meets the standards and expectations [108]. Breweries must also coordinate with raw material suppliers for timely delivery of ingredients, with warehouses for storage of the produced beer, and with distributors for its transportation [108]. Within the Breweries, in the Midstream Supply Chain houses a cadre of key personnel, including the Supply Chain Manager, Procurement Manager, Production Manager, Warehouse Manager, and Logistics Manager (Interviewee 7). These individuals and their teams play significant roles in the operational excellence of the brewery.

| Actor | Role | Responsibilities |
|---|---|---|
| Supply Chain Managers | Provides strategic oversight and coordinates all supply chain operations | Oversees entire supply chain operations, ensures smooth integration of all stages, improves efficiency, manages risks, formulates strategic plans, and monitors supply chain performance [115]. |
| Procurement Managers | Manages sourcing and acquisition of materials | Responsible for procuring quality raw materials, negotiating contracts, maintaining relationships with suppliers, conducting market research for better sourcing opportunities, and managing supplier performance [69]. |
| Production Managers | Oversees brewing process and ensures quality control | Manages brewing process, maintains quality of beer, ensures standards compliance, handles equipment maintenance, supervises production staff, and implements production strategies [116] |
| Warehouse Managers | Supervises inventory storage and management | Manages storage of raw materials and finished goods, oversees inventory levels, ensures optimal storage conditions, implements inventory control techniques, and coordinates with other departments for storage needs [80]. |
| Logistics Managers | Directs transportation and distribution of materials and final products | Oversees transportation of raw materials and finished beer, coordinates with distributors, ensures timely deliveries, plans and implements transport schedules, and manages relationships with logistics service providers [117]. |

Table 3: Roles and Responsibilities of Midstream Actors

### 5.1.3 Downstream Supply Chain Actors

In the beer supply chain, the Downstream actors play a critical role in bridging the gap between breweries and the end consumers. This phase comprises a complex network of distributors, wholesalers, and retailers, who collectively facilitate the journey of beer from production facilities to consumers.

**Distributors** They are key intermediaries in the supply chain, facilitating the transport of beer from breweries and warehouses to the different points of sale, which could be regional wholesalers or direct to retail establishments [83]. Their job is not only about physical transportation but also about managing the logistics of supply, ensuring the timely and efficient delivery of beer without compromising its quality [83].

**Wholesalers** Wholesalers usually buy large quantities of beer from distributors or directly from breweries. They store the beer in their warehouses and then sell it to retailers in smaller quantities [62]. Their role is particularly significant in markets where alcohol distribution is strictly regulated (Interviewee 4).

**Retailers** Retail outlets such as bars, restaurants, liquor stores, and supermarkets sell beer directly to the end consumer (Interviewee 4). Retailers often work with multiple distributors and wholesalers to offer a variety of beer products to their customers [83].

**End Users** The end consumers are the final link in the beer supply chain. They consume the beer and often influence trends in beer consumption, which in turn affects the entire supply chain (Interviewee 5). Feedback from end consumers can affect production decisions at the brewery level and distribution decisions at the distributor and retailer levels [69].

| **Actor** | **Role** | **Responsibilities** |
|---|---|---|
| Distributor | Distributors serve as the critical connection between breweries and the various points of sale. They manage the physical distribution and logistics of the beer from the brewery to the wholesalers and retailers. | •Their primary responsibility is to maintain the quality and integrity of beer during transport, ensure timely delivery, and handle any logistical challenges that might arise [68].<br>•They also often serve as representatives of the breweries, advocating for their products to be stocked at retail locations [83]. |
| Wholesaler | They purchase beer in large quantities from distributors or directly from breweries, store them, and then resell to various retailers. | •They are tasked with maintaining a well-managed and diverse inventory of beer. They need to make beer products available to retailers as and when needed, and ensure the storage conditions preserve the quality of the beer [62]. |

| | | |
|---|---|---|
| Retailers | Retailers, including supermarkets, liquor stores, bars, and restaurants, sell beer directly to the end consumer. | •They need to ensure a variety of beer products are available to meet consumer demand [61].<br>•They handle the final point of sale transaction, providing information about the products, and often shaping the consumer's beer choice [83]. |
| End Consumers | The end consumer is the final link in the chain, consuming the beer. | •Consumers' choices in beer can influence beer consumption trends [61].<br>•They provide feedback on beer products, influencing breweries' decisions on production [69]. |

Table 4: Roles and Responsibilities of Downstream Actors

## 5.2 Actor Interactions and Relationships between the Beer Supply Chain

The beer supply chain is a complex network of actors, each contributing unique roles and responsibilities to the overall value chain. As shown in Beer supply chain overview Figure 6, the network spans from the initial sourcing of raw materials to the final point of end customers, encompassing multiple stages in between that involve intricate interactions and relationships between various actors.

Each relationship within this chain is vital, and the nature of interactions significantly influences the supply chain's efficiency and resilience [118]. Coordination across these actors becomes a fundamental component of effective supply chain management. Inadequate coordination can lead to inefficiencies, disrupt the flow of goods, and negatively impact the overall performance of the supply chain [119].

This section, therefore, focuses on understanding these relationships and interactions, highlighting the importance of coordination and exploring the potential impact of external factors on the actor dynamics within the beer supply chain.

### 5.2.1 Upstream Actors Interactions

In the beer supply chain, raw material and packaging material suppliers play a crucial upstream role, providing the essential inputs for beer production. These suppliers interact and form relationships with various downstream and middlestream actors (Interviewee 6). The nature of these interactions can range from direct and frequent communication with breweries, to more indirect and occasional contact with the rest of the actors (Interviewee 6). Some potential interaction and relationships between Upstream actors and the other actors are:

- **Suppliers and Breweries (Middlestream)** Suppliers typically have a direct relationship with breweries (Interviewee 6). This relationship revolves around ensuring the consistent supply of high-quality raw materials and packaging, and typically involves frequent communication, joint quality assurance activities, collaboration on innovation and sustainability, and risk management coordination [120].
- **Suppliers and Distributors/Wholesalers (Downstream)** The relationship between suppliers and distributors or wholesalers tends to be indirect and is usually mediated by the breweries (Interviewee 6). However, changes in packaging or innovations can lead to necessary coordination to ensure seamless integration into distribution processes [81]. Also in the case of industry-wide sustainability initiatives or supply chain optimization programs, suppliers might interact directly with distributors or wholesalers [120].

- **Suppliers and Retailers (Downstream)** Retailers often require their suppliers to provide specific details about the environmental aspects of their operations. This can involve information about their carbon footprint, water usage, or resilience measures against climate hazards [49]. Retailers can rely direct relationship with suppliers or indirectly via intermediaries like breweries for the information (Interviewee 6).

- **Suppliers and End Users (Downstream)** Direct relationships between suppliers and end users are less common in the beer industry, but they are becoming more prevalent with increasing consumer interest in the origins and sustainability of products (Interviewee 6). Suppliers might engage with end users through social media, product labeling, or public events, offering insights into their production processes and sustainability practices [120].

### 5.2.2 Midstream Actors Interactions

In the midstream part of the beer supply chain, the breweries itself play a crucial role. Within the brewery, the Supply Chain Manager, Procurement Manager, Production Manager, Warehouse Manager, and Logistics Manager form the core of the operational structure (Interviewee 7). Their combined efforts are instrumental in navigating the uncertainties and risks introduced by climate change or other disruptions faced by breweries [108]. Some potential interaction and relationships between Midstream actors and the other actors are:

- **Supply Chain Manager and Raw Material/Packaging Suppliers (Upstream):** The Supply Chain Manager interacts directly with suppliers to ensure the consistent delivery of high-quality raw materials and packaging [120]. This relationship is a vital link in the chain as the quality and consistency of inputs significantly impact the beer production process [108]. In a climate change context, the Supply Chain Manager also interacts closely with suppliers to anticipate potential climate-related disruptions, such as changes in crop yields or quality, and develop appropriate contingency plans [115].

- **Procurement Manager and Raw Material/Packaging Suppliers (Upstream):** The Procurement Manager's role involves identifying, vetting, and building relationships with suppliers who can deliver the necessary inputs reliably and sustainably [69]. They may work with suppliers to develop contracts that account for potential variability in supply due to climate change, or to encourage suppliers to adopt more resilient and sustainable practices [120].

- **Supply Chain Manager and Distributors/Wholesalers (Downstream):** The Supply Chain Manager liaises with distributors and wholesalers to understand

their needs and ensure that the brewery can meet them [69]. This involves coordinating on volume requirements, delivery schedules, and packaging requirements [108]. As climate change can impact transportation, the Supply Chain Manager must also work with distributors and wholesalers to develop resilient logistics strategies (Interviewee 7).

- **Logistics Manager and Distributors/Retailers (Downstream):** The Logistics Manager is responsible for coordinating the transport of beer from the brewery to the distribution channels [117]. This includes managing delivery schedules, transportation modes, and routes. The Logistics Manager would need to be in close communication with these downstream actors to promptly address any potential climate-induced disruptions to delivery to effectively plan the logistics (Interview 7).

- **Production Manager and Distributors/Retailers (Downstream):** Production Manager has mostly an indirect relationship with downstream actors (Interviewee 7). The quality and consistency of the beer produced can affect the brand's reputation and sales [108]. Therefore, any changes in production due to climate-related impacts on raw materials would need to be communicated to distributors, wholesalers, and retailers (Interviewee 7).

### 5.2.3 Downstream Actors Interactions

In the downstream part of the beer supply chain, the distributors, wholesalers, retailers and end users play a crucial role. These actors often interact directly with the midstream actors and indirectly with the upstream actors (Interviewee 5). Some potential interaction and relationships between Downstream actors and the other actors are:

- **Wholesalers and Breweries (Middlestream)** Wholesalers often have a direct and ongoing relationship with breweries (Interviewee 5). This connection often relies on regular and clear communication with the Supply Chain Manager, the Logistics Manager, and sometimes the Production Manager to align production and delivery schedules, negotiate prices, and address potential challenges or disruptions (Interviewee 5). In the context of climate change, the communication could include securing alternative supply routes or arranging for buffer stocks to mitigate potential impacts of extreme weather events on transportation [113].

- **Wholesalers and Suppliers (Upstream):** The relationship between wholesalers and upstream suppliers such as communication regarding packaging changes is typically indirect, mediated by the breweries (Interviewee 6). They might also in some cases engage with suppliers to understand and respond to industry-wide sustainability initiatives [83].

- **Retailers and Breweries (Middlestream):** Retailers can have direct relationships with breweries, especially in scenarios involving large retail chains or specialized beer stores (Interviewee 5). This relationship can involve negotiations for exclusive deals, specialty product lines, or direct shipment arrangements (Interviewee 5). Retailers often provide market feedback directly to breweries, helping them to adjust production according to the latest market trends [84].
- **End Users and Other Actors:** End users interact primarily with retailers but may also have indirect interactions with breweries and suppliers (Interviewee 5). Breweries may engage end users through social media, brewery tours, or promotional events, where suppliers might share information about raw materials or their sustainability practices to increase consumer awareness and enhance brand image [85].

## 5.3 Power Dynamics within the Beer Supply Chain

Power dynamics refers to the distribution and exercise of influence among various actors, which ultimately shape operational and strategic decisions in supply chains [121]. They determine who can demand, who can command, and who complies within the supply chain [121]

These dynamics are shaped by various factors such as company size, market share, unique value proposition, capacity to influence consumer demand, and even their approach towards climate change [122]. However, there dynamics are not fixed but continuously evolve, reflecting shifts in market conditions, consumer preferences, and broader environmental considerations.

1. **Breweries:** The particularly large-scale ones hold significant power within the beer supply chain due to their central role in product creation [123]. They dictate the demand for raw materials and packaging based on their production schedules and often influence the pricing due to their purchasing volume [123]. Also, breweries with well-known brands can command power through their influence on consumer preference, driving demand downstream [84].
2. **Upstream Suppliers:** Suppliers typically have less power compared to breweries, especially if there are many potential sources for the materials they supply [124]. However, suppliers who provide uniquely sourced, high-quality, or sustainable materials can command more power and negotiate better terms with breweries who are looking to differentiate their product or enhance their sustainability profile (Interviewee 8).
3. **Distributors and Wholesalers:** Distributors and wholesalers possess a fair amount of power in the supply chain due to their role in connecting the breweries with retailers [124]. They can influence the market accessibility of certain brands, especially

in geographically expansive or complex markets (Interviewee 5). However, their power is often counterbalanced by the power of the breweries and large retailers, who may have other options for distribution or may opt for direct-to-consumer models (Interviewee 5).

4. **Retailers:** The power of retailers varies greatly. Large retailers, such as supermarket chains, can have significant power due to their customer base and their ability to decide which products to stock and promote[83]. While smaller retailers may have less power but can still influence consumer choice by their selection of products [61].

5. **End Users:** Their power lies in their collective ability to drive demand [124]. Changes in consumer preferences can have significant impacts up the chain, influencing what products are made, which raw materials are sourced, and how products are packaged and distributed [61].

Additionally climate change can also add an another layer of complexity to these power dynamics [125]. Actors who can effectively manage climate risks, such as breweries with robust climate resilience strategies or suppliers offering climate-resilient raw materials, may see an increase in power [125]. Conversely, those severely affected by climate hazards or who are ill-prepared for climate change may see a decrease in their relative power in the supply chain [125].

| **Actor** | **Factors Impacting Power** | **Communication Protocols** | **Climate Disruption Communication** |
|---|---|---|---|
| Breweries | Company size, Market share, Brand influence, Production schedules | Communication with suppliers for orders and quality assurance; Scheduled updates and negotiations with distributors; Branding messages directed towards consumers | Sharing of climate risk assessments and mitigation strategies with suppliers and distributors; sustainability reports for the public |
| Upstream Suppliers | Uniqueness and Quality of products, Sustainability credentials | Confirmation of orders and delivery updates to breweries; Quality control reports and sustainability certifications shared with breweries | Sharing of sustainability certifications and climate resilient farming practices with breweries |

| | | | |
|---|---|---|---|
| Distributors and Wholesalers | Market accessibility, Geographical reach | Sharing of sales and inventory reports with breweries and retailers; Coordination of deliveries and schedules with retailers | Communicating about transport optimization and fuel-efficiency measures to reduce carbon footprint with breweries and retailers |
| Retailers | Customer base, Ability to stock and promote products | Requests for inventory restocks to distributors; Sharing of sales data and consumer feedback with distributors and breweries | Informing customers about the environmental impact of the products and promoting sustainable brands |
| End Users | Consumer preferences, Demand | Direct feedback to retailers and product reviews; Social media engagement with all supply chain actors | Feedback on sustainable practices and preferences for climate-friendly products |

Table 5: Power Dynamics and Communication Overview of Beer Supply Chain Actors

## 5.4 Influence of External Factors on Actor Interactions

Various external factors can significantly influence the interactions among actors in a supply chain. These factors could be broadly divided into two categories: Traditional Supply Chain Factors and Climate Change Factors.

### 5.4.1 Traditional Supply Chain Factors

1. **Economic Factors:** Economic conditions can affect all levels of the supply chain [126]. For instance, an economic downturn could reduce consumer demand for premium beers, prompting breweries to adjust their production schedules and demand for raw materials. This can lead to more intense negotiations between breweries and suppliers over prices and volumes (Interviewee 8). Conversely, a booming economy could increase demand, leading to stronger coordination among all actors to ensure adequate supply (Interviewee 8).

2. **Social Factors:** Changes in societal norms and consumer preferences can drive significant shifts in the supply chain [126]. For instance, growing consumer interest in environmentally-friendly products can foster closer collaborations between breweries and suppliers to innovate and deliver these products (Interviewee 8).

3. **Regulatory Factors:** Changes in regulations like stricter emissions standards, can necessitate adjustments in the supply chain (Interviewee 8). Breweries might need to work closely with it's suppliers to comply with new regulations (Interviewee 8).

4. **Technological Factors:** Implementation of an advanced supply chain management system can enhance communication and data sharing among all actors, leading to more efficient operations (Interviewee 8). Moreover, new technologies like blockchain could enhance traceability and transparency in the supply chain, fostering trust and collaboration among actors (Interviewee 1).

### 5.4.2 Climate Change Factors

Climate change is increasingly being recognized as a critical external factor affecting supply chains globally [1]. While climate change includes a multitude of hazards, this thesis emphasizes the effects of drought and heatwaves due to their profound impact on the beer industry.

#### Drought

Drought, an increasingly frequent climate hazard, brings a myriad of challenges beer supply chain, significantly altering the nature and extent of interactions among the various actors.

- The primary impact of drought is the compromised availability and quality of crucial raw materials like barley and hops, directly affecting the suppliers and breweries [102]. To navigate this, the frequency and depth of communication between these actors are likely to intensify and may need to develop a shared understanding of the severity and duration of the drought, reassess forecasts for raw material availability, and recalibrate expectations on both sides (Interviewee 8).
- Contractual relationships might also evolve. Pricing terms may need to be renegotiated in light of the higher costs associated with sourcing. The procurement teams at breweries might need to explore relationships with alternative suppliers, especially those in less drought-affected regions, leading to the inclusion of new actors and adding complexity to the supply chain network (Interviewee 8).
- The increased cost of production due to drought conditions might necessitate a rise in beer prices. Breweries would need to work closely with distributors and retailers to strategize on these price increases and possibly shared initiatives to absorb some of the increased costs (Interviewee 8).
- As consumers become more environmentally conscious, drought conditions provide an opportunity for breweries to demonstrate their commitment to sustainability (Interviewee 8).

#### Heatwaves

Heatwaves, although they bring a surge in beer demand [84], also cause substantial changes in the interactions within the beer supply chain.

- The sudden increase in demand for beer during heatwaves can put considerable strain on the existing raw material supplies. This could lead to heightened coordination and collaboration between breweries and suppliers. Breweries may need to expedite orders, potentially negotiate higher volumes, and maintain a close line of communication to monitor the fulfillment process (Interviewee 8).

- The increased demand necessitates enhanced coordination with distributors and retailers. This might involve more frequent restocking, quick responses to changes in sales data, and agile adjustment of distribution routes and schedules to ensure timely delivery (Interviewee 8).

- Heatwaves present opportunities for breweries to connect with their consumers around the shared experience of extreme heat. Breweries might increase consumer interaction through social media campaigns (Interviewee 8).

# 6 Exploring Existing Coordination Mechanisms for Climate Resilience: A Case Study of Heineken

## 6.1 Introduction to Heineken and Its Supply Chain

Heineken, established in 1864 in Amsterdam, is one of the world's most recognized and internationally widespread breweries. It operates on an expansive scale with production at more than 110 breweries spread across over 60 countries [127]. Headquartered in the Netherlands, Heineken's presence is especially prominent in Europe, while also making significant strides in the United States, its principal market outside Europe [127].

Heineken's supply chain is unique in its holistic integration, encompassing every step from the procurement of raw materials to the delivery of the final product to consumers [128].

- At the upstream end, the company sources various raw materials, the principal ones being water, barley, hops, and yeast [127]. Operating in a global presence, Heineken not only produces and markets its beverages globally but also sources its raw materials locally, owning farmlands that supply ingredients integral to beer production [128]. This vertical integration within their supply chain enables Heineken to exercise better control over quality and costs [128]. Global Business Services (GBS) is a key pillar of Heineken's organizational structure, encompassing purchasing and finance functions (Interviewee 7). It plays a crucial role in upstream supply chain, contributing to effective procurement and financial operations (Interviewee 7).

- The midstream supply chain commences with the transportation of grains and hops to the factory [128]. Trucks, equipped with advanced logistics technology, ensure safe and efficient delivery of these raw materials (Interviewee 7). Heineken has superior management system, which oversees the critical phase of production, transforming raw materials into quality beer undergoing undergo various stages of processing [128]. A key aspect of Heineken's midstream operations is its environmentally-conscious approach, emphasizing recycling and sustainability [128]. Beer cans, for instance, are sourced from recycling centers, underscoring Heineken's commitment to reducing its environmental footprint (Interviewee 7).

- The downstream supply chain is equally robust. After the brewing process, beers are stored in cool environments to maintain their quality [92]. The responsibility then shifts to the various distributors and retail stores that sell Heineken's products to the final consumers (Interviewee 7).Heineken leverages advanced logistics technologies such as telematics to monitor temperature conditions and vehicle movement to enhance its downstream supply chain (Interviewee 7). Additional stringent quality checks and monitoring mechanisms help ensure that the beer reaching the consumer retains its quality and freshness [128].

## 6.2 Heineken's Supply Chain Coordination for Climate Resilience

Recognizing the significant risks posed by climate change, Heineken has enacted numerous strategies to enhance resilience within its supply chain. This section will examine two examples demonstrating Heineken's approach to coordinating its supply chain in response to climate hazards, primarily focusing on heatwaves and droughts.

While the study predominantly emphasizes the adaptation strategy, showcased by Heineken's water stewardship initiative, the significance of the "Drop the C" mitigation measure is also acknowledged. To provide a more nuanced understanding, a comparison between these two initiatives was undertaken, evaluating how coordination mechanisms differ between mitigation and adaptation strategies. Such a comparison is essential to ascertain why these differences exist and the implications they might have. For the beer industry, understanding these nuances could guide strategic approaches to resilience. Moreover, by highlighting the contrasts and parallels between mitigation and adaptation coordination, insights can be provided into potential challenges and opportunities not just for the beer sector but also for other industries. The interconnectedness of adaptation and mitigation measures suggests that an integrated approach can offer comprehensive insights into climate change responses, which is pivotal for industries aiming for holistic sustainability.

### 6.2.1 Drop the C Initiative and Heatwaves:

Heineken's "Brewing a Better World" program is a comprehensive sustainability initiative that intersects with various facets of the supply chain, encompassing socio-economic and environmental aspects [129]. Established in 2010, the program has six key focus areas: water management, reduction of CO2 emissions, sourcing sustainably, advocating responsible consumption, promoting health and safety, and growing with communities [129].

In Heineken's "Brewing a Better World" program, the pillar most directly related to mitigating the effects of heatwaves is the commitment to "Drop the C" or reducing CO2 emissions (Interviewee 10). This is due to the scientifically established link between increased atmospheric carbon dioxide and rising global temperatures, which lead to more frequent and intense heatwaves [130] (Interviewee 10).

The strategy came into action after the company pledged its allegiance to the Science Based Targets initiative in 2018 [131]. Under this strategy, Heineken aims to reduce its carbon footprint significantly by 2030, setting a clear target of reducing its carbon emissions to 80% of its 2008 levels [131].

The revised carbon reduction strategy mainly focuses on these areas:

**Production:** The creation of 'Green Breweries' is a pivotal part of Heineken's plan. The company has made noteworthy strides in this area, converting its breweries in Austria

and Göss into fully carbon-neutral operations [129].

**Packaging:** Heineken has been innovating its packaging practices, with a commitment to using 100% returnable or majority recycled packaging materials by 2030 [129]. For instance, in Vietnam, Heineken is piloting the use of 'bag-in-keg' technology to reduce the weight and waste associated with traditional kegs (Interviewee 9).

**Logistics:** Heineken has taken steps to optimize its logistics, such as increasing the load factor of its delivery vehicles and testing low-emission transportation methods [132]. For Instance, In the Netherlands, Heineken has been using river transport to deliver beer from its brewery in Zoeterwoude to the port of Rotterdam, significantly reducing road traffic and associated carbon emissions (Interviewee 9).

**Cooling:** Heineken has been upgrading cooling equipment in bars and restaurants to be more energy-efficient [133]. As part of its 'Green Fridges' program, Heineken launched an energy-efficient fridge that uses 45% less energy than the most commonly used fridge (Interviewee 9).

**Processing** Heineken has initiated efforts to improve energy efficiency in its malting processes [133]. For instance, its malt house in France has been redesigned to be a benchmark for energy and water efficiency, while still maintaining high-quality malt production [129].

**Agriculture:** Heineken has engaged in agro-forestry initiatives as a part of its commitment to sustainable agriculture [133]. Through its 'Brewing a Better World' initiative, Heineken has been working on a project in Spain that integrates barley cultivation with the planting of almond trees, aiming to combat desertification and improve soil health [129].

### 6.2.2 Water Stewardship in the Face of Droughts

Water is a key ingredient in beer production, making Heineken particularly sensitive to water availability [27]. As droughts become increasingly common due to climate change, securing water supplies has become a crucial concern [93]. Heineken's "Every Drop" strategy is a comprehensive, water-focused initiative that underlines the company's commitment to safeguarding water resources and managing water usage more sustainably [134]. Launched in 2018, this strategy acknowledges the critical role of water in brewing and the challenges that water scarcity and pollution pose to their business, local communities, and the environment [134]. Key focus areas of this strategy are:

**Water Stewardship:** As a global brewer, Heineken operates in various geographies, some of which are water-stressed. With "Every Drop" strategy, Heineken actively addresses these water risks. In water-stressed areas, such as those in Africa and the Middle East, Heineken has committed to sustainable water practices, such as improving water efficiency in its breweries, investing in advanced water recycling technologies, and working with local stakeholders to protect and rejuvenate water basins [135]. They have also initiated partnerships with local governments, NGOs, and communities to safeguard water resources that their breweries and the surrounding communities rely on (Interviewee 9).

**Full Circularity:** Recognizing that every drop matters, Heineken is working on wastewater treatment across all its breweries to ensure that the water returned to the environment is safely treated [134]. They have pledged to return 100% of the wastewater from their production processes back to the environment after thorough treatment, preventing water pollution and ensuring the sustainability of local water sources [134].

**Water Balance:** Heineken aims to achieve 'Water Balanced' sites in water-stressed areas. Water Balanced refers to when a company restores to the local watershed at least as much water as it uses in its products and production [136]. To achieve this balance, Heineken undertakes local initiatives, like constructing water harvesting structures, cleaning local water bodies, or supporting community-led water conservation projects, to offset its water usage and replenish the local water sources [134].

**Greater Transparency:** "Every Drop" also focuses on enhancing transparency around Heineken's water usage. The company has pledged to report its water usage in a comprehensive and transparent manner, with detailed breakdowns by catchment area for its breweries in water-stressed regions (Interviewee 9). This transparency is aimed at building trust with local communities and other stakeholders and maintaining accountability for their water conservation efforts [134].

**Water-saving technologies** Heineken's "Every Drop" strategy embraces various water-saving technologies to enhance water efficiency. The strategy includes advanced water recycling technologies for wastewater reuse, water-efficient equipment in breweries, precision irrigation technologies in agricultural production, and smart metering systems for real-time water usage data [134].

**Coordination and communication** Coordination and communication play a key role in executing this strategy. Heineken works closely with its suppliers, ensuring that they are fully aligned with the company's water-saving goals (Interviewee 9). Meetings, workshops, and training sessions are often conducted to share best practices and provide necessary support. The company also collaborates with local governments and NGOs

to support water conservation efforts in the broader community where its breweries are located (Interviewee 9).

## 6.3 Applying IAD's Action Situation framework to the Heineken strategies

The Heineken's initiatives—"Drop the C" and "Every Drop" exhibit a firm commitment to climate resilience, achieving considerable milestones in emission reduction and water conservation. The 'Drop the C' strategy has successfully garnered internal and external stakeholder engagement, targeting CO2 reduction through energy-efficient brewing technologies, renewable energy contracts, and optimized distribution processes [133]. Conversely, the 'Every Drop' strategy holistically addresses water management, encompassing water consumption reduction, efficiency improvement, and water scarcity resilience [134]. While these strategies exemplify Heineken's proactive and reactive stance on climate change, a detailed analysis through the lens of the Action situation framework from the IAD identifies the areas of potential enhancement.

### 6.3.1 Drop the C Strategy

**Participants:** The "Drop the C" program engages a variety of stakeholders both within and outside Heineken.

- Internally, it involves a wide array of departments and roles - from upper management who endorse and finance the initiative, the Research & Development department who develops or adapts low-carbon technologies, the procurement division which engages sustainable suppliers, to the logistics and distribution sectors which optimize processes to reduce emissions (Interviewee 10).
- External participants include renewable energy providers, material suppliers, environmental consultants, and third-party sustainability certifiers such as the Science Based Targets Initiative, along with local communities and governments in regions where Heineken operates (Interviewee 10).

**Positions and Actions:** Each participant has a unique role in the program and corresponding actions they take.

- Heineken's leadership team is the driving force behind the company's sustainability strategies, paving the path towards a sustainable future through setting strategic goals and ensuring adequate financial resources are allocated.(Interviewee 10).
- The Research and Development (R&D) department is the hub of innovation, constantly developing and refining energy-efficient brewing technologies that align with

the "Drop the C" initiative. Their ongoing contributions are pivotal to Heineken's successful reduction in CO2 emissions (Interviewee 10).

- Heineken's Procurement department plays a significant role by securing contracts for renewable energy and sourcing sustainable materials. Their rigorous selection process ensures all suppliers meet Heineken's sustainability standards, thereby strengthening the company's overall environmental impact (Interviewee 10).
- The Logistics and Distribution departments are integral to Heineken's climate response, adopting low-emission vehicles and optimizing delivery routes to minimize CO2 emissions. Their efficient operations significantly contribute to Heineken's carbon footprint reduction targets set under the 'Drop the C' initiative (Interviewee 10).
- External suppliers are also part of Heineken's extensive sustainability network, required to adhere to the company's rigorous sustainability standards. This collaborative approach extends Heineken's sustainability impact beyond its immediate operations (Interviewee 10).
- Independent certifiers such as the Science-Based Targets initiative (SBTi) validate Heineken's progress towards its environmental targets, enhancing the transparency and credibility of its sustainability reporting (Interviewee 10).

**Potential Outcomes and Action-Outcome Linkages:** Each action within the strategy is aimed at an outcome that contributes to CO2 reduction.

- Heineken utilizes renewable energy sources like solar, wind, and biomass in its breweries [129]. This transformation reduces reliance on fossil fuels, thereby significantly cutting down CO2 emissions during the production process.
- By using lighter materials and investing in recyclable or reusable packaging, Heineken minimizes the energy required for packaging production and waste management (Interviewee 10).
- Heineken has adopted logistical strategies including route planning and delivery schedules that maximize vehicle load capacity and minimize fuel consumption thereby minimizing CO2 emissions [129].
- Heineken's use of energy-efficient cooling equipment in bars and restaurants reduces electricity consumption and corresponding CO2 emissions [129].
- Heineken promotes sustainable agriculture, incorporating practices like agroforestry that contribute to carbon sequestration. These initiatives combat deforestation, improve soil health, and reduce CO2 emissions, thereby enhancing the overall environmental footprint of the company's supply chain [133].

**Actor Control and Information Accessibility**

- Heineken, as the main initiator of the "Drop the C" initiative, has significant control over its implementation, shaping the strategy based on the company's sustainability vision.
- Suppliers play a crucial role, their capabilities in providing low-carbon materials and technologies directly influence Heineken's ability to achieve its sustainability targets (Interviewee 10).
- Transparency is at the forefront of Heineken's approach; comprehensive information about its sustainability objectives, progress, and future plans is made available to the public through various channels [129].
- Regular updates via sustainability reports, press releases, the corporate website, and public announcements ensure all stakeholders stay informed about Heineken's sustainability endeavors [129].
- Heineken's consumer base, increasingly conscious about sustainability, indirectly steers the company's strategy by demanding environmentally friendly products, prompting further efforts in CO2 reduction [132].

**Costs and Benefits:** The costs of implementing the "Drop the C" strategy include:

- Heineken's significant financial investment into carbon-neutral breweries, such as the ones in Austria and Göss [129], is a substantial cost tied to the implementation of the "Drop the C" strategy .
- Heineken's commitment to implement circular economy principles [129], particularly in packaging, can involve higher costs, given that sustainable and recyclable materials are often more expensive than traditional alternatives [81].
- Working with suppliers to drive renewable energy and energy efficiency measures can also incur costs, particularly in the initial stages as suppliers adapt their processes to align with Heineken's sustainability standards (Interviewee 10).

The costs are also balanced by a variety of benefits:

- The implementation of energy-efficient solutions, like the 'Green Fridges' program and initiatives to improve energy efficiency in malting processes [129], are expected to reduce Heineken's operational costs.
- Through its agro-forestry initiatives and collaborations with suppliers to promote sustainable agricultural practices, Heineken is enhancing its resilience against climate-related risks [133]. This risk mitigation is a long-term benefit.

- The "Drop the C" initiative greatly contributes to enhancing its corporate image as a sustainability leader, fostering trust and loyalty among consumers and other stakeholders [132].
- Transparent communication and demonstrable action on sustainability can improve Heineken's relationships with stakeholders, including suppliers, customers, investors, and local communities [133].

### 6.3.2 Every Drop Strategy

**Participants** The participants could be broadly classified to:

- Internal: Heineken management team , composed of decision-makers, is responsible for formulating and steering the "Every Drop" strategy. The other Heineken employees who directly or indirectly contribute to the strategy's implementation through their roles, such as brewery workers, supply chain managers, or environmental sustainability coordinators (Interviewee 9).
- External: External participants include a diverse set of stakeholders. These comprise suppliers who need to follow Heineken's water management guidelines, regulatory bodies that lay down relevant regulations, and local communities affected by Heineken's operations. In addition, customers, whose purchase decisions might be influenced by Heineken's sustainable water management practices can impact Heineken's actions (Interviewee 9).

**Positions and Actions:** Each participant has a unique role in the program and corresponding actions they take.

- Heineken's leadership team, the strategy initiator acts as the principal architect of the "Every Drop" strategy, conceptualizing the vision and operationalizing it through concrete actions (Interviewee 9).
- Suppliers must comply with Heineken's water use guidelines, ensuring that their raw materials (like hops and barley) are grown using sustainable water practices [134]. In some cases, they collaborate with Heineken to develop water-saving technologies, such as irrigation systems that reduce water usage in crop cultivation [134].
- Local communities often partner with Heineken on specific water sustainability projects. For instance, in water-stressed regions in Nuevo León, Mexico, Heineken has worked with communities to improve watershed health, demonstrating respect for local water resources and improving community relations [134].
- Regulatory bodies assess Heineken's water management practices and certify their compliance with certain environmental standards. Acquiring such certifications can

strengthen Heineken's reputation and provide assurance to stakeholders about the efficacy of the "Every Drop" strategy [129].

**Potential Outcomes and Action-Outcome Linkages:**

- Heineken's actions, such as implementing water-saving technologies or optimizing water use in agriculture, lead to outcomes like reduced water consumption, improved water efficiency, and better resilience to water scarcity (Interviewee 9). These outcomes feed back into the action situation, influencing future actions and decisions.
- Heineken's visible commitment to water sustainability can enhance its corporate reputation. It's a direct result of executing sustainable practices and transparently reporting on water usage metrics [129], demonstrating accountability to shareholders, customers, and the wider community.
- By implementing water-saving techniques and technologies, Heineken effectively safeguards its operations against potential water shortages, contributing to the company's long-term resilience and operational sustainability (Interviewee 9).
- The adherence to international, national, and local water management guidelines and regulations emerges from Heineken's responsible water usage strategy. It ensures the brewery is mitigating any legal risks, penalties, and maintains a positive relationship with regulatory bodies [135].
- By proactively engaging with local communities, suppliers, and regulators in the execution of its water strategy, Heineken enhances its stakeholder relations, fostering trust and collaboration, which directly impacts the success of the strategy [134].
- Heineken's push for improved water efficiency fuels technological and process innovation within the company (Interviewee 9). This ranges from new water recycling systems to more efficient cleaning processes, directly impacting the brewery's water conservation outcomes and fostering a culture of continuous improvement [135].

**Actor Control and Information Accessibility**

- As the main orchestrator of the "Every Drop" initiative, Heineken employs a holistic, company-wide approach, setting quantifiable water reduction targets, establishing guidelines, and implementing sustainable practices across all their global breweries (Interviewee 9).
- Suppliers are pivotal actors in Heineken's water strategy. The choices they make, from their farming practices to their choice of water-efficient technologies, can have a profound impact on Heineken's water consumption and overall footprint [135].

- Local authorities' regulations are of considerable significance, often dictating the permissible water usage levels and the need for conservation measures (Interviewee 9). Heineken must tailor its strategies to comply with these regional variations in water-related laws and regulations.
- Transparency underpins Heineken's "Every Drop" strategy. Heineken consistently provides comprehensive sustainability reports and public announcements, thereby offering all stakeholders a clear view of their water conservation progress [129]. This transparency helps maintain trust and drive continuous improvement in their water conservation practices.
- Collaborative efforts with NGOs, research institutions, and local water authorities are integral to Heineken's strategy. These partnerships facilitate the exchange of innovative insights and methods for water management, allowing Heineken to contribute to broader conservation efforts and continually refine its water conservation strategies [135].

**Costs and Benefits** The costs of implementing the "Every Drop" strategy includes:

- To achieve the "Every Drop" targets, Heineken needs to make significant upfront investments in new technologies, machinery, and infrastructure to ensure water efficiency and recycling (Interviewee 9). This encompasses the procurement and installation of state-of-the-art technologies, machinery, and infrastructure aimed at enhancing water efficiency, such as advanced water recycling systems or wastewater treatment plants (Interviewee 9).
- Shifting to more water-efficient practices may necessitate changes in operational procedures (Interviewee 9). This can involve re-training staff, adopting new techniques, and possibly dealing with some initial operational inefficiencies.
- Heineken operates in a variety of regions, each with its unique set of water-related regulations and permits [134]. Compliance with these standards can induce additional costs, such as fees for water usage or discharge, expenses related to periodic water audits, or necessary modifications to facilities to meet specific water treatment or disposal requirements (Interviewee 9).

The costs are also balanced by a variety of benefits:

- By implementing water-efficient processes and technologies, Heineken can significantly reduce its water usage, thereby decreasing the costs associated with water procurement, treatment, and disposal. This could range from lower charges for water supply and wastewater treatment, to savings from reduced energy use for water heating and cooling processes, particularly in its breweries where water is extensively used [134].

- Heineken's proactive approach towards better water resource management can help mitigate risks related to water scarcity or contamination. This is particularly critical for Heineken's operations in water-stressed regions like Sub-Sahara [133], where access to clean and affordable water can be a significant business risk.
- By voluntarily adopting sustainable water management practices, Heineken positions itself ahead of potential future water regulations, reducing the risk of fines or sanctions and avoiding disruptive last-minute adjustments to its operations [134]. It also positions Heineken favourably in the eyes of regulators, potentially easing permit acquisitions and renewals.
- As a brewing company, water is a key ingredient for Heineken's products. Ensuring its sustainable use and conservation directly aligns with Heineken's long-term business interests, aiding the continuity and quality of its production processes and products (Interviewee 9). Furthermore, efficient water management can open up opportunities for innovative water-saving product and process development, creating a competitive advantage for Heineken in the market (Interviewee 9).

## 6.4 Analysis from the Action Situation framework

In the pursuit of comprehensive analysis, the action situation of the IAD framework proves indispensable. This framework facilitates a structured evaluation of how diverse actors interact within institutional settings to produce outcomes [23], especially in complex contexts like environmental sustainability. When applied to Heineken cases, in Drop the C it aids in pinpointing where carbon reduction efforts can be most effectively intensified, accounting for actor dynamics and institutional constraints. Meanwhile, with Every Drop, it delineates the nuanced relationships between water resource management, brewery operations, and stakeholder collaborations. By leveraging the IAD's action situation, it can be used in holistically understanding the challenges and potential areas of improvement within these initiatives, ensuring that proposed strategies are not only theoretically robust but also practically feasible in the real-world settings of Heineken's operations.

In the examination of Heineken's strategies, 'Drop the C' and 'Every Drop', the insights garnered from interviewees play a pivotal role. It is conceivable that insights from another key stakeholder within Heineken or an industry expert might lead to alternative interpretations or conclusions. Individual contributors, with their unique experiences and perspectives, possess the potential to influence, refine, or even counteract the analysis delineated within this study. To ensure depth and rigor in this study, the insights from the interviewees on these strategies were continually cross-referenced with official documentation, third-party reviews, and prevailing literature on sustainability in the beverage sector. However, the individual narrative from a single interviewee might introduce

unique biases or perspectives. It's an inherent challenge in qualitative research to balance these rich, individual insights with the broader consensus [48].

### 6.4.1 Analysis of the "Drop the C" Strategy

The "Drop the C" initiative reflects Heineken's systematic efforts to mitigate CO2 emissions. Drawing from primary data sources such as corporate reports and in-depth stakeholder interviews, it's evident that Heineken adopted a multifaceted approach. This approach includes leveraging energy-efficient brewing technologies, renewable energy contracts, sustainable materials, and optimizing delivery routes, which collectively resulted in a significant reduction in the company's CO2 footprint [133].

An examination of Heineken's sourcing strategy revealed an emphasis on sustainable agriculture [133]. However, the heterogeneity of agricultural practices, diverse environmental regulations, and varying regional conditions, inferred from cross-referencing global agricultural practices, pose hurdles [57]. These diversities can potentially disrupt the consistency and scalability of such initiatives.

Stakeholder coordination including collaborative efforts, encompassing internal personnel and external entities emerged as a dominant theme in the Drop the C initiative execution (Interviewee 10). The collective decision-making and shared objectives enabled decisive actions towards carbon reduction. While the "Drop the C" initiative draws upon the collective effort of a diverse group of stakeholders, including Heineken's management, R&D department, procurement, logistics and distribution departments, as well as external suppliers and certifiers like SBTi [129]. The complexity and breadth of these engagements, while an asset, can also potentially create bottlenecks in the form of communication lapses or misalignments. The coordination among these diverse stakeholder groups, each with their own objectives and operational styles, is a crucial aspect that could affect the smooth execution of the initiative (Interviewee 10). For instance, communication gaps between Heineken's upper management and its R&D or procurement departments could result in inefficient utilization of resources or delays in implementing energy-efficient technologies.

Moreover, the effective synchronization between internal departments like logistics and distribution and external entities, including suppliers and certifiers, is another critical aspect (Interviewee 10). Any misalignment here could jeopardize the overall impact of the initiative by causing inconsistencies in sustainable sourcing or in tracking and reporting progress towards set targets.

In examining the "Drop the C" initiative, it is observed that the coordination intricacies inherent in mitigation strategies differ significantly from those in adaptation strategies. Mitigation, as showcased by "Drop the C", focuses on proactively minimizing greenhouse gas emissions. This strategy demands a macro-level perspective, seeking systemic changes in operations, technology adoption, and supply chain management [137]. Central to its success is a cohesive inter-departmental alignment (Interviewee 10). For instance,

the shift to energy-efficient brewing technologies isn't merely a procurement decision; it necessitates synchronization between R&D, logistics, and even marketing to effectively communicate these efforts to stakeholders.

Comparing the two, adaptation strategies, in contrast, tend to be reactive, addressing the already manifested consequences of climate change [138]. Given that the effects of climate change vary regionally, adaptation often needs decentralized decision-making [138]. This implies that while "Drop the C" may prioritize harmonizing global operations under a singular vision, an adaptation strategy on the other hand might emphasize regional managers' autonomy to tackle unique challenges. This distinct divergence in the operational scope means that while mitigation like "Drop the C" involves high internal orchestration [137], an adaptation approach demands higher agility, local insights, and a deep engagement with regional stakeholders [138]. Furthermore, from a risk management standpoint, mitigation strategies like "Drop the C" are often preemptive, attempting to curve potential future risks [137]. In contrast, adaptation responds to immediate and tangible risks [138]. This difference in temporal focus further underscores the distinct coordination challenges in both approaches.

### 6.4.2 Analysis of the "Every Drop" Strategy

The driving force behind Heineken's "Every Drop" strategy is its commitment to a holistic design principle of water stewardship. The strategy isn't limited to mere conservation; it seeks to proactively reduce consumption, improve efficiency, and build resilience against looming water scarcities.

Heineken's decision to integrate water-saving technologies and recycling systems emerged from an in-depth quantitative examination of water consumption patterns across their global breweries (Interviewee 10). Their aim was to pinpoint inefficiencies and strategically address them (Interviewee 10). However, the broad ambition of creating universally applicable solutions was tempered by regional challenges, such as varying local regulations, inherent geographical nuances, and deep-seated cultural perspectives. For instance, Heineken uses treated water in its manufacturing process, but only for auxiliary activities and not in the actual beer brewing (Interviewee 6). This decision is influenced by the stigma associated with using treated water in beer production, even though the technology used for water treatment is certified and safe (Interviewee 6). The need to manage such social perceptions adds another layer of complexity to the task of implementing sustainable practices.

Community partnerships, particularly in watershed protection, were forged not as mere corporate inclusivity gestures but as vital components to the strategy. Heineken's deep-dive analysis into regional water consumption and potential scarcity projections illuminated the urgency to intervene in specific zones [134]. However, the principle of localized adaptability posed its own challenges. Engaging with these communities meant adapting

to their distinct viewpoints, navigating diverse regulatory environments, and assessing the broad socio-economic implications of these programs (Interviewee 9).

Heineken's "Every Drop" initiative showcases an example of strategic coordination, with a multi-stakeholder collaboration contributing significantly to its achievements. The initiative's complex objectives, ranging from reducing water consumption to fortifying resilience against water scarcity are met effectively due to the concerted efforts of internal entities like Heineken's workforce and external bodies, including suppliers, regulatory authorities, and local communities. However, it is worth acknowledging that the landscape of water management is inherently complex, fraught with evolving environmental scenarios and changing stakeholder expectations [136]. In the case of Heineken, the challenge lies not only in achieving its set targets but also in dynamically adjusting its strategic coordination to respond to these changing circumstances (Interviewee 10).

One consistent challenge has been the fluid landscape of water-related regulations as identified in the descriptive analysis[57]. Heineken's commitment to the agile alignment principle has proven pivotal (Interviewee 9). With data underscoring evolving regional norms, Heineken continually recalibrates its strategies, underpinning the importance of understanding intricate local conditions and ensuring rigorous coordination with regulatory bodies. Also the dynamic nature of environmental scenarios and stakeholder expectations calls for constant vigilance, proactive communication, and adaptive strategies to ensure the initiative's ongoing success [69].

Heineken's "Every Drop" strategy is emblematic of a localized, nuanced approach often seen in adaptation measures [138]. When comparing the two, a mitigation type strategy often employs a top-down, technologically driven approach, streamlining operations for broad impact. On the other hand, adaptation, as showcased by "Every Drop," necessitates a bottom-up, grassroots-oriented analytical process, often demanding rigorous coordination at the ground level to tailor interventions [138].

## 6.5 Potential areas of improvement

Heineken's 'Drop the C' and 'Every Drop' initiatives reflect the company's robust approach towards environmental sustainability. While 'Every Drop' underscores Heineken's dedication to water conservation and sustainable use, 'Drop the C' emerges as a pivotal mitigation strategy aimed at reducing carbon emissions and countering the detrimental impacts of climate change. Recognizing the distinct objectives of these initiatives, there exist further opportunities for strategic refinement.

Reflecting upon the intricate stages of the beer supply chain spanning from sourcing raw materials like barley and hops to the end consumer as identified in the descriptive study, it is clear that Heineken's 'Drop the C' initiative could benefit from a more expansive stakeholder engagement strategy. The beer supply chain's complexity underscores the significance of forming collaborations beyond existing partnerships (Interviewee 9). For

instance, uniting the upstream suppliers with NGOs focusing on carbon reduction might not only bring innovative solutions but also provide a deeper understanding of upstream challenges, particularly those concerning sourcing under climate vulnerabilities. Such collaborations would also enrich Heineken's decision-making process by enhancing its legitimacy.

Supplier accountability emerges as another pivotal aspect, especially given the diverse roles and responsibilities throughout the chain [129]. Currently, compliance largely relies on suppliers' self-reporting (Interviewee 10). This could be supplemented with third-party audits and tracking mechanisms which can not only reinforce compliance (Interviewee 10) but also cater to the vulnerabilities associated with drought and heatwaves that upstream suppliers, such as barley and hops providers, face [102]. This way, Heineken could improve the accuracy and transparency of the initiative's implementation.

Alongside external coordination, internal communication within Heineken can be better aligned by taking cues from the midstream supply chain. A dedicated sustainability team, akin to the roles of Supply Chain Manager or Production Manager, could streamline the flow of information (Interviewee 9), making 'Drop the C' more cohesive across the vast network of actors involved. Dedicated sustainability teams does exist within Heineken, however regular cross-team communication with sustainability leads in different regions could be incorporated (Interviewee 8)

Turning to the 'Every Drop' initiative, the comprehensive understanding of the beer supply chain illuminates the scope for adaptation and implementation of water-saving technologies. While the initiative has made strides in reducing water usage, especially in the 'Work-in-Progress' phase centered around breweries, a closer examination of the broader supply chain reveals potential gaps.

The upstream supply chain, with its focus on procuring essential ingredients like malt, hops, yeast, and water present avenues for water conservation. This assertion stems from the recognition of water's critical role, as detailed in the descriptive analysis, where even minor disruptions in water supply due to droughts can significantly affect the entire supply chain [57]. Therefore, further integrating water-saving measures across Heineken's operations, including facility management and logistics, is a potential enhancement strategy. Moreover, given the diverse nature of the beer supply chain across different regions, as highlighted in D-SQ1 and D-SQ3, standardizing these water-saving and recycling technologies presents a significant logistical challenge. Differing local conditions, regulations, and capabilities, further exacerbated by the unique roles and responsibilities of actors in different regions, can hinder the standardization of these practices [73].

Furthermore, to truly align their water-saving measures with localized challenges, a collaboration with local communities and water resource management bodies would be invaluable (Interviewee 9). Given the intricate interplay between drought, heatwaves, and the entire beer supply chain, such engagements can foster mutual learning, addressing challenges from procurement to end consumption.

Beyond these initiative-specific improvements, there are broader areas where Heineken could enhance its strategies. One such area involves the complete adoption and integration of green technologies throughout its entire production chain [133]. While the company has made significant strides in enhancing energy efficiency within its brewing processes, incorporating renewable energy sources and low-carbon technologies in other areas such as heating, cooling, and transportation could further amplify its carbon reduction impact (Interviewee 6).

Finally, incorporating consistent risk assessments into Heineken's localized water resource management strategies is essential (Interviewee 9). However, for these assessments to be genuinely impactful, they need to be coordinated with other facets of the supply chain. Collaboration between raw material suppliers, brewers, and distributors will ensure that the entire network is prepared for potential future scenarios, whether they stem from climate changes or demographic shifts (Interviewee 9). By fostering inter-departmental and inter-organizational coordination when evaluating these risks, Heineken could proactively manage uncertainties and streamline its response mechanisms.

# 7 Outlining Coordination Mechanisms for Climate Resilience: For the broader beer industry

## 7.1 Discussion: Leveraging Learnings from Heineken's Strategies

Heineken's 'Drop the C' and 'Every Drop' initiatives serve as valuable blueprints for the broader beer industry in the quest for environmental sustainability and resilience. They highlight the importance of both internal and external coordination, comprehensive sustainability policies, and the integration of sustainability practices into every level of corporate operations.

One key takeaway from Heineken's strategies is the importance of a multi-stakeholder approach. As Heineken's experiences with these initiatives demonstrate, alliances with key stakeholders, including NGOs, suppliers, local communities, and water resource management bodies, can drive the implementation of sustainability efforts. Beer companies can learn from Heineken's model, striving to establish collaborative relationships with diverse stakeholders to harness their unique insights, skills, and resources.

Moreover, Heineken's sustainability standards for suppliers indicate a proactive approach to influencing the supply chain. By enforcing robust sustainability standards and complementing them with strong tracking mechanisms for improved accuracy and transparency, beer companies can influence their suppliers' practices and contribute to a more sustainable value chain.

Heineken's internal coordination mechanisms also offer important lessons. A dedicated sustainability team, improved communication channels, and the integration of sustainability into corporate culture have all contributed to Heineken's success. For other beer companies, creating similar structures can facilitate the streamlining of sustainability practices across all levels of the organization, fostering a culture of sustainability, and ensuring the successful implementation of environmental initiatives.

Heineken's approach to water management, particularly their efforts to collaborate with local communities and water resource management bodies, is another important lesson for the beer industry. By aligning their water-saving measures with local contexts and promoting mutual learning and capacity building in water stewardship, beer companies can make significant strides towards sustainable water management.

Being a global brewer, Heineken's attempts to globalize their sustainability standards offer an example of how to create cohesion in environmental efforts across all operating regions. The beer industry could benefit from adopting similar practices, setting a unified, company-wide standard that takes into account the local regulations and exceeds the minimum requirements of all operating countries.

## 7.2 Tailoring Ostrom's Principles to the Beer Industry: Proposing New Pathways for Coordination Mechanisms

The applicability of Ostrom's design principles extends beyond the context of managing common-pool resources. These principles provide a useful foundation for designing new coordination mechanisms within complex, interconnected systems [43], like the beer industry. With a focus on collaboration, adaptability, and equitable resource management, they can guide the development of strategies to navigate shared challenges and maximize collective benefits.

In the context of the beer industry, the principles can help structure collaborative efforts among multiple stakeholders toward shared sustainability goals [43]. They offer insight into how to foster joint decision-making, create fair and effective rules, and establish accountability mechanisms, all of which are essential for coordinating actions and ensuring compliance with sustainability standards.

For a nuanced understanding of the applicability of each principle within the beer industry, a comprehensive table has been constructed, rooted in meticulous research and insights gleaned from industry interactions. This table categorizes principles based on their pertinence in the prevailing context, identifying those potentially less relevant, while also providing the rationale for each delineation.

| **Design Principle** | **Relevance to Beer Industry** | **Rationale** |
|---|---|---|
| Clearly Defined Boundaries | Relevant | Within the beer industry's vast network of stakeholders, clear boundaries are crucial (Interviewee 8). They ensure that each actor understands their specific rights and responsibilities concerning vital resources like water. This is especially pivotal in water-scarce regions, promoting transparency, preventing conflicts, and guaranteeing sustainable resource management by delineating distinct roles and entitlements. |

| | | |
|---|---|---|
| Collective-Choice Arrangements | Relevant | In the multifaceted beer industry, decisions on operational boundaries and resource management significantly impact all stakeholders [139]. Therefore, inclusive decision-making, involving everyone from farmers to breweries, ensures a shared sense of ownership. This inclusivity not only strengthens commitment but also minimizes potential disagreements, fostering harmonious operations and better compliance with mutually agreed-upon standards [42]. |
| Monitoring | Relevant | Droughts and heatwaves can severely affect key ingredients like barley and hops. Continuous monitoring of water resources ensures timely interventions, facilitating the industry's proactive responses to these climate challenges and safeguarding consistent and sustainable production [57]. |
| Graduated Sanctions | Relevant | To ensure sustainable resource usage, escalating penalties for deviations from consumption guidelines can effectively deter non-compliance [42]. Concurrently, rewarding adherence can motivate stakeholders towards more sustainable practices, maintaining industry standards and promoting sustainability [42]. |
| Proportional Equivalence between Benefits and Costs | Not Relevant | The beer industry's current challenges prioritize clear resource boundaries and collaborative decision-making (Interview 1). Balancing benefits and costs proportionally, though significant in other scenarios, is secondary in the face of these urgent concerns. |
| Conflict-Resolution Mechanisms | Not Relevant | The primary focus is on proactive resource management and coordination. By clearly defining roles and responsibilities through the other principles, potential conflicts are anticipated and minimized, making specific conflict-resolution mechanisms less pertinent in the current context [42]. |
| Minimal Recognition of Rights to Organize | Not Relevant | The beer industry's stakeholders already have a degree of autonomy and organizational rights [129]. The primary challenges revolve more around resource management and coordination. |

| | | |
|---|---|---|
| Nested Enterprises | Not Relevant | In the beer industry, the focus is on streamlined, centralized strategies for resource management. Hierarchical, nested approaches could introduce complexities that detract from the primary goal of clear and efficient coordination [40]. |

Table 6: Tailoring Ostrom's Design Principles

In addressing the challenges faced by the beer industry, particularly in light of the impacts of droughts and heatwaves, it becomes evident that some of Ostrom's principles align more directly with the industry's immediate needs. Clear boundaries, collective decision-making, rigorous monitoring, and a system of sanctions emerge as the most pertinent. However, as the industry evolves and the landscape of challenges shifts, the relevance of other principles might come to the forefront. It's a testament to the adaptability and comprehensive nature of Ostrom's principles, emphasizing their value not just for common-pool resources but also for complex industries [42] like beer production.

Applying the selected Ostrom's design principles to outline new potential coordination mechanisms for the beer industry:

### 7.2.1 Clear Boundaries and Shared Responsibility:

Heineken's initiatives provide a good starting point for establishing clear operational boundaries and shared responsibilities. However, a deeper examination reveals potential gaps, especially regarding the precise definition of who has access to resources and information. For the beer industry to implement this principle effectively, it would need a comprehensive mapping of all actors involved in its supply chain and an explicit delineation of their roles and responsibilities.

Building upon its own initiatives, Heineken should take the lead in establishing precise operational boundaries within the beer industry, especially concerning vital resources like water (Interviewee 6). Recognizing that different regions have distinct water stress profiles, and with some breweries potentially situated in water-scarce zones [57], Heineken must spearhead efforts in clearly defining who has access to these shared resources and the limits of their utilization. By partnering with local communities, regulatory bodies, and other stakeholders, Heineken can collaboratively set benchmarks and guidelines [40], ensuring sustainable water use throughout its operations and supply chain.

First, a comprehensive map of all stakeholders involved in the supply chain needs to be formulated [40], including farmers, breweries, bottling plants, distributors, retailers, and the end consumer. Each actor's role in managing and conserving water resources should be explicitly delineated. For instance, farmers should be responsible for implementing water-efficient irrigation, breweries for optimizing water use in brewing processes, and

consumers for responsible consumption and recycling.

Second, operational boundaries should be set [40]. For instance, these would include specific guidelines on water use based on regional water stress levels, seasonal fluctuations, and availability. A well-defined water quota system, using real-time data and predictive analytics to allocate water resources, can be instrumental in ensuring the effective implementation of this principle [73].

- Breweries (e.g., Heineken): As primary beneficiaries and users of water resources, breweries should spearhead the initiative (Interviewee 6). They possess the on-ground data related to water consumption patterns during brewing and can provide a realistic assessment of the water quantities they need, given optimized processes.
- Suppliers (e.g., Barley and Hops Farmers): They have firsthand experience with seasonal fluctuations and regional water stress, especially in agricultural zones prone to drought [57]. Their inputs can shape water allocation during critical growth periods.
- Local Water Authorities: These bodies maintain a vast reservoir of data on regional water availability and stress levels [68]. Their insights, when combined with predictive analytics, can anticipate shortages and guide quota adjustments in real-time.
- Regulatory Bodies: For the implementation of a well-defined water quota system, there should be a legal framework. Regulatory bodies can set the standards and guidelines, ensuring they align with broader environmental and sustainability goals [40].
- Tech and Data Firms: For the use of real-time data and predictive analytics. Collaborations with tech firms specializing in big data and analytics can help design an efficient system that allocates water based on immediate needs, historical data, and predictive trends [73].

Lastly, the shared responsibilities should be legally enforceable [40]. This would involve drafting clear operational agreements that each actor in the supply chain must adhere to, which include stipulations for water use, waste disposal, and greenhouse gas emissions. Compliance with these agreements can be incentivized through a combination of rewards for sustainable practices and sanctions for non-compliance [41], thereby ensuring that every stakeholder is motivated to fulfill their responsibility.

### 7.2.2 Collective Decision-Making:

The value of Collective Decision-Making is evident in Heineken's sustainability initiatives, with their effort to include a range of stakeholder perspectives in their strategy development [129]. However, there's room for deeper analysis and enhancement.

The prowess of Collective Decision-Making lies in its ability to assimilate diverse voices [42], especially when addressing complex challenges like climate change. Suppliers, grappling with unpredictable weather patterns, distributors navigating logistical hurdles due to extreme weather events, retailers facing fluctuating demands, consumers witnessing price changes, local communities at the frontline of climate impacts, and regulatory bodies formulating adaptive policies, all have unique perspectives [40]. Currently, while major brewers like Heineken engage with a subset of these stakeholders, there's a perceptible gap in embracing grassroots-level insights, particularly from local communities and smaller suppliers who are often the first to experience climate-induced shifts (Interviewee 7).

To address these climatic intricacies effectively, the beer industry should accentuate its focus on digital platforms, facilitating cross-dialogues [40]. These platforms can democratize knowledge sharing about climate challenges and adaptive mechanisms, especially from regions already confronting severe climate impacts.

Furthermore, the collective might of the beer industry can be harnessed to drive research and innovation. Whether it's climate-resilient barley varieties or more water-efficient brewing processes, collaboration can foster accelerated innovation [34]. An integral component of this collective approach should be scenario planning workshops (Interviewee 10). By collaboratively envisioning potential climate-induced challenges and solutions, the beer industry can position itself better for an array of future outcomes.

In evaluating Heineken's approach to climate adaptability, it becomes imperative to consider the representation of marginalized voices, often the most affected by climate variations. An in-depth analysis indicates a potential under representation of these critical perspectives. For a comprehensive climate strategy, the beer industry must prioritize the inclusion of every stakeholder, particularly those at the grassroots, ensuring they significantly influence the industry's climate response [34].

For Collective Decision-Making to truly serve as a beacon in these turbulent times, it must be institutionalized [42]. Regular engagements, iterative strategy modifications based on real-time feedback, and a focus on shared resilience against climate adversities should be the modus operandi [41], ushering the beer industry into an era of proactive climate adaptability .

### 7.2.3 Monitoring and Sanctions:

Heineken has taken commendable steps towards monitoring its sustainability initiatives and being transparent about the process [129]. However, a comprehensive approach to climate resilience demands a more nuanced and expansive strategy.

Presently, Heineken predominantly hinges on suppliers for self-reporting sustainability metrics (Interviewee 10). This system, while efficient, might lack the depth and impartiality needed to address complex climate challenges. The broader beer industry,

including giants like Heineken, would benefit from introducing impartial third-party audits (Interviewee 10). External auditors, with a specialization in climate resilience, can offer unbiased insights and ensure rigorous adherence to evolving sustainability standards. This collaboration between breweries, suppliers, and auditors will enhance the credibility of the monitoring process and ensure comprehensive climate risk assessments.

The sanctions put forth by Heineken serve as a deterrent for non-compliance (Interview 8). However, it's imperative to dissect their fairness and effectiveness in enforcing climate resilience standards [42]. Instead of a uniform sanction model, the beer industry should explore graduated sanctions. In this approach, penalties vary based on the severity and recurrence of non-compliance, offering a more tailored and just system [40]. For example, a minor infraction by a supplier might result in a corrective action plan, while repeated major infractions could lead to contract termination.

Transparency remains paramount and a key driver of these initiatives [129]. All stakeholders, ranging from barley farmers affected by changing rainfall patterns to end consumers concerned about their carbon footprint, should have access to monitoring results and sanction mechanisms. A transparent system, wherein the criteria for monitoring and consequences for non-compliance are laid out clearly, will instill trust and bolster collective efforts towards climate resilience [40].

Lastly, the beer industry's monitoring system should not just be reactive but also proactive (Interviewee 10). In addition to ensuring adherence to current standards, industry leaders like Heineken should be vigilant about emerging climate trends, innovative sustainability technologies, and shifts in regulatory landscapes [40]. This proactive stance will position the beer industry to adapt swiftly to new climate challenges, ensuring both environmental responsibility and business continuity.

## 7.3 Potential Challenges and Prospects: Realizing the Designed Coordination Mechanisms

Implementing new coordination mechanisms in line with Ostrom's design principles in the beer industry can present both challenges and prospects. It requires significant effort, commitment, and adaptability from all stakeholders.

**Clear Boundaries and Shared Responsibility:** One of the significant challenges lies in the complexity of the beer industry's supply chain, characterized by a large number of actors with varying capacities and priorities as identified in the descriptive study. Effectively defining roles, establishing clear boundaries, and promoting equitable benefit sharing among these actors can be difficult. The inherent diversity among stakeholders may breed conflict, impede consensus-building, and limit the effectiveness of collective decision-making mechanisms, initially resulting in protracted decision-making processes [140]. Additionally, the introduction of collective decision-making mechanisms may ini-

tially slow down decision-making processes due to the need to consult multiple parties [140]. But if addressed adeptly, this principle holds the promise of streamlining operations and fostering a shared vision of sustainability [140]. With clear demarcations, stakeholders can work within defined realms, reducing overlaps, and potential disputes, thus enhancing the efficacy of collective action [140].

**Collective Decision-Making:** Including diverse stakeholder voices is a commendable initiative but demands cautious navigation. The risk lies in the potential for dominant voices to overshadow marginalized ones, skewing the decision-making process [42]. The diversity in the beer supply chain, from large manufacturers to small-scale suppliers, can further complicate consensus-building, possibly elongating decision timelines. Yet, the upside is considerable. A successfully implemented collective decision-making system can instill a profound sense of ownership across the board [42]. Decisions that emerge from collaborative efforts often enjoy broader acceptance, reducing implementation resistance and fostering a cohesive strategy towards sustainability [40].

**Monitoring and Sanctions:** Monitoring and enforcement can pose another challenge. Setting up an efficient monitoring system requires significant investment in technology and personnel [43]. Similarly, enforcing compliance and imposing graduated sanctions can be complex due to legal constraints and potential resistance from stakeholders (Interviewee 9). However, a well-structured monitoring system, augmented by unbiased audits, can revolutionize accountability in the industry. Graduated sanctions, while complex, can be potent deterrents, ensuring that stakeholders align with the industry's sustainability vision without feeling oppressed [43].

While the path to incorporating Ostrom's design principles in outlining strategies for the beer industry is riddled with complexities, the potential rewards are transformative. Overcoming the inherent challenges of defining boundaries, ensuring inclusive decision-making, and establishing robust monitoring can set the stage for an industry that is not only resilient but also at the forefront of sustainable practices.

Amidst these, it's vital to also consider the balance between adaptation and mitigation strategies. The beer industry's pronounced inclination towards mitigation is evident, given the overarching goals to reduce emissions and lower the sector's carbon footprint [129]. Such mitigation efforts directly address the root causes of climate change. Yet, the exigency of adaptation cannot be downplayed. Adaptation, with its focus on real-time evolution and shifts based on immediate environmental transformations, is crucial for resilience [4]. While mitigation strategies chart a sustainable trajectory for the future, adaptation ensures the industry's viability and survival amidst the unfolding challenges of climate change.

# 8 Discussion and Conclusion

## 8.1 Research Questions Overview

The section focuses on answering the main research question: *"What effective coordination measures can beverage (beer) supply chain companies adopt to minimize their vulnerability to drought and heatwave risks and enhance their climate resilience?"*.

The main research question is an assemblage of the three descriptive sub-research questions and three relational sub-research questions and thus answering the sub-questions will conjointly answer the main research question.

### D-SQ1) What are the different levels and the key components of the beverage (beer) supply chain?

The beer supply chain comprises a network of interconnected entities involved in a series of business processes.

Delving into the intricate details of the beer supply chain, it can be segmented into three fundamental components - Upstream, Work-in-Progress, and Downstream. Such a structured approach helps to demystify the complexity of the processes, offering stakeholders a clearer understanding of the activities within the chain. This elucidation subsequently aids in identifying areas for improvement and strategizing enhancements in supply chain collaboration [61].

The upstream supply chain comprises processes preceding the manufacturing stage, primarily revolving around sourcing, transporting, and managing raw materials and semi-finished goods required for beer production [62]. In the beer industry, this includes procuring essential ingredients such as malt, hops, yeast, and water, as well as packaging materials like bottles and cans. These ingredients undergo strict quality control checks to meet the brewing requisites of different beer types.

The 'Work-in-Progress' phase is central to breweries, housing crucial stages like production, warehousing, and packaging. The transformation of raw materials into the finished product, ready for distribution and sale, takes place here [79].

The downstream supply chain concerns activities post the work-in-progress phase. It incorporates processes related to distribution, such as warehousing, order fulfillment, logistics management, and transportation [82]. In the beer industry, this phase commences once the beer is packaged and ready for delivery. The beer is transported from breweries to distribution centers or directly to regional wholesalers. These wholesalers play a critical role in the beer supply chain as they purchase beer in bulk, store it under optimal conditions, and sell it to retail outlets [83]. The retailers, in turn, deliver the beer to the end consumers.

Each of these stages within the beer supply chain houses its own set of roles, vulnerabilities, and challenges. A more deeper exploration into each of these components facilitated a more comprehensive understanding of the overall supply chain structure, helping to strategize more effective and resilient processes.

**D-SQ2) What are the impacts and vulnerabilities of drought and heatwave hazards on the beer supply network?**

The impacts and vulnerabilities of drought and heatwave hazards on the beer supply network are extensive and multifaceted [92], cutting across every stage of the value chain. At the initial stage of agricultural production, both barley and hops, which are the primary ingredients in beer production, are greatly affected by these hazards.

Barley, as the principal cereal grain in beer, suffers significantly during periods of intense heat and insufficient water supply. The crop's growth is stunted under such harsh conditions, which can lead to premature maturation and a substantial reduction in overall yield [102]. Moreover, the quality of the barley can be severely degraded, which in turn impacts the malting process [104], a crucial midstream operation in the beer supply network.

Similarly, hops, which lend beer its unique flavor and balance, are sensitive to excess heat and water shortage. Drought and heatwaves can cause wilting, stunted growth, premature maturation, and increased susceptibility to pests and diseases [105]. Consequently, there's a reduced yield and poorer quality hops, which can adversely affect the quality and taste of the final product.

Simultaneously, water, a critical resource in beer production, becomes scarce during drought conditions. Lower water levels in reservoirs, rivers, and groundwater sources directly impact not only the irrigation of barley and hops but also the brewing process [73]. Furthermore, this scarcity often leads to increased water prices, further straining the operational costs of breweries.

Breweries also face direct consequences due to water shortages and increased temperatures. The scarcity of water adds to the operational expenses, and the potential changes in water quality can alter the taste of the beer [108]. In addition, heatwaves necessitate increased cooling during the brewing process, leading to higher energy consumption and consequently increasing the breweries' carbon footprint and operational costs [109].

At the downstream level, the packaging and distribution stages are not immune to these adverse conditions either. Higher temperatures and water shortages can cause supply disruptions and increased costs in operations [82]. Moreover, heatwaves can lead to potential transportation disruptions, which affect the smooth distribution of beer [113].

At the retail point, there could be a surge in beer demand during heatwaves [84], exac-

erbating the strain on the supply chain. This increased demand also escalates the need for refrigeration, leading to higher energy usage and operational costs.

Thus, the impacts of drought and heatwaves on the beer supply network are broad-ranging, affecting every step from agricultural production to the end consumer.

### D-SQ3) What are the key roles and responsibilities of the actors involved in the beer supply chain?

The beer supply chain is a complex network of key actors, each with distinct roles and responsibilities. Each actor's actions can significantly affect the overall system's efficiency and success. Therefore, understanding these roles and responsibilities is essential.

In the upstream supply chain, raw materials and packaging providers form the core. These actors are responsible for maintaining the quality and availability of essential inputs [62]. These actors in the upstream supply chain are also tasked with ensuring quality control, timely delivery, and smooth coordination with breweries [62]. Any disruptions in their operations can potentially have significant ripple effects on the entire supply chain.

In the midstream supply chain, breweries form the crux. These entities are charged with transforming raw materials into beer through the brewing process [108]. Breweries have to manage the brewing process, maintain the beer's quality, and ensure that the produced beer meets the set standards and expectations. Besides, they also have to coordinate with raw material suppliers for timely delivery of ingredients, with warehouses for storage of the produced beer, and with distributors for its transportation [108]. The midstream supply chain also houses critical personnel, including the Supply Chain Manager, Procurement Manager, Production Manager, Warehouse Manager, and Logistics Manager. These individuals and their teams play significant roles in maintaining the brewery's operational excellence.

In the downstream supply chain, distributors, wholesalers, and retailers act as vital links between breweries and the end consumers. Distributors transport beer from breweries and warehouses to various points of sale, including regional wholesalers or direct retail establishments [83]. Retailers often work with multiple distributors and wholesalers to offer a variety of beer products to their customers [83].

The end consumers are the final link in the beer supply chain. Their consumption patterns often shape trends in beer consumption, influencing the entire supply chain [61]. Feedback from these end users can affect production decisions at the brewery level and distribution decisions at the distributor and retailer levels.

The beer supply chain is a well-orchestrated ecosystem where each actor plays a critical role in ensuring the chain's smooth functioning and success.

**R-SQ1) How do the nature and depth of relationships among various actors in the beer supply chain intersect with and shape existing coordination mechanisms?**

The relationships between the different actors in the beer supply chain are inherently interdependent and complex, defined by a web of interactions that help ensure the smooth operation of the chain from start to finish [118].

In the upstream sector, raw material and packaging material suppliers wield considerable influence. Their interactions and relationships with other actors traverse across the midstream and downstream segments. It's interesting to note that the nature of these interactions isn't homogeneous [120]. Direct, regular communication is maintained with breweries, reflective of a relationship that underscores the mutual dependency for smooth operation. Conversely, interactions with other stakeholders are more sporadic and indirect, highlighting a degree of separation [120].

In the midstream portion of the chain, the breweries themselves assume a pivotal role. They house key personnel in the breweries form the operational backbone of the breweries and their collaborative efforts help the breweries to navigate uncertainties and challenges, including those associated with climate change [108]. Their interactions and relationships with other actors in the supply chain can span from procuring raw materials from the upstream suppliers to coordinating with downstream actors for distributing the final product [120].

The downstream sector, composed of distributors, wholesalers, retailers, and end-users, serves as the final yet critical bridge between breweries and consumers [113]. Their interactions and relationships are primarily directed towards midstream actors, although some indirect ties with upstream suppliers are maintained. They ensure the final product reaches the consumers, thus playing a significant role in defining the consumer's experience [83].

The power dynamics in the beer supply chain form another facet of this network. Defined by the distribution and exertion of influence among different actors, these dynamics steer strategic decision-making and overall supply chain operations [121]. Factors influencing these dynamics extend beyond traditional metrics like company size and market share to include unique value propositions, capacity to influence consumer demand, and even the stance towards climate change [122]. However, these dynamics are far from being static; they oscillate in response to changing market conditions, evolving consumer preferences, and shifting environmental considerations.

**R-SQ2) To what extent are the existing mechanisms or strategies in the beer supply chain effective in enhancing climate resilience?**

A detailed study and critical analysis of existing strategies was conducted. For this analysis, two strategies implemented by Heineken were chosen - "Drop the C" and "Every Drop". These strategies were critically evaluated using the Institutional Analysis and Development (IAD)'s Action Situation Framework.

The "Drop the C" initiative is a part of Heineken's broader "Brewing a Better World" program, specifically targeting the reduction of CO2 emissions. The strategy is characterized by a range of coordinated efforts including adoption of energy-efficient brewing technologies, securing renewable energy contracts, sustainable materials sourcing, and optimization of distribution processes [133]. The success of this initiative largely hinges on the effective collaboration between internal departments as well as external entities like suppliers and certifiers.

However, a critical analysis of this initiative also brought to light potential challenges. These included the necessity for continuous innovation, the risk of communication lapses, and the need for adaptations to accommodate ever-evolving logistic realities.

Heineken's "Every Drop" strategy is the company's comprehensive response to water management. The strategy outlines efforts to reduce water consumption, improve efficiency, and enhance resilience against water scarcity [134]. The effective execution of this strategy is heavily reliant on coordination with local communities, suppliers, and regulatory bodies.

Despite its effectiveness, the analysis of the "Every Drop" strategy identified several challenges. These challenges include managing the cultural perceptions associated with water usage in brewing, accommodating the complexity resulting from diverse regulatory environments, and the need for constant vigilance and adaptability to respond to changing environmental scenarios and stakeholder expectations.

Critical analysis of Heineken's strategies reveals that effective coordination mechanisms often involve strategic internal collaborations, robust partnerships with external entities, and a comprehensive understanding of the intricate interplay between technical, environmental, and socio-cultural factors. Moreover, these mechanisms require continuous evaluation, innovation, and adaptability to the changing landscape of the beer supply chain.

Finally, within strategic planning, there exists a distinction between mitigation and adaptation strategies. The "Drop the C" initiative epitomizes a mitigation strategy, as it primarily focuses on reducing the causes of climate change, particularly carbon emissions. On the other hand, the "Every Drop" strategy represents an adaptation approach. Adaptation strategies aim to decrease the vulnerabilities and increase the resilience of a system against actual or expected climatic changes [138]. Both strategies have their merits: mitigation approaches like "Drop the C" endeavor to prevent further exacerbation of climate change [137], whereas adaptation strategies such as "Every Drop" emphasize resilience and responsiveness to current environmental realities [138]. A truly holistic cli-

mate response would ideally harness the strengths of both approaches, ensuring not just reduced carbon footprint but also bolstered resilience against environmental disruptions.

**R-SQ3) How do coordination mechanisms in the beer supply chain contribute to enhancing climate resilience, and what improvements can further bolster this resilience?**

Extrapolating the findings from the case of Heineken's "Drop the C" and "Every Drop" initiatives was used to outline new potential coordination mechanisms. These initiatives highlights the importance of both internal and external coordination and the incorporation of sustainable practices into corporate operations at every level.

Ostrom's principles provide a valuable frame of reference for evaluating and crafting institutions and collaborative mechanisms across various sectors, inclusive of complex supply chains [43] such as those seen in the beer industry. By structuring relationships and interactions among different actors effectively, these principles facilitate sustainable management of shared resources. The following design principles were found to be the most relevant for outlining an effective strategy in the beer industry:

| **Design Principle** | **Analysis** | **Detailing the Prospects** |
|---|---|---|
| Clear Boundaries and Shared Responsibility | The intricacy of defining clear boundaries is accentuated in an industry like beer. The diversity of stakeholders – farmers, producers, bottlers, distributors, retailers, consumers – each with its own perspective and priorities, further convolutes the process. Regional disparities in regulations, socio-economic conditions, and resource availabilities compound these complexities. | If tackled strategically, establishing clear boundaries and shared responsibilities can optimize resource utilization. Precise roles and responsibilities can prevent operational overlaps, which often lead to resource wastage or underutilization. Moreover, a clear sense of responsibility is likely to stimulate a more dedicated and proactive approach to sustainability. |

| | | |
|---|---|---|
| Collective Decision-Making | Given the vast spectrum of stakeholders in the beer industry, achieving genuine collective decision-making can be fraught with difficulties. Larger entities, like global beer brands, may unintentionally dominate the discourse, potentially sidelining smaller, local actors who might bear more direct consequences of climate changes. | A robust collective decision-making framework can lead to more sustainable, grounded, and holistic strategies. By involving grassroots-level actors who experience climate change first-hand, strategies can be tailored to address immediate, localized needs. Moreover, decisions born from collective deliberation often enjoy higher acceptance and buy-in from all involved, ensuring smoother implementation. |
| Monitoring and Sanctions | The vastness of the beer supply chain makes monitoring a complex task. While self-reporting fosters a sense of responsibility, it's prone to biases or oversights. Third-party audits, although more impartial, introduce financial and logistical challenges. | Despite these challenges, diligent monitoring can yield numerous benefits. It not only keeps stakeholders accountable but also provides valuable data that can guide future strategies. Adopting an approach with graduated sanctions can motivate compliance while maintaining fairness. A transparent sanctioning process can build trust, a key component for collective commitment to sustainability. |

Table 7: Selected Design Principles Overview

The integration of Ostrom's design principles for outlining climate resilience strategy into the beer industry, while intricate, harbors transformative potential. By navigating the inherent challenges, the industry can emerge not only more resilient but also as a beacon of sustainable practices. Achieving this will require an combination of strategic vision, collaboration, and commitment to sustainability.

## 8.2 Generalizability of the Findings

Heineken's commitment to sustainability, anchored in Ostrom's principles, offers a beacon for industries aiming to bolster their environmental footprints. The success of Heineken's approach prompts to ponder its potential applicability across diverse sectors. This section embarks on generalizability of the findings.

### 8.2.1 For Beer Industry

The beer industry, with its inherent challenges and synergies, stands to gain significantly from Heineken's clear boundaries and shared responsibility strategy. Collaborative measures that delineate roles and responsibilities can foster more efficient, sustainable practices across breweries. Tailoring this approach, especially in light of regional variations and socio-economic contexts, becomes crucial [141]. Here, it's not about mere replication, but about embracing the underlying ethos while adapting to specific circumstances [141].

### 8.2.2 For the Wider Beverage Industry

Transcending to the larger beverage canvas, Heineken's sustainability paradigms beckon with promise. For the wine industry, the emphasis might shift more towards sustainable land and vineyard management, given the significance of terroir [142]. Conversely, soft drink manufacturers could draw insights from Heineken's close-knit relationships with ingredient suppliers. Moreover, Heineken's water conservation ethos can be a touchstone for water-intensive segments, like the dairy and meat sectors. These industries could strive for a similar clarity in operational boundaries and responsibilities, ensuring optimized water resource management [141].

### 8.2.3 Other Complex Industries

The renewable energy domain, with its multifaceted stakeholder landscape, can derive value from Heineken's inclusive, collective decision-making strategy. This sector's vast expanse, encompassing policymakers, environmental groups, and local communities, demands nuanced engagement [143]. The essence of the strategy is universal, but its manifestation necessitates distinct, tailored approaches to cater to the unique expectations of diverse stakeholders.

Heineken's sustainable tenets, especially the collective decision-making pillar, resonate with the textile industry's complexities. A supply chain that spans from cotton farmers to final garment manufacturers can be streamlined and made more sustainable through collaborative efforts [144]. However, given the industry's vastness and diversity, the application of these principles requires a balance between universality and specificity.

## 8.3 Societal Impacts and Policy Recommendation

The societal relevance and policy implications of this research are far-reaching, emphasizing the importance of effective coordination mechanisms for climate resilience within global supply chains.

The research findings suggest a shift in policy focus is warranted. Both corporate en-

tities and government bodies are prompted to consider fostering an environment that champions cross-organizational collaboration and coordination mechanisms. However, navigating such a transition presents challenges. It demands policymakers, at both industry and government levels, to reconcile the inherent tension between competition and cooperation, aiming for a balance that champions transparency [42]. Thus, policy strategies must be delicately constructed, promoting collaboration while maintaining the spirit of competition.

From a corporate perspective, policies might incentivize companies to collaborate, exchange information, and jointly invest in climate adaptation measures [40]. Such incentives could be tax reductions or subsidies for corporations that effectively leverage coordination mechanisms to counter climate risks. Careful design of these incentives is imperative to preclude unforeseen outcomes.

From a government stance, national and regional policies could be envisioned to provide support structures, such as information platforms for data sharing on climate risks and adaptation strategies [40]. Governments could also consider fostering public-private partnerships (Interviewee 4), facilitating collaborative research and development in climate resilience, and perhaps, establishing sector-specific resilience standards.

The societal implications of this study are notable. The beer supply chain represents a significant segment of the global economy, underpinning countless jobs and communities. Amplifying its resilience can protect these jobs, especially in areas where the beer trade is a major economic force. Realizing these findings into palpable societal advantages is, however, influenced by numerous determinants, including the industry's propensity for change and the overarching economic and legislative landscape [40].

Furthermore, this research's implications resonate beyond the confines of the beer industry. Given the major threat climate change poses to global supply chains, the principles and strategies unearthed in this investigation can be modified and implemented across various sectors. This might instigate a transformative shift in business strategies related to supply chain management in a changing climate, propelling them towards a more collaborative and robust framework.

## 8.4 Scientific Contributions

The groundbreaking aspects of this research are multifold, pushing the boundaries of traditional study methods and introducing novel frameworks in the domain of supply chain management, climate change adaptation, and cross-organizational collaboration:

- **Utilization of the IAD Framework for Decomposing the Beer Beverage Supply Chain:** One of the standout contributions of this research is the innovative use of the IAD framework to dissect the beer beverage supply chain. This unique application provides a structured approach to understanding the intricate dynamics

of this chain, a method that remains sparsely explored in existing literature. By employing this framework, the study sheds light on novel perspectives and identifies previously overlooked vulnerabilities and opportunities within the beer supply chain, enriching the academic discourse on the subject.

- **Adoption of Ostrom's Design Principles for Climate Resilience Strategies:** Another key contribution is the application of Ostrom's design principles to delineate strategies for climate resilience. By doing so, this research bridges the gap between theory and practice, facilitating the formulation of actionable and effective strategies to counter climate-induced challenges. Ostrom's principles, while traditionally not associated with climate resilience in supply chains, prove to be a potent tool, offering fresh insights into the multi-faceted challenges and solutions in this domain.
- **Holistic Approach through Dual Strategy Examination:** The study further stands out by comparing two distinct strategies: adaptation and mitigation. By evaluating these strategies side by side, the research provides a holistic lens to comprehend the climate resilience imperative within supply chains. This dual approach not only enhances the depth of the investigation but also broadens its scope, capturing the nuances of each strategy and drawing comprehensive conclusions that cater to a wide array of challenges.

These contributions offer a fresh lens to approach problems in the domain, setting the stage for future research that can build on these novel methodologies and insights.

## 8.5 Research Limitations

While this study provides important insights into the role of coordination mechanisms in enhancing climate resilience in the beer supply chain, it is not without limitations.

The focus of the research is heavily centered on a single industry, and more specifically on one major player in the beer market - Heineken. While this has the advantage of a more in-depth examination, it also limits the extent to which findings can be generalized across different industries or sectors. There may be unique factors specific to the beer industry that may not hold true in other contexts. Furthermore, as the study focused primarily on one large-scale beer company, it may not have fully captured the potential challenges and strategies relevant to smaller companies with potentially fewer resources or different operational models.

Second, the research employed an inductive and qualitative approach involving data collection through interviews. While this method allows for a rich, detailed understanding of the topic, it could potentially introduce bias based on interviewee responses [48]. Their perspective could be influenced by their role within the company, their experience, or their perception of the issue, potentially limiting the objectivity of the findings [48].

While the study did include interviews, they were limited in number and predominantly focused on representatives from Heineken and other supply chain experts. Increasing the number of interviews and expanding their range to encompass different levels and types of actors within the supply chain would have provided a more robust and comprehensive data [48], and would likely have added depth to the study's findings.

Third, the study also bases its assumptions and recommendations on the threat of two specific climate hazards: drought and extreme heat. While these are significant and relevant, it's important to note that climate change poses a multitude of other risks which could also impact supply chains [27], such as floods, storms, or shifts in crop diseases. Therefore, the strategies and coordination mechanisms identified may need to be adjusted or supplemented when dealing with other climate-induced disruptions.

Lastly, the temporal scope of the research might present a limitation. The study provides a snapshot of strategies and mechanisms based on current conditions and practices. As the climate change phenomenon and its impacts continue to evolve, the effectiveness and relevance of these strategies may change [1]. There is also a continuous evolution in technologies and practices related to supply chain management and climate adaptation [145], which this study may not be able to capture.

## 8.6 Recommendations and Future Scope

### 8.6.1 Recommendation for Beer Brewers (e.g., Heineken)

Beer brewers like Heineken should spearhead and engage in collaborative initiatives, leveraging shared resources, knowledge, and best practices to enhance resilience across the beer supply chain. As the industry undergoes increasing pressures from climate change, an investment in supply chain visibility tools is paramount. Such technology can not only optimize operations but can also assist in real-time decision-making during supply chain disruptions, aiding in quicker response times [145]. Continuous training of personnel in understanding climate change impacts, potential risks, and adaptation strategies is pivotal for the long-term sustainability of operations. This knowledge base will enable better decision-making and foresight. Before implementing new coordination mechanisms or resilience strategies on a large scale, Heineken could consider launching pilot studies in select regions or product lines, allowing for iterative improvements based on real-world outcomes. Furthermore, engaging with governments and local bodies to foster public-private partnerships can be beneficial, as such collaborations can help in securing infrastructure and logistical support, especially during extreme climatic events.

### 8.6.2 Recommendations for Royal HaskoningDHV

With the insights gained from this research, Royal HaskoningDHV has an opportunity to offer specialized consultation services to industries aiming to enhance their supply chain resilience against climate change impacts. Given the potential of technology in bolstering supply chain coordination, the company could work diligently on developing or integrating technological solutions tailored for industries prone to climate disruptions. Organizing workshops and training sessions for clients across sectors can be a pivotal step. These sessions can focus on sharing best practices, strategies, and coordination mechanisms that can help industries navigate the myriad challenges brought forth by climate change. Additionally, there is significant merit in investing further into research to refine and expand the findings of this thesis, making them more applicable across a broader spectrum of industries. Lastly, using the insights from this research, Royal HaskoningDHV could engage in policy advocacy, pushing for a conducive regulatory environment that encourages cross-sector collaboration [40] and supply chain resilience.

### 8.6.3 Future Research Scope

A potential area for future research would be the utilization of a quantitative research methodology. This could serve as a complementary approach, quantifying the impacts of specific coordination mechanisms and their influence on supply chain resilience. The robustness of a quantitative study lies in its capacity to provide numerical data and statistical analyses [146]. This would allow for rigorous comparisons across different coordination mechanisms, supply chain structures, or diverse geographic regions. Such research could yield critical data to identify trends, make generalizable conclusions, and bolster resilience strategies within the industry [146].

The scope of this research could also be broadened to explore other sectors within the beverage industry or entirely different industries. This recommendation is drawn from the premise that the principles and coordination mechanisms explored within this thesis likely hold applicability beyond the beer industry. Extending the research parameters in this manner could further validate the findings of this study, increase their generalizability, and illuminate industry-specific nuances and unique adaptive strategies.

Another potential direction could revolve around investigating the cost implications of implementing various coordination mechanisms within the supply chain. Given that economic factors often play a significant role in the practical adoption of sustainability strategies, understanding the financial impact of different coordination mechanisms is crucial [147]. Quantitative methods could be employed to analyze the cost-effectiveness of different mechanisms, and case studies could be conducted to understand how these costs impact the overall profitability and resilience of the company.

Finally, another interesting avenue for research could be exploring the intersection of

technology and coordination mechanisms. Technological tools can greatly enhance supply chain visibility, communication, and coordination [145]. Future studies could investigate how technology can be leveraged to optimize coordination mechanisms and enhance supply chain resilience in the face of climate change.

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# Appendix

## Consent Form

You are being invited to participate in a research study titled Enhancing Climate Resilience in Supply Chains: Investigating Coordination mechanisms to reduce Vulnerability to Drought and Extreme Heat Climate Hazards For the Beer Sector. This study is being done by Arjun Santhosh from the TU Delft in collaboration with Royal HaskoningDHV.

The purpose of this research study is to provide valuable insights into the adaptation strategies of companies in the beverage sector in response to the impacts of climate change on their supply chains and will take you approximately 30-45 minutes to complete. The data will be the video recording and trancripts which would be encoded and included in MSc thesis, which will be publicly available. Video and Transcript would be deleted at the end of the project.

As with any online activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by keeping the personal data anonymous and the data will be stored securely in TU Delft private access one-drive which would be accessible to Dr. Amineh and Dr. Nihit who are the research supervisors from TU Delft during the course of the study.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit any questions.

Contact Details of the Researcher:
Arjun Santhosh
Email: arjunsanthosh1998@gmail.com
Phone: +31613281840

**TEMPLATE 2: Explicit Consent points**

| PLEASE TICK THE APPROPRIATE BOXES | Yes | No |
|---|---|---|
| **A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION** | | |
| 1. I have read and understood the study information dated [*DD/MM/YYYY*], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction. | ☐ | |
| 2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason. | ☐ | ☐ |
| 3. I understand that taking part in the study involves: Audio/Video-recorded interview which will be transcribed as text and the recording would be deleted after the course of the study | ☐ | ☐ |
| 4. I understand that the study will end by the mid of August. | ☐ | |
| **B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)** | | |
| 7. I understand that taking part in the study also involves collecting specific personally identifiable information (PII): name, designation, location and email address with the potential risk of my identity being revealed public. | ☐ | |
| 9. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach such as securely storing the data on TU Delft one drive with limited access and deletion of recording after the study duration. | ☐ | |
| 10. I understand that personal information collected about me that can identify me, such as name, email address and job designation, location will not be shared beyond the study team. | ☐ | |
| 11. I understand that the (identifiable) personal data I provide will be destroyed immediately after the duration of the study. | ☐ | |
| **C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION** | | |
| 12. I understand that after the research study the de-identified information I provide will be used for would be encoded and included in MSc thesis, which will be publicly available. | ☐ | ☐ |
| **D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE** | | |
| 16. I give permission for the de-identified video recording, transcripts that I provide to be archived in TUD thesis repository so it can be used for future research and learning. | ☐ | ☐ |

**Signatures**

_____ _____ _____

Name of participant [printed] Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____ _____ _____

Researcher name [printed] Signature Date

Study contact details for further information:

Name: Arjun Santhosh

Phone: +31613281840

Email address: arjunsanthosh1998@gmail.com

## Interview Pool 1

### Interview 1- Expert- Supply Chain and Automation

Interviewee 1 has substantial expertise in the complexities of supply chains and the strategic use of the data they generate. They noted a marked shift over the past two to three years in the management of supply chains for international entities. This has evolved from solely focusing on optimization to incorporating sustainable considerations, mainly due to the disruptions brought about by COVID-19.

Supply chain resilience has become a prime focus, with efforts to balance risk across networks and ensure customer satisfaction, even during turbulent periods. The interviewee emphasized the value of dynamic supply chains, which offer the flexibility to adapt and modify strategies based on varying circumstances. This is particularly significant within the context of climate change resilience. The respondent noted that companies well-prepared for such changes could show resilience against future natural hazards.

According to Interviewee 1, the advent of COVID-19 has led businesses to start integrating climate resilience considerations into their strategic thinking. While locally focused companies face less risk due to their limited dependence on high-risk locations, those operating globally are progressively prioritizing climate resilience.

Interviewee 1 proposed a systematic approach to address the complexities of supply chains, starting with the consideration of raw materials. They highlighted industries such as denim production, which require significant water resources and are likely to be affected by droughts. They also discussed the potential impact of droughts on logistics, particularly for transport routes dependent on waterways.

When asked about the sectors most vulnerable to climate change, the interviewee recognized all sectors as vulnerable, but singled out the food and beverages industry as one of the most proactive in taking initiatives against climate change.

Interviewee 1 discussed the critical role technology plays in adapting to climate change effects on supply chains. They emphasized the need to understand and address the most urgent climate change-related issues in the industry.

They also touched on the changing consumer preferences due to climate change and its impact on supply chains. Interviewee 1 detailed their approach to integrating sustainability and climate resilience considerations into supply chain planning and decision-making, focusing on a step-by-step evaluation of the chain from raw materials to the end product.

The interviewee, being a prominent expert in the field, articulated the intricate nature of supply chains in the beer industry, where value is delivered to customers through a complex series of upstream and downstream links. These links encapsulate a multitude of activities from production to service provision, with each segment critical to the delivery of the final product. Of particular interest was the interviewee's emphasis on the

"work-in-progress" (WIP) section of the supply chain. Encompassing crucial stages such as production, warehousing, and packaging, the WIP forms the core of supply chain operations. Understanding these core areas is essential for any efforts aimed at enhancing resilience and sustainability.

Our conversation also delved into the intricate flows that constitute the supply chain. These include the demand flow, material flow, financial flow, value flow, return flow, and the sustainability flow. Each of these flows signifies a unique aspect of supply chain operations and offers a different perspective for understanding its dynamics.

In the evolving landscape of supply chain management, technology also emerged as a key theme during our dialogue. The interviewee pointed out that new technologies like blockchain hold immense potential to amplify supply chain transparency and traceability. By fostering trust and collaboration among actors in the supply chain, such technologies can significantly contribute to building a more resilient and sustainable supply chain.

**Interview 2- Supply Chain Manager- Food & Beverage Company**

The interview commenced with the respondent explaining their company's business model. The organization sources agricultural products from farmers, processes these goods, and subsequently distributes them to various markets and brands. The respondent highlighted the importance of social proofing within their operations. This process ensures suppliers strictly adhere to sustainable and ethical farming practices and involves regular on-site visits and meticulous quality checks.

Regarding communication, email serves as the primary means, supplemented by telephone and on-site visits. For logistics and transportation, the company employs multiple modes, including road, railway, air, and sea, reflecting the intricate nature of logistics due to India's vast geographical landscape. The respondent discussed contingency plans in place for potential disruptions, such as seaport shutdowns.

Emphasis was placed on the crucial role of the Harmonized System Number (HSN) or tariff codes in global trade operations, indicating a comprehensive understanding of international trade laws within the company's operations. The significant influence of weather conditions on the agricultural supply chain was also acknowledged. The company explores sourcing alternatives from other countries during weather-induced raw material shortages, although some losses may be unavoidable.

The second part of the interview focused on the impact of natural disasters on food production. Strategies like maintaining a safety stock and forecasting weather conditions were discussed to mitigate such risks. The respondent also highlighted how they adjust sourcing and production strategies in these situations, for example, sourcing different types of products when availability is low. The role of the Indian government in supporting farmers through subsidies and initiatives, especially in drought-prone regions, was

also highlighted.

The importance of communication and transparency when managing supply chain disruptions was emphasized, with the respondent stating that sharing information with buyers and suppliers helps maintain good relationships and enables necessary adjustments. In case of disruptions affecting specific products, strategies are in place to identify potential suppliers who can act as a backup. The need for multiple suppliers for any product and balancing quantities purchased from each was underscored to ensure supplier satisfaction and continuity of supply.

Finally, the respondent highlighted the importance of understanding specific needs, locations, and quantities required to establish a successful supply chain. They also emphasized the role of negotiation skills in these processes, aiming for a win-win situation for all parties involved.

**Interview 3- Logistics Manager- A Fairtrade organization**

Our enlightening discussion with Interviewee 3, a Logistics Manager at a Fairtrade organization, revolved around the intricate role seaports play in their supply chain and the unique challenges these operations encounter.

Interviewee 3 shed light on the primary function of a seaport within their logistics framework. The primary responsibility revolves around the safe unloading of containers and their transfer to the designated inland transport. However, this seemingly straightforward task can be fraught with a multitude of disruptions, ranging from heavy winds that jeopardize the safety of unloading operations to computer-related problems at the port causing unwelcome delays.

Further complicating this scenario are external disruptions like natural disasters, pandemics, or socio-political changes. For instance, extreme weather conditions, such as droughts and heatwaves, not only disrupt transportation and logistics but also can have a severe impact on the retail outlets' infrastructure. The interviewee highlighted that these external factors could significantly influence the beer supply chain, potentially affecting the reliability and efficiency of distribution.

Given these potential disruptions, the interviewee acknowledged the need for distributors to establish contingency plans. These plans are vital to maintaining operations in the face of unexpected events or crises. Despite the preparation, however, the organization finds itself particularly susceptible to weather-induced disruptions due to its reliance on a single seaport.

Addressing the question of port shutdowns, the interviewee noted that the severity of such an event's impact escalates with its duration. While a day or two of closure might be manageable, shutdowns stretching over a week or longer would lead to significant logistical complications. The organization could hypothetically relocate operations to alternative

ports like Antwerp or Hamburg in severe disruptions, but this would drastically increase inland transport costs.

Despite the prevailing challenges, Interviewee 3 indicated a positive relationship with the seaport. While there might not be active collaboration, the organization ensures it stays updated with any new developments, particularly those concerning potential weather-related risks.

In a forward-looking statement, the interviewee commended they envisage further evolution and automation at seaports over the years, reminiscent of the progress observed over the past 15 years. By embracing these advancements, they hope to mitigate the impact of weather-related and other potential disruptions further, enhancing their supply chain's resilience in the process.

### Interview 4- PhD Scholars- Climate resilient Supply Chains

In an enlightening conversation, two research scholars collectively known as Interviewee 4 delved deep into the implications of climate change on supply chains, particularly highlighting the beverage industry's vulnerabilities. Additionally, they brought to light the complexities presented by intricate regulations and evolving consumer preferences in the beer industry.

The dialogue commenced with Interviewee 4 offering an extensive understanding of climate change's pervasive impact on various sectors' supply chains. They pointed out that the industries most affected are those dependent on specific climatic conditions, such as the beverage sector. In such industries, fluctuations in key ingredients' availability, cost, and quality due to climate changes can cause substantial disruptions, hindering the end product delivery.

In their groundbreaking research, Interviewee 4 revealed the development of advanced 'business rules' designed to forecast potential climate-related disruptions. This predictive strategy is vital in mitigating the damaging effects of such events. Interviewee 4 further emphasized the need for businesses to integrate climate-resilient strategies into their models, including adopting adaptive sourcing techniques, diversifying the supply base, and investing in climate-resilient agricultural practices.

Navigating the labyrinthine regulatory landscape of alcohol beverage control also emerged as a crucial theme during the conversation. As Interviewee 4 pointed out, these regulations, which can vary significantly by region, state, or country, dictate the sale, purchase, and distribution of beer. Non-compliance can lead to severe consequences, such as hefty fines and operational disruptions, underscoring the need for distributors to remain cognizant of these laws.

In terms of managing relationships, Interviewee 4 touched upon the challenges faced by wholesalers dealing with multiple breweries, each potentially offering a variety of beer

styles and brands. Here, negotiating prices, managing these relationships, and ensuring a consistent supply become critical yet challenging tasks.

The discussion also shed light on the importance of retailers, such as grocery stores, liquor stores, bars, restaurants, and online stores. As the final link in the beer supply chain before the product reaches the end consumer, retailers bear the challenge of predicting and responding to changing consumer preferences.

The interview concluded with a discussion on the necessity of collaboration and information sharing among industry stakeholders. Interviewee 4 underlined that these cooperative actions can foster the development of more resilient supply chains, highlighting a collective approach to addressing the climate change crisis.

In essence, the discussion with Interviewee 4 illuminated their comprehensive understanding of the multi-faceted challenges faced by the beverage industry's supply chain amidst climate change. Optimistically, they await sharing their valuable research findings to further contribute to the industry's resilience-building efforts.

**Interview 5 - Distribution Expert- Beverage Company**

In a detailed discourse with Participant 5, a distribution expert in the beverage industry, we gained valuable insights into the disruptive impacts of unanticipated events, such as the COVID-19 pandemic and climate change, on the beverage supply chain. More importantly, Participant 5 elaborated on the innovative strategies adopted to navigate these disruptions.

When the COVID-19 pandemic struck, Participant 5 reported an abrupt contraction in their customer base, with half of their sales coming to a standstill due to government-imposed closures. These closures primarily affected educational and entertainment outlets. In response, the company initiated a transition from a third-party logistics (3PL) model to direct selling, a move that allowed greater control over their supply chain during an uncertain period. This shift involved creating dedicated delivery teams responsible for overseeing distribution directly from the distributor to the consumer. Simultaneously, the company was quick to acknowledge and respond to changing consumer demands, pivoting from soda-centric products to alternatives like milk, juices, and bottled water.

Furthering the conversation on mitigation strategies, Participant 5 emphasized the role of 'asset productivity'. They noted that during the pandemic, several of their assets, particularly those in the education and entertainment sectors, became dormant. To circumvent this, the company reassigned these assets based on emerging market scenarios. They also capitalized on the surge in online shopping, forming alliances with online aggregators and integrating them into their newly formed distribution model.

The downstream supply chain, referring to activities transpiring after the work-in-progress phase and before reaching the end consumer, came into sharper focus during this time.

This part of the supply chain includes all procedures related to distribution, like warehousing, order fulfillment, logistics management, and transportation. The company had to strategically manage these components to counterbalance the unpredictability introduced by the pandemic.

Wholesalers, who form an integral part of the beverage supply chain, also faced unprecedented challenges. Their role involves buying in bulk quantities, storing under optimal conditions, and selling to retail outlets like supermarkets, stores, bars, and restaurants. These retailers eventually deliver the beverage to the end consumers. Participant 5's company, by moving to direct selling, was essentially navigating some tasks conventionally performed by wholesalers, thereby demonstrating adaptability under the extraordinary circumstances.

On a related note, the potential interactions between these downstream actors are essential for the smooth functioning of the supply chain. Regular meetings between different divisions, such as marketing and logistics, facilitated the understanding of evolving consumer behavior and effective management of warehouse stock. However, Participant 5 acknowledged the scope for improved communication with the production and manufacturing team to better anticipate and respond to the impact of climate change on product cycles.

Climate change and its associated extreme weather events, such as floods, droughts, and volcanic eruptions, also posed significant disruptions. However, Participant 5 elaborated on the company's proactive approach to overcoming these obstacles. The company fostered strong relationships with local communities and government agencies, ensuring deliveries to even the most inaccessible areas, employing unconventional means of transport like boats when needed.

Inter-departmental communication emerged as a significant aspect of their strategy. Regular meetings between marketing and logistics divisions enabled an understanding of evolving consumer behavior and efficient management of warehouse stock. Nonetheless, Participant 5 acknowledged that communication with the production and manufacturing team could be improved to better anticipate and respond to climate change impacts on product cycles.

Concluding the dialogue, Participant 5's insights underlined the importance of adaptability, strategic diversification, and transparent communication within the industry. Such elements are essential to bolstering the resilience of the beverage sector's supply chain in the face of ongoing climate change challenges.

## Interview Pool 2

### Interview 6- Project manager- Global engineering consultancy

Interviewee 6, a Project Manager at a global engineering consultancy, illuminated the significant influence climate change exerts on an international brewery's supply chain. Specifically, irregular weather patterns significantly disrupt the production of essential ingredients such as barley and hops and induce operational disruptions owing to severe weather events.

The pivotal risks identified by Interviewee 6 include the climate sensitivity of barley and hops and the availability of fresh, uncontaminated water, an indispensable ingredient in beer production. For instance, droughts have profound ripple effects on the brewery's operations, leading to a decrease in barley supply, an increase in commodity prices, and heightened energy consumption due to intensified irrigation requirements.

To navigate these climate-induced uncertainties, Interviewee 6 suggested several strategies. These include supporting sustainable farming practices, using drought-resistant crops, and implementing water-efficient irrigation methods. However, a key challenge is the brewing industry's heavy reliance on water. While water treatment technology exists, its underutilization—mainly due to public perception—limits its effectiveness. Currently, treated water is used mostly for auxiliary purposes rather than core brewing operations.

Demand fluctuations further complicate this landscape. Peak times can induce increased warehouse stock, production, and packing lines. Tactfully, the brewery has situated its breweries near abundant water sources and established malting cooperatives close to these breweries to minimize transport distances and buffer against potential supply disruptions.

The brewery, according to Interviewee 6, perceives this climate change-driven flux as an opportunity for transformation and innovation rather than a hindrance. There exist untapped opportunities for incorporating sustainable practices across the supply chain, deploying advanced technology for weather forecasting and crop monitoring, and innovating packaging solutions to reduce waste and carbon footprint.

He discussed the brewery's decisions to manage some parts of their supply chain in-house. Some breweries choose to malt their barley, which offers them complete control over the malting process and allows them to fine-tune the malt's characteristics to their specific needs. On the other hand, purchasing malt directly from maltsters or malting cooperatives saves breweries the time, equipment, and expertise needed to malt barley themselves. The balance between control and efficiency varies across breweries.

Interviewee 6 further elaborated on sourcing strategies. Most breweries obtain their hops by purchasing directly from growers or dealers. Local sourcing is favored by many breweries due to its dual benefits: supporting local agriculture and reducing transportation-related emissions. Large breweries or those focusing on unique beer styles may even

choose to propagate and maintain their yeast strains in-house. Additionally, many breweries source their water locally, from municipal supplies or natural sources like wells, rivers, or springs.

The importance of good supplier relationships was underlined, ensuring the timely delivery of quality raw materials. This involves coordinating the transportation and delivery of the beer from the warehouse to various outlets like retail stores, bars, restaurants, or directly to consumers. Kegging, the process of filling large quantities of beer into stainless steel kegs for pubs, restaurants, and bars, was highlighted as a popular method for larger orders.

A considerable focus was placed on maintaining quality throughout the supply chain. Once the beer is packaged, it undergoes rigorous quality control checks to ensure the product reaching consumers is of the highest standard. The distribution stage serves as a vital conduit, linking the brewery to the network of wholesalers, retailers, and eventually consumers. Regional wholesalers play a pivotal role by purchasing beer in bulk from breweries or distributors and reselling it to various retailers.

The participant also shed light on the varying nature of interaction among the supply chain actors. While breweries communicate directly and frequently with suppliers, the interactions with other actors can be indirect and occasional. Mentioning upstream actor interactions, Interviewee 6 further highlighted the role of these connections in managing the supply chain effectively.

Lastly, the interviewee touched upon some unique decisions made by the breweries due to social perception. For example, Heineken uses treated water in its manufacturing process, but only for auxiliary activities and not in the actual beer brewing. This is due to the stigma associated with using treated water in beer production, even though the water treatment technology used is certified and safe. Such decision-making intricacies indicate the complex and multifaceted nature of supply chain management within the beer industry.

### Interview 7- Supply Chain Planner- International Brewery

In an enlightening discussion, Interviewee 7, a supply chain planner at a multinational brewing company, illuminated the dynamic interplay between climate change and the company's supply chain operations. According to Interviewee 7, fluctuating weather patterns have introduced changes in the availability and quality of key ingredients such as barley and hops, critically influencing the supply-demand dynamics of the beverage industry.

The brewing process, which is heavily dependent on water availability, crop health, and cooling systems, faces significant challenges amidst a shifting climate. Risks include inconsistent agricultural yields due to unpredictable weather, water scarcity, and inflated

energy costs. Extreme weather events like heatwaves or droughts exacerbate these difficulties by driving up product demand while simultaneously straining resources due to increased cooling requirements and diminished crop quality.

To navigate these risks, Interviewee 7 underscored the critical role of climate resilience strategies. A holistic approach involving comprehensive water stewardship programs, climate-smart agricultural practices, investments in renewable energy, and advanced analytics for enhanced supply chain visibility has been adopted.

Interviewee 7 also provided an overview of the intricate network within the company's supply chain, which extends from barley and hop farmers to packaging suppliers, breweries, distributors, and finally, retailers. This complex interconnected system necessitates effective communication and coordination for the smooth functioning of the supply chain. The planner recounted instances of successful collaboration, such as farmers adopting climate-resistant barley varieties, as well as situations of unexpected demand surges leading to stockouts, which highlighted the necessity for improved demand forecasting tools.

Delving further into the supply chain operations, the interviewee outlined the importance of robust supplier relationships. Ensuring the timely delivery of quality raw materials is crucial to maintaining an efficient supply chain, necessitating a strong rapport with suppliers.

At the heart of the brewery's operations is the Midstream Supply Chain, comprising key personnel such as the Supply Chain Manager, Procurement Manager, Production Manager, Warehouse Manager, and Logistics Manager. Each member plays a critical role, and their interactions shape the overall supply chain's efficiency and effectiveness. For instance, the Supply Chain Manager oversees the overall process, the Procurement Manager ensures the timely acquisition of quality raw materials, and the Warehouse Manager is responsible for the optimal storage and retrieval of these materials. The Production Manager ensures smooth manufacturing processes, while the Logistics Manager is responsible for efficient distribution to various downstream actors.

The brewing company's Global Business Services (GBS) forms a key pillar of its organizational structure, encompassing purchasing and finance functions. The GBS plays a crucial role in consolidating and streamlining business processes to achieve operational excellence.

With an eye on sustainability, the company emphasizes recycling initiatives, notably, sourcing beer cans from recycling centers. This demonstrates a tangible commitment to reducing its environmental footprint.

After brewing and packaging, the responsibility of getting the beverages to the final consumers shifts to various distributors and retail stores. The supply chain planner outlined how these downstream actors play an essential role in bridging the gap between the brewery and the consumers.

Lastly, the interviewee shared how the company leverages advanced logistics technologies to enhance its downstream supply chain operations. Specifically, they use telematics to monitor temperature conditions and vehicle movement. This innovative approach further demonstrates the company's commitment to maintaining high quality and efficiency throughout its supply chain, even in the face of challenging climate changes.

### Interview 8- Sustainability Expert 1- International Brewery

Our anonymous interviewee who is a sustainability expert shed light on the holistic approach the brewery takes to optimize their supply chain operations and enhance their planning capabilities. A prime example of this is their Sales & Operations Planning (S&OP) CORE strategy, fine-tuned to meet local market demands. For more complex, high-volume operations, they elevate their planning game with the S&OP NEXT strategy, which integrates automation into their financial planning.

Handling warehouse operations is an integral part of the brewery's supply chain. Their Primary Warehouse Excellence Strategy is aimed at managing warehousing complexity while bolstering efficiency and safety. The brewery doesn't operate in isolation; instead, it works in close collaboration with suppliers and customers to optimize product availability and decrease stock levels.

In the conversation, the anonymous interviewee illuminated the power dynamics within the brewery's supply chain, especially regarding suppliers. Suppliers who provide distinct, high-quality, or sustainable materials can possess significant leverage, enabling them to negotiate more favorable terms with breweries. This is particularly true for breweries that aim to differentiate their products or enhance their sustainability profiles.

The discussion further highlighted that factors external to the breweries, including economic fluctuations, can have a profound impact on the beer supply chain. For instance, an economic downturn could lead to a reduced consumer demand for premium beers, prompting breweries to adjust their production schedules and raw material demand. Such circumstances can spark intense negotiations between breweries and suppliers over prices and volumes. Climate factors can also profoundly affect the beer supply chain, requiring breweries to be adaptable and resilient.

Exploring the balance of benefits and costs within the beer industry, the interviewee suggested that a more proportionate balance could be achieved through strategic initiatives. For example, implementing a reward system that equitably recognizes and compensates the contributions of each stakeholder in the supply chain could be an effective strategy.

In light of these discussions, the interviewee recommended that the beer industry adopt a more proactive approach to monitoring. This could help to anticipate and mitigate potential disruptions in the supply chain, thereby ensuring smooth operations and consistent product quality. Ultimately, the conversation underscored the brewery's holistic

approach to optimizing its operations, demonstrating its commitment to efficiency, quality, and sustainability.

### Interview 9- Sustainability Expert 2- International Brewery

In a fascinating conversation with an anonymous Sustainability Specialist from a top-tier global brewery, a multitude of strategies and initiatives designed to nurture climate-resilient supply chains were discussed. These initiatives lie at the heart of the company's unwavering dedication to sustainability.

The introduction of Life Saving Rules is a cornerstone of the company's strategy, aiming to protect life and ensure business continuity. These guidelines, enforced through rigorous compliance assessments, detailed action plans, and strict Consequence Management procedures, are designed to instill safety and prevent life-threatening incidents.

Notably, the company is investing in enhancing the efficiency of their processes and equipment. By identifying potential bottlenecks, implementing targeted improvements, and offering technical support to peers, as well as fostering supplier collaborations, the company seeks to optimize its workflow and fortify its sustainability profile.

Sourcing high-quality, locally sourced raw materials is a strategic priority, enabled by risk mitigation, local supply assessments, reshaping of specifications, and fostering stronger supplier partnerships. For example, Heineken is pioneering the use of 'bag-in-keg' technology in Vietnam to reduce both the weight and waste associated with traditional kegs.

In a bid to optimize their production capacity, the company fine-tunes their beer recipes and streamlines processes, while an innovative Brewery Capacity Model ensures effective asset utilization. Simultaneously, they are committed to reducing energy and water usage at the shop floor level, supported by a Centre of Excellence that devises detailed action plans and offers on-site support.

One such initiative is the 'Every Drop' water stewardship campaign, which emphasizes transparency in water usage. The company has committed to providing detailed, catchment area-specific breakdowns of its water usage in water-stressed regions. In addition, they actively engage with suppliers, local governments, NGOs, and communities to safeguard critical water resources.

Alongside resource conservation, the company focuses on reducing its carbon footprint. In the Netherlands, for example, they have embraced river transport for delivering beer from their Zoeterwoude brewery to the port of Rotterdam, significantly diminishing road traffic and associated carbon emissions. They are also increasing renewable energy consumption, with a goal to achieve a carbon-positive status.

The company's 'Green Fridges' program represents another significant step towards sustainability. It involved the launch of an energy-efficient fridge that consumes 45% less energy than commonly used alternatives.

There is an impressive emphasis on people development, with programs designed to reduce competency gaps and encourage sustainable performance improvement. The company has also implemented a comprehensive food safety system across all departments, reassuring consumers about the safety of their products.

Utilizing the High Performance Organisation (HPO) model to address operational challenges, the company conducts management team workshops to devise action plans steering towards its sustainability goals. Also, they have launched initiatives like the 'Brew A Better World' program for waste management and the Environmental Management System Support strategy to reduce their environmental impact.

The interview with the Sustainability Specialist also touched upon numerous other strategies, including Safety First in Logistics, Drop the C, Logistics Cost Modelling, Integrity of Raw Materials, and Customer Satisfaction Barometer.

These holistic, integrated strategies underpin the company's commitment to transforming its supply chain into a more climate-resilient model. As the Specialist emphasized, the initiatives showcased the company's firm commitment to a sustainable future.

**Interview 10- Consultant- De-carbonisation Project**

A comprehensive discussion was recently conducted with an anonymous representative from a top-tier brewery, where they delved into the intricate roadmap towards achieving net-zero emissions. This enthralling conversation traversed the convoluted landscape of emission targets, operational changes, and dealing with the multifaceted uncertainties and risks inherent in such a transformative journey.

The dialogue began with a reaffirmation of the company's allegiance to the Science Based Targets initiative (SBTi). The company has committed itself to meet the mandates of the Paris Agreement, striving to reduce CO2 emissions by an impressive 90% by 2030. The representative candidly acknowledged that aligning with SBTi's stringent criteria is no mean feat, and it requires robust, concerted efforts.

The conversation then delved into the distinctions between Scope 1, 2, and 3 emissions, representing various facets of the company's operational footprint. While Scopes 1 and 2 are concerned with the brewery's direct production processes, Scope 3 is broader, encompassing emissions from sources like transportation, use, and packaging. The objective is to minimize Scope 1 and 2 emissions by 90% and to cut Scope 3 emissions by 21%.

To attain these audacious goals, the company's strategy zeroes in on enhancing efficiency and curtailing energy consumption within Scopes 1 and 2 – primarily within the brewery. This strategy involves pinpointing areas where installations could be updated, frequently opting for electrification or bio gas, subject to feasibility.

A noteworthy point in the conversation was the company's program, "Brewing a Better World". Within this initiative, the representative spotlighted the pillar most directly

tied to mitigating heatwave effects, namely the commitment to "Drop the C" or reducing CO2 emissions. The "Drop the C" initiative is Heineken's substantial stride towards their ambitious sustainability goals, and it was discussed at length. However, the representative pointed out that the monitoring of this initiative largely hinges on suppliers' self-reporting, indicating an area that might need further attention and refinement.

Underscoring the importance of internal alignment and collaboration, the representative highlighted how their team participates extensively in this eco-friendly transition, right from the conceptual design and engineering, to the implementation and commissioning of these green modifications. Further, they ensure that the teams operating the new equipment are adequately trained.

Managing communication across various entities located globally is accomplished by the Global Net Zero Program Team. Acting as a centralized hub, it facilitates dialogues with operating companies, i.e., the breweries stationed in different countries.

The company also meticulously assesses potential environmental risks, employing a comprehensive risk management approach. This covers not just technical but also commercial, organizational, political, and environmental risks. These considerations guide their decisions, determining whether a potential impact is severe or manageable.

Challenges, both financial and technical, were discussed in depth, particularly those related to integrating green solutions into existing infrastructure. There were also references to political issues linked to the use of non-green grids, alongside organizational challenges within the company itself. Nevertheless, the company is committed to maintaining beer prices stable, believing that consumers won't pay a premium for net-zero products.

In terms of governmental regulations and incentives, the representative emphasized their substantial impact on the transition towards net-zero emissions. They referred to the European Energy Directive that encourages companies to reduce energy consumption, with the Netherlands implementing even stricter rules to curb the use of gas. The representative also brought up the influence of taxes imposed by individual Member States and the European Union.