Greening Corridors

Cross chain collaboration and sustainable development

This research aims to identify capabilities that can be used in the supply chain and protect these boundaries through collaboration.

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Nowadays, several initiatives are taken to achieve sustainable development. In this article, the capabilities of cross chain collaboration focusing on planetary boundaries and social thresholds will be explored. Despite past failures, it looks into ways for prioritizing these boundaries. This research aims to identify capabilities that can be used in the supply chain and protect these boundaries through collaboration. It outlines theoretical background, methodology, and categorizes collaboration types. Emphasizing horizontal collaboration, it delves into planetary boundaries and social thresholds, cross chain capabilities, and materiality in sustainability. Challenges like governance and data sharing are discussed, along with the necessity for government intervention. The paper concludes by stressing the multifaceted approach needed for sustainable development and the importance of cross chain collaboration in achieving it, alongside addressing associated challenges.

Introduction

In recent years, national and international institutions have introduced various measures to promote sustainable development, such as the Paris Climate Agreement, the European Green Deal, Corporate Sustainability Reporting Directive, Nederland Circulair, and various subsidy schemes to promote zero-emission vehicles. Companies have taken various initiatives to reduce emissions, such as transitioning to renewable energy sources, reducing waste, promoting reuse and recycling, and investing in electric vehicles and energy-efficient production processes, as well as contributing to the development of organizations, society and the achievement of broad prosperity. Despite these initiatives, sustainable development has not been achieved.

Sustainable development can be determined by comparing actual resource use with planetary boundaries and actual social performance with social thresholds. Planetary boundaries refer to nine critical biogeochemical and physical processes essential for the functioning of Earth's ecological system. Social thresholds are the minimum standards for a society to achieve equity, justice, and inclusivity.

In recent years (2009 – 2023), the number of planetary boundaries which have been overshot has increased, and furthermore, the degree of overshoot of these planetary boundaries has increased. The overshoot of planetary boundaries can lead to severe ecological problems, such as extreme weather and rising sea levels, and can seriously jeopardize the viability

of future generations on Earth. In recent years, although life expectancy and participation in education have increased, seven out of the eleven social thresholds are still not met (Fanning et al., 2022). Failure to meet social thresholds is already leading to increasing inequality, various tensions, and conflicts between societies, loss of human potential, and a decrease in social cohesion.

Therefore, in order to accomplish sustainable development, it is important to take action in a way which respects the planetary boundaries and social thresholds. One possible way to respect planetary boundaries is to set an emission budget per country or per sector (logistics, agriculture, industry, services, information and communications technology) (World Economic Forum, 2024). An emission budget for the logistics sector requires various supply chains to collaborate to maximize an efficient use of the budget, and, in case of an overshoot, to set priorities.

An emission budget applies not so much at the level of companies or supply chains, however, primarily at the level of multiple supply chains or 'cross chain'. Moreover, at this level, capabilities are required to safeguard planetary boundaries and social thresholds. Currently, it is unknown whether knowledge exists to support these capabilities at this level.

The aforementioned developments make it relevant to provide an overview of the current knowledge in the field of cross chain collaboration and especially to explore its capabilities to improve efficiencies and set priorities which safeguard planetary boundaries and social thresholds. Furthermore, by taking the planetary boundaries and social thresholds as a starting point for cross chain collaboration, we expect to more accurately describe how companies and supply chains can contribute to sustainable development. Finally, this paper intends to develop a research agenda for cross chain collaboration and sustainable development.

This leads to the following research questions:

1. What are the capabilities of cross chain collaboration to improve efficiencies which safeguard planetary boundaries and social thresholds?
2. What are the capabilities of cross chain collaboration to set priorities which safeguard planetary boundaries and social thresholds?

These research questions are addressed by comparing the current capabilities of cross chain collaboration regarding sustainable development with the capabilities required to safeguard planetary boundaries and social thresholds.

Capabilities can be subdivided into: processes, people, practices and technologies. This paper is structured as follows. Section 2 theoretical background focuses on cross chain

collaboration, planetary boundaries, and social thresholds. Section 3 explains the methodology. Section 4 describes the results of the literature review. Section 5 discussion. Section 6 conclusions. Section 7 opportunities for further research.

Cross chain collaboration

Supply chain collaboration refers to the partnership process of independent firms in which two or more companies work together along a supply chain to plan and execute supply chain operations to achieve common goals and mutual benefits (Chen et al., 2017; Simatupang & Sridharan, 2008). Collaboration is essentially categorized into two types: vertical collaboration and horizontal collaboration (Baratt, 2004; Rodrigues et al., 2015). While there has been a strong focus on internal and vertical collaborations with suppliers and customers, there has been a lack of attention to horizontal collaborations with competitors and other organizations (Chen et al., 2017). Horizontal collaboration refers to cooperation among independent but related firms, where organizations operate and collaborate at the same level in the supply chain, in other words, independent but related organizations, regardless of whether they are competitors or non-competitors, such as companies or business units, working together to create mutual benefits, which can involve the alignment of internal business functions in order to coordinate and integrate processes between supply chain actors to meet customer requirements. (Abideen et al., 2023; Andriolo et al., 2015; Banomyong, 2018; Bodendorf, Dentler & Frankel., 2023; Karam , Reinau & Østergaard., 2021; Simatupang & Sridharan, 2008).

To promote and facilitate horizontal collaboration in logistics, the Dutch government launched in 2010 the cross chain collaboration center program, which is a specific initiative that functions as a practical application and framework (Cruijssen. & 't Hooft,, 2020). A Cross chain collaboration center is a managerial approach to the movement of commodities, assets, and information that orchestrates multiple supply chains, coordinated and managed with the aid of the best modern technology, advanced software concepts, and top logistics professionals, in order to achieve efficiency and environmental friendly logistical solutions. (Fransoo et al., 2009; Cruijssen & 't Hooft, 2020; Van Schijndel & Braat, , 2012). A Cross chain collaboration center can be physical, virtual, or a mix of both (Dalmolen, Moonen, & van Hillegersberg ., 2015).

In terms of physical Cross chain collaboration center, "a Cross chain collaboration center as a legal entity performs supply chain management (SCM) or supply chain execution (SCE) activities, granted this responsibility by more than one legally independent partner in one or more supply chains" (De Kok, van Dalen & van Hillegersberg., 2015). In terms of virtual, or a mix of physical and virtual Cross chain control center, a Cross chain collaboration center is a control tower that takes care of the coordination of logistics activities for various shippers

and logistics service providers in order to provide a centralized, panoramic view of demand and supply-side trading network operations. (De Kok, van Dalen & van Hillegersberg, 2015; Trzuskawska-Grzesińska, 2017).

In terms of a mix of physical and virtual cross chain control center, a Cross chain collaboration center is a control tower, a centralized and dynamic platform that gathers, analyses, and displays data in real-time to monitor performance and allow the alignment of individual actions with broader strategic goals in order to facilitate decision-making at various levels (De Kok, van Dalen & van Hillegersberg, 2015; Greene & Caragher, 2015; IBM, 2023). A qualitative insight highlighted by Cruijssen & 't Hooft (2020) is that a control tower is a loose type of Cross chain control center, which can be used in order to implement Cross chain collaboration center. In fact, the Cross chain control center was launched by the Dutch government in 2010 to promote horizontal collaboration.

Planetary boundaries and social threshold

The doughnut framework represents a safe and just space for humanity to thrive, ensuring that human wellbeing and planetary wellbeing are both assured and their interdependence is respected (Ferretto et al., 2022; Raworth, 2012). A just space represents the minimum requirements for human wellbeing, encompassing dimensions such as food, water, health care, and energy, which are essential for fulfilling human rights (Bate, 2009; Ferretto et al., 2022; Raworth, 2012; Van Peborgh, 2023).

Planetary boundaries represent a scientific framework that defines the safe space for humanity on Earth, which identifies limits for human activities within the Earth system to avoid causing irreversible environmental damage and destabilizing critical natural processes (BCG Global, 2024; Steffen et al., 2015; Sureth et al., 2023). The concept of planetary boundaries presents a set of nine planetary boundaries within which humanity can continue to develop and thrive for generations to come, where six of these nine boundaries have already been transgressed (Richardson et al., 2023).

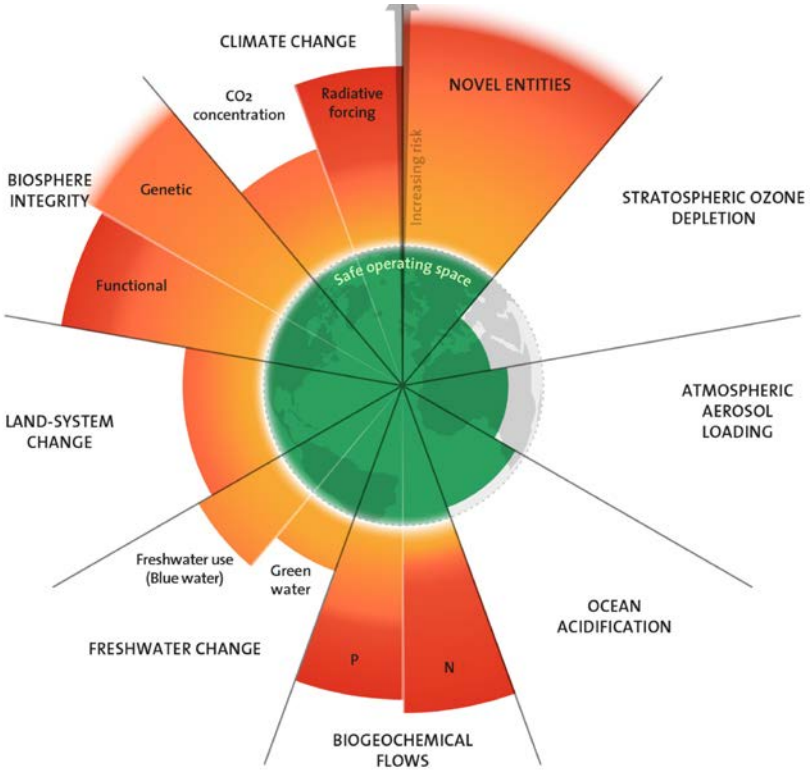

Figure 1 The planetary boundaries globally in 2023 (Richardson et al., 2023). Photo credit: Azote Images for Stockholm Resilience Centre, Stockholm University

Cross chain collaboration capabilities

One of the many ways to bridge the gap between global-scale Earth system science, local-scale social-ecological resilience, and sustainability is the application of models emphasizing horizontal as well as vertical collaboration (Häyhä et al., 2016). The implementation of a cross chain collaboration center promotes horizontal collaboration among companies (Cruijssen & 't Hooft,.2020). The cross chain collaboration capabilities are horizontal collaboration, coordination and advanced information and communications technology architecture.

Horizontal collaboration aims to develop a cooperation framework for organizations, potential cost savings, and the reduction of road traffic, emissions, and costs (Leitner et al., 2011). Horizontal logistics collaborations come in many shapes in practice and encompass various dimensions (Leitner et al., 2011).

Table 1 The process of horizontal collaboration. Adapted from : Cruijssen, 2012; Pomponi et al., 2013.

Identify partner based on: • Motives • Objectives • Competition Type of collaboration: • Intensity • Directions for consolidation	Partnering: • Collaboration • Resource management Negotiation Risk management	Contracting Execution Dispute resolution	Management and control Evaluation and process improvement

The cross chain collaboration center emphasized the importance of information and communications technology support and advanced information technology architectures to enable swift business-to-business integration, which is crucial for its successful operation. In this context, control towers emerge as a technological, organizational, and process-based solution for capturing product movement visibility (Greene & Caragher , 2015; De Kok, van Dalen & van Hillegersberg, 2015). The supply chain control tower integrates diverse technologies, people, and data across the supply chain for real-time information sharing and improved decision-making. (Deloitte, 2019; Gupta, 2022; Liotine, 2019; Patsavellas, Kaur & Salonitis, 2021; Vlachos, 2021; Vlachos, 2022). The control tower can give a centralized and holistic view of the entire supply chain, such as suppliers, manufacturers, transportation carriers, and third-party logistic vendors, in order to change the supply chain approach from reactive to proactive (Barthwal & Roy, 2020; Liotine, 2019).

Materiality

Three main concepts of materiality in sustainability are single materiality, focusing on financial implications; double materiality, accounting for both financial and environmental impacts; and triple materiality, extending to include planetary boundaries and social thresholds (Mezanotte et al., 2024; Baumüller & Sopp, 2022; Alder, 2022; THRIVE, 2023).

Single materiality: The financial impacts of the environment on businesses are multifaceted and encompass various aspects such as the state of consumption, performance, legal aspects, natural risks, and societal demands. This shapes their practices and actions. (Da Rosa et al., 2015; Ecoact, 2021). In the Netherlands, the Rijksdienst voor ondernemend Nederland (2024), for instance, sets important international Corporate Social Responsibility laws and regulations for certain companies from European regulations and directives (examples: The European directive Corporate Sustainability Directive, European Deforestation Regulation, amongst many more)

Double materiality: There are multiple advantages to the implementation of cross chain collaboration center through horizontal collaboration and a supply chain control tower:

Table 2 Literature talking about the advantages of the implementation of cross chain collaboration center through horizontal collaboration and supply chain control tower.

Authors	Leitner et al., 2011	Van Schijndel et al., 2012	Cruijssen, 2012	Pomponi et al., 2013	De Kok et al., 2015	Dalmolen et al., 2015	Deloitte, 2019	Liotine, 2019.	TKI Dinalog, 2020	Patsavellas et al., 2021	Vlachos, 2021	Gupta, 2022	Bodendorf et al., 2023
Advantages													
Better environmental impact	x	x	x	x	x	x			x				
Financial benefits	x	x	x		x	x			x	x			
Efficiency in the logistics industry	x	x	x	x	x		x		x	x			x
Better service level	x	x	x	x	x	x			x	x			
Joint innovation and networking benefits	x	x	x	x	x	x			x				x
Better risk management				x			x	x					
Supply chain control tower for enhanced visibility								x			x	x	
Improved organizational model with supply chain control towers								x		x	x	x	

Despite most of the advantages of cross chain collaboration center not directly and entirely focusing on sustainability improvements, the other advantages, which are not explicitly linked to the environment, can nonetheless lead to sustainability gains.

Efficiency significantly impacts sustainability by optimizing resource management, reducing waste production, and conserving resources. It improves financial performance by reducing costs and reducing environmental impact. Efficiency also aids in decision-making in sustainable development initiatives and enhances employee productivity, contributing to social sustainability. It plays a crucial role in the triple bottom line, impacting environmental, social, and economic dimensions (adapted from Borza, 2014; Fu & Su,2021; Mejias, Paz, & Pardo , 2016; Giménez, Sierra & Rodón,2012.). Joint innovation, networking, and partnerships promote sustainability by promoting social values, developing industrial

values, increasing productivity, creating blended finance partnerships, and fostering accountability. They also improve understanding and action on sustainability challenges, such as waste, energy, and pollution (Davies, 2002; Hartman, Hofman & Stafford, 1999; Mirvis & Worley , 2014). Risk management is crucial for sustainability, assessing future generations' impact and limiting harm (Krysiak, 2009; Lenssen, Dentchev & Roger, 2014; Nobanee et al., 2021). Visibility in supply chain management helps create a sustainable competitive advantage, business performance, and responsible sourcing. It supports sustainability risk management and fosters modular designs for flexible supply chains (Kalaiarasan et al., 2022). An improved organizational model involves refined decision-making, strategic planning, value cultivation, supply chain synchronization, and elevated management practices (Gupta, 2022; Liotine, 2019; Patsavellas, Kaur & Salonitis, 2021; Vlachos, 2021). It improves corporate social responsibility, fosters sustainability culture, and emphasizes waste reduction and participation (De Souza & Alves., 2018; Farfield, Harmon & Behson., 2011; Ketprapakorn & Kantabutra , 2022).

Studies show that supply chain collaboration has a statistically significant positive impact ($p \leq 0.10$) on the triple bottom line (Giménez, Sierra & Rodón,, 2012). The triple bottom line framework incorporates measuring the performances of the business and the success of a firm in three dimensions: economic, social, and environmental (Goel, 2010; Slaper & Hall, 2011). According to the sustainability outcomes of the capabilities of the cross chain collaboration from the preceding section, a classification of each capability relating can be drawn in regards to the triple bottom line:

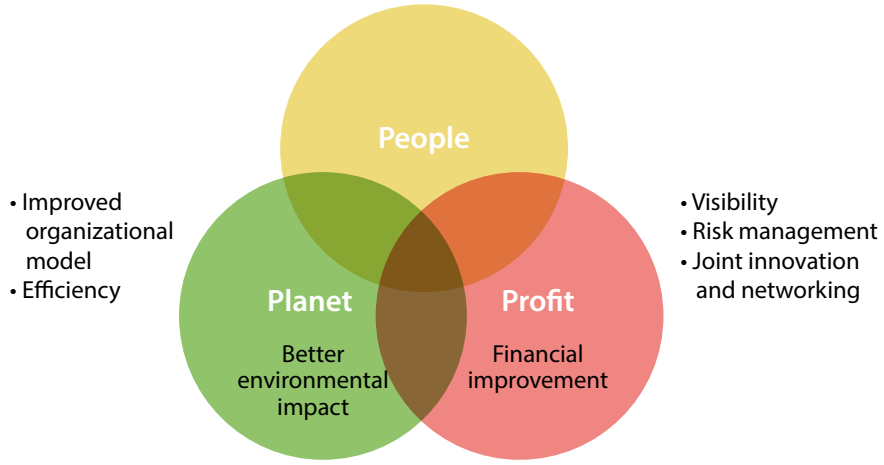

Figure 2 The cross chain collaboration capabilities

Triple materiality: Similar to the observation regarding cross chain collaboration center's impact on sustainability, a notable characteristic is the focus on solely broad sustainability benefits without their specific influence on each planetary boundary or social threshold. ECLAC (2020), divides the concept of sharing planetary boundaries in two parts: resources and pollution. It is, therefore, possible to categorize each planetary boundary based on its core impact. Consequently, the diverse effects outlined in cross chain collaboration center advantages can be categorized as follows:

Table 3 Cross chain collaboration center capabilities in relation to planetary boundaries and social thresholds

<table>
<tr><td rowspan="8">Planetary boundaries</td><td rowspan="3">Resources</td><td>Biosphere integrity</td><td rowspan="3">• Efficiency
• Joint innovation and networking benefits
• Visibility</td><td rowspan="12">Better environmental impact and risk management</td></tr>
<tr><td>Land-system change</td></tr>
<tr><td>Freshwater change</td></tr>
<tr><td rowspan="5">Pollution</td><td>Biochemical flows</td><td rowspan="5">• Joint innovation and networking benefits
• Improved organizational model</td></tr>
<tr><td>Ocean acidification</td></tr>
<tr><td>Atmospheric aerosol loading</td></tr>
<tr><td>Stratospheric depletion</td></tr>
<tr><td>Novel entities</td></tr>
<tr><td>Climate change</td><td></td></tr>
<tr><td colspan="2" rowspan="3">Social threshold</td><td>Sustainable Development Goal focused</td><td>• Joint innovation and networking</td></tr>
<tr><td>Corporate Social Responsibility focused</td><td>• Improved organizational model
• Efficiency</td></tr>
<tr><td>Responsible sourcing</td><td>• Visibility</td></tr>
</table>

Setting priorities relative to planetary boundaries and social thresholds

When addressing environmental challenges, it is often difficult for countries, regions, industries, or companies to simultaneously address the entirety of sustainability issues. In addition, certain environmental concerns may also require greater attention or urgency than others. Consequently, there arises a necessity for prioritization. Furthermore, an essential component of this process involves the establishment of a framework or methodology to equitably distribute the responsibility for mitigating environmental impacts among countries, regions, industries, or companies.

Setting priorities relative to the planetary boundaries: Sharing approaches describe different ways in which the limited amount of available emissions can be shared amongst actors, such as countries, regions, cities, businesses, and supply chains. Sharing approaches are enacted by a metric which establishes a norm for sustainability. Subsequently, this norm is compared with the actual output to determine the sustainability of an actor. Actual / Norm < 1 = Sustainable. Actual / Norm > 1 = Not sustainable. Sharing approaches can be applied stand-alone or as a mix of sharing approaches and on a single scale or across multiple scales. A scale relates to a specific planetary boundary.

Table 4 Sharing approaches and enacting metrics (adapted from Bai et al., 2024 and EAA, 2020)

Sharing approach	Description	Enacting metric	B	R
Legacy	Shares are in proportion to current or historical entitlements, ecological impacts, or environmental footprints generated by the entity (also referred to as grandfathering).	Per unit of emission	B	R
Responsibility	Shares are allocated by accounting for cumulative impacts and emissions or environmental footprints over time (that is, historical debt of individuals, nations, cities, sectors, businesses).	Per unit of cumulative emission over time	B	R
Sovereignty	Shares are in proportion to the current stocks and flows of natural capital in possession within territorial boundaries.	RR: consumption rate to regeneration rate NRR: consumption rate to adoption of sustainable alternatives rate Per Kg waste generated per time unit	B B B	R R R
Economic contribution	Shares are allocated in proportion to the current economic contribution of the country, sector, industry or company, for example, measured in contribution to gross domestic product.	Per € gross domestic product Per € revenue	 B	R
Social contribution	Shares are allocated in proportion to the current contribution of the sector, industry or company to communities and wider society, for example, measured in numbers of people employed.	Per full-time equivalent employee Per € expenditure on wages and salaries Per € taxes paid	B B B	
Resource efficiency	Shares are determined for countries (or sub-national regions) on the basis of their current resource use efficiency relative to the global average level, benefiting those with higher efficiency, or where the largest efficiency gains can be expected.	Per unit of emission per ha cropland		R

Capability	Shares are allocated by accounting for the ability of an actor to take actions based on relative capabilities as a basis, for example, through financial means.	Per € gross domestic product per capita Per € revenue per full-time equivalent employee	B	R
Basic needs and preferences	Shares are allocated such that fulfilment of human basic needs comes first, before distributing the rest of the resources to other non-basic needs.	Per capita below a certain level of income Per Food Nutrient Adequacy		R R
Equality	Shares are in proportion to population size of the country, region or city.	Per capita		R
Green incentive (merit)	Shares are allocated in a manner that incentivizes or rewards companies with low emission intensity or higher shares of renewable energy use.	Per unit of energy required per unit of activity or output Per unit of water required per unit of activity or output Per unit of GHG emissions required per unit of activity or output Per share of renewable energy use	B B B B	
Development rights	Shares are allocated by accounting for the socioeconomic context of the country, in particular, the resources required to lift people out of poverty in the future.	Per Human Development Index (1) Per Life Expectancy Index Per Education Index Per GNI index Per Gini coefficient	 B B B	R R R R R

(1) Human Development Index = Life Expectancy Index, Education Index, and GNI index
B = enacting metric applies to businesses and supply chains; R = enacting metric applies to countries, regions, and cities
RR = Renewable Resources; NRR = Non-Renewable Resource

Sharing approach relative to the social thresholds: Economies and societies should be seen as embedded parts of the biosphere. This vision is a move away from the current sectorial approach where social, economic, and ecological development are seen as separate parts. (Stockholm Resilience Center, 2016). Without societal progression and wellbeing, economic goals cannot be achieved, and vice versa, where societal goals will not be met when humanity misses its environmental goals or, more precisely, transgresses the Planetary Boundaries (Kammüller, 2021; Desing et al., 2020). Without societal progression and wellbeing, economic goals cannot be achieved, and vice versa, where societal goals will not be met when humanity misses its environmental goals or, more precisely, transgresses the Planetary Boundaries (Kammüller, 2021; Desing et al., 2020).

Considerations

- Prior to the implementation of cross chain collaboration center, it is essential to address several key requirements and challenges. The large-scale implementation of cross chain collaboration center is hindered by barriers such as governance mechanisms, data sharing, unclear business models, or the lack of proper information and communications technology support (Dalmolen, Moonen, & van Hillegersberg, 2015).

- Another consideration is the potential costs associated with forming alliances among organizations and the entrepreneurial approach that a cross chain collaboration center could assume (De Kok, van Dalen & van Hillegersberg., 2015).
- While the cross chain collaboration center model primarily emphasizes support for horizontal collaboration, it is crucial to also consider the importance of vertical collaboration (De Kok, van Dalen & van Hillegersberg., 2015; Van Schijndel & Braat, ., 2012).
- The challenges with horizontal collaborations in logistics are multifaced and require establishing and maintaining trust, mutual understanding, long-term visions, and the allocation of benefits and workload among partners. (Cruijssen, 2012; Pomponi et al., 2013).
- The objectives of the cross chain collaboration center program can only be achieved through government intervention. In fact, the government's support and sponsorship are of importance, indicating the role of government assistance in advancing the cross chain collaboration center concept and promoting collaboration within the logistics and supply-chain management sector. (De Kok, van Dalen & van Hillegersberg, 2015, Cruijssen & 't Hooft, 2020).

Conclusion

In conclusion, in this paper, we have presented the theoretical basis of cross chain collaboration and sustainable development. Sustainable development encompasses the planetary boundaries and the social boundaries by consecutively being the limits on the actions of humans on the limits of the planet Earth and meeting the needs of society. Integrating concepts like planetary boundaries and social boundaries into supply chain practices is imperative for ensuring both human and planetary wellbeing. Cross chain collaboration can play an important role in empowering horizontal collaboration.

Horizontal and vertical collaboration models can bridge the gap between global-scale Earth system science and local-scale social-ecological resilience and sustainability. Implementing a cross chain collaboration center promotes horizontal collaboration among companies, while horizontal collaboration aims to develop cooperation frameworks, cost savings, and reduce road traffic and emissions. The cross chain collaboration center also emphasizes information and communications technology support and advanced information technology architectures for successful operation, where control towers provide real-time information sharing, a centralized view of supply chain, and a proactive approach.

The environment's impact on businesses is multifaceted, influencing consumption, performance, legal aspects, natural risks, and societal demands. In the Netherlands, regulations are set from European directives. On the double materiality side, there are multiple effects of cross chain collaboration center which might not explicitly be linked to the environment but can nonetheless lead to sustainable outcomes. These outcomes can

then be categorized within the planetary boundaries and the social thresholds within the triple materiality. The prioritization of both planetary boundaries and social thresholds requires a framework to distribute responsibility, establishing sharing approaches.

The implementation of a cross chain collaboration center faces challenges such as governance mechanisms, data sharing, unclear business models, and lack of information and communications technology support. It also requires considering the costs of alliances and the entrepreneurial approach. Horizontal collaborations in logistics require trust, mutual understanding, long-term visions, and allocation of benefits and workload. Government intervention is crucial for achieving the objectives of the program and promoting collaboration within the logistics and supply chain management sector.

Alternative frameworks like cooperative game theory and carbon budget can be used to share planetary boundaries, promoting cooperation and addressing social and economic dimensions. Sustainability goes beyond environmental conservation, involving inclusive human development and a stable Earth system.

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