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Maritime Blockades, the Ukraine War, Tariff Trade Tensions, and Supply Chain Parameters as Drivers of Humanitarian Supply Chain Performance: The Mediating Role of Stochastic MILP Optimization Capability

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Abstract

Humanitarian supply chains have been facing a growing accumulation of disruption events of war conflict, maritime blockade and trade protectionism and humanitarian aid delivery cannot rely anymore on secure channels. This research aims at examining the impact of maritime blockades, Ukraine war, supply chain parameters and tariff trade tension on humanitarian supply chain performance and tests the mediation effect of stochastic MILP optimization capability. Anchored in the Dynamic Capabilities Theory, the research proposes optimization capability as the ability of humanitarian organizations in dealing with unfavorable environment. Data was collected using a quantitative cross-sectional survey from 157 humanitarian logistics, supply chain, procurement and disaster relief professionals of Finland, Sweden, Norway and Estonia using purposive sampling method and analyzed by IBM SPSS 27 and SmartPLS 4.1 version with PLS-SEM. The proposed measurement model achieved construct's validity with regard to internal consistency reliability and convergent validity with a total of six measurement constructs and thirty-seven indicators. Structural findings revealed that maritime blockades, Ukraine war, supply chain parameters, and tariff trade tension have significant impact on stochastic MILP optimization capability and humanitarian supply chain performance, and also confirm its mediation role between them. From theoretical perspectives, the study contributes to Dynamic Capability Theory by defining stochastic optimization as one particular reconfiguring capability at the forefront of the business model disruption process. Regarding practical perspectives, the finding recommends humanitarian agencies to use optimization tools, forecast in scenarios, conduct trainings for the staff, and employ quantitative support tools to assist decision-making. It is recommended in the discussion to address limitations based on the cross-sectional design, use of a non-random sample, relying on self-reports and exploring only four external influences. It also suggests, for future studies, to employ large and longitudinal sample, study further countries and disruption sources, explore alternatives like AI-based methods to improve efficiency or look for alternative solutions for dynamic modeling optimization.

Keywords: Humanitarian Supply Chain, Ukraine War, Maritime Blockade, Stochastic Milp, Tariff Trade Tension, Dynamic Capabilities

Introduction

Background of the Study

Humanitarian supply chains focus on delivering critical supplies, including medicine, food, shelter material to populations affected by disasters. The success of these networks is mainly measured in speed, reliability, accessibility, and service continuity under much harsher conditions than would generally be found within a typical commercial supply chain network. The recent three years (2022-2024) have seen substantial evolution of this operating environment in Europe thanks to three coupled and intertwined disruption sources: maritime shipping blockades, the extensive war in Ukraine and, and renewed tariff-based trade protectionism. Although these disruption sources have existed and impacted supply networks throughout history as standalone forces, their concurrence has created a much more complex and unpredictable operating environment, leading to increased emphasis on sophisticated quantitative decision-support capabilities within humanitarian logistics.

Maritime blockades and targeting of key maritime routes such as the maritime traffic disrupted within the Red Sea and Suez Canal in the recent period since late 2023 has contributed to a high percentage of the maritime transportation networks connecting Asia and Europe being re-routed around the Cape of Good Hope. This longer route, more transit time and increased freight costs in a context of decreasing shipping capacity- with capacity shortages of 15-20 percent recorded during times of high crisis levels (Maersk, 2024). The united nations conference on trade and development has indicated similar levels of stress upon major maritime chokepoints, such as the Suez Canal, and warn of impacts on a higher price of consumer goods globally and a detrimental effect upon states largely reliant on importing.

Morgan (2024) report estimated potential increases to global core goods inflation at measured percentage point increases per year, with the Atlas Institute for International Affairs (2025) concluding broader consequences for automotive, electronics, and agricultural supply chains that are reliant on long distance global transport. Separately, the Ukraine War has greatly impacted logistics corridors, access to terminals, logistics infrastructure and cross-border logistics processes both northwards and eastwards across Eastern and Northern Europe. Krykavskyy, Chornopyska, Dovhun, Hayvanovych and Leonova (2023) showed the ways that exporters within Ukraine, and traders importing from it, have been forced to question what supply chain resilience means in an active warzone and how can such an entity achieve it, whereas Kumar and Kumar (2023) noted how it exacerbated the vulnerabilities and challenges that were highlighted due to the disruptions stemming from the Covid-19 pandemic. Furthermore, Jagtap et al. (2022) documented profound disruption to production and export activities and agriculture within Ukraine. And Mishra, Sharma, and Khound (2025) emphasize the collateral impact not only upon those closer to the conflict region such as the Scandinavian states within the proximity of the North/Baltic Sea economic peripheries, but on food supply systems across Europe.

Finally, a resurgence in tariff-based trade protectionism adds another layer of uncertainty within the international supply network. Miller and Jin (2025) described a framework of analysis within which a firm can organize the tariff adjustment costs (transaction and opportunity costs) in the context of policy uncertainty. Complementary findings from the Thomson Reuters Institute (2025) and supply chain brain (2025) identify changing commodity prices, and revised global purchasing patterns as tariffs impact upon sourcing and global supplier networks. Such effects, whereas humanitarian organizations typically do not operate for profit, will surely impact those concerned due to its reliance on global supply chain networks for the sourcing and shipping of urgent supplies.

As the operating environment evolves and becomes increasingly complex and volatile across all fronts described, advanced optimization techniques-specifically stochastic mixed-integer linear programming (MILP)-offer a quantitative, systematic means for humanitarian organizations to assess scenario options and select optimal responses, identify acceptable transport routes and suppliers and allocate limited resources both proactively and reactively under uncertain demand and network conditions. Stochastic MILP formulations are already widely utilized in humanitarian logistics such as location-allocation for relief provision to populations, inventory pre-positioning strategies, response under demand variation and other types of network modelling (Balcik and Beamon, 2008; Ghasemi, Goodarzian, & Abraham, 2022; Heng, Phutthanawong, & Boonmee, 2025). Advances are in the realm of machine learning which enable more dynamic and probabilistic modelling (Jin, 2025).

Therefore, this research investigates the impact of maritime blockades, Ukraine war, supply chain parameters and tariff trade tensions upon the humanitarian supply chain performance under the mediation effect of Stochastic MILP optimization capability within 4 Nordic and Baltic countries: Norway, Sweden, Finland and Estonia. The particular reason for focusing on this region is the fact that they lie within the immediate proximity of Ukraine, being both logistically vulnerable and subject to changes affecting the North and Baltic Sea maritime networks. By assessing the direct impacts of each source of disruption on the humanitarian supply chain performance along with mediating stochastic MILP optimization capability, this research provides a holistic understanding of how to strengthen performance and decision-making capabilities under an environment of persistent disruption.

Research Problem

Increasing geopolitical conflict, maritime restriction, tariff tension and normal constraint like variability in demand and deficiency of resources lead to increasing uncertainty and threaten humanitarian supply chain performance by degrading transport dependability and cargo delivering timeliness and even the humanitarian supply chains performance (Stumpf, Besiou & Wakolbinger, 2023). Though optimization approaches like stochastic MILP can facilitate the decision-making under uncertainty, there have been few empirical works, especially survey studies testing how to determine the linkage from major geopolitical and supply chain disruption to humanitarian supply chain performance through the mediating mechanism of Stochastic MILP Optimization Capability in general especially within European area which has simultaneously been influence by war, maritime restriction and tariff tension. This research aims to investigate whether and how stochastic MILP optimization capability mediates the link between geopolitical disruption (war, maritime restriction, tariff tension), other supply chain disruptions, and humanitarian supply chain performance across four European countries, i.e., Finland, Sweden, Norway and Estonia.

Research Gap

A body of researches exist in humanitarian logistics, geopolitical risk, and optimization, but they remain independent literatures largely. Dynamic capability in humanitarian organizations has studied mostly from perspectives different to evaluating specific quantitative optimization capability as mediators (Son, Roscoe, & Sodhi, 2025; Srivastava & Bag, 2025). Stochastic MILP research usually only focus on technical issues rather than structural analysis through survey modeling (Ghasemi et al., 2022; Heng, Phutthanawong & Boonmee, 2025). Ukraine War, maritime bloc, and tariff tension research are mainly focus on sector and macroeconomics rather than organizations (Krykavskyy, Chornopyska, Dovhun, Hayvanovych & Leonova, 2023; UNCTAD, 2024; Miller & Jin, 2025). An integrated framework in connection with those four dimensions of disruptive factors and one mediating capability is not published, testing in an empiric way with survey data collected from practitioners in four European countries is required. Specifically, the mediating effect of stochastic MILP optimization capability must be addressed further in the European humanitarian supply chains to address this research gap.

Research Questions and Objectives

RQ1: What is the impact of maritime blockades on stochastic MILP optimization capability? **RQ2:** What is the impact of the Ukraine war on stochastic MILP optimization capability?

RQ3: What is the impact of supply chain parameters on stochastic MILP optimization capability?

RQ4: What is the impact of tariff trade tensions on stochastic MILP optimization capability?

RQ5: What is the impact of stochastic MILP optimization capability on humanitarian supply chain performance?

RQ6: Does stochastic MILP optimization capability mediate the relationships between maritime blockades, Ukraine war, supply chain parameters, tariff trade tensions and humanitarian supply chain performance?

Research Objectives

RO1: To examine the impact of maritime blockades on stochastic MILP optimization capability.

RO2: To analyze the impact of Ukraine war on stochastic MILP optimization capability.

RO3: To identify the impact of supply chain parameters on stochastic MILP optimization capability.

RO4: To analyze the impact of tariff trade tensions on stochastic MILP optimization capability.

RO5: To identify the impact of stochastic MILP optimization capability on humanitarian supply chain performance.

RO6: To examine the mediating role of Stochastic MILP Optimization Capability in the relationships between Maritime Blockades, the Ukraine War, Supply Chain Parameters, Tariff Trade Tensions, and Humanitarian Supply Chain Performance.

Significance of the Study

The study makes three primary contributions. Academically, it connects the dynamic capability theory and a tangible and a technically defined capability-stochastic MILP optimization, instead of abstract one, and using primary survey evidence instead of abstract analytic modeling or simulation-based analysis. Practically, it will enable humanitarian organizations in Finland, Sweden, Norway, and Estonia by providing evidence on how significantly disruption types affect the decision making with optimization, which will contribute to investments in planning technologies, staff training, and analytical capacity. Contextually, it is one of the first to evaluate humanitarian supply chain performance with combined pressure from maritime blockade, Ukraine war and trade tariff tension with only one Scandinavian sample in particular, where humanitarian logistics' simultaneous impact from three such disruptions was only scarcely addressed through academic research methods.

Literature Review

Theoretical Foundation: Dynamic Capabilities Theory

The study is theoretically framed within the dynamic capabilities perspective. Dynamic Capabilities theory emphasizes the role of a firm's ability to integrate, reconfigure and renew its external and internal competencies to meet the demands of rapid changing environment as a mechanism to sustained competitive performance in dynamic environments (Teece, Pisano & Shuen, 1997). In this view, while the resource-based view explains why an organization's resources as having valuable, inimitable, rare and non-substitutable characteristics create competitive advantages (Barney, 1991), dynamic capabilities explains how they recognize emerging opportunities, seize appropriate choices with timing and resource efficiency and reconfigure resources, routines and processes to maintain pace with the environmental change.

This concept helps in the present study since maritime blockades, Ukraine war, supply chain parameters, and tariff trade tensions represent dynamics of external environmental forces not organization's resources. Stochastic MILP optimization capability, on the other hand, may be conceived as an organizational capability which facilitates humanitarian organization's dynamic capability of sensing a disruption and seizing opportunity and reconfiguration of resources and operation of humanitarian supply chain to the maintain or improve performance.

The research applying the theory of dynamic capabilities in humanitarian operations have recently received much attention. Using specific sets of capabilities for global and local humanitarian organizations' performance in dealing with emergency response and development aid needs respectively, Son, Roscoe & Sodhi (2025) found significant difference in dimensions of capabilities among two distinct humanitarian organizations. In another relevant research study, digital-twin-enabled capabilities were utilized to strengthen humanitarian supply chain resilience against various disruptions in terms of detect disruptions and reconfigure operational processes by Srivastava and Bag (2025). Similar application is seen from Singh (2024) where technological capability helps humanitarian supply chain performance both directly and indirectly via mediation effects of agility and cooperation to uphold in crisis, suggesting the underpinning idea that both internal capability and external disturbance have a relationship. The study supports the underlying assumptions for present research: while external disturbance raises a certain requirement for capability to facilitate effective adaptation; the capability that evolves from response process subsequently ensures better performance.

Through the prism of these dynamic capabilities, stochastic MILP optimization capability can be regarded as quantitatively-minded and technical tool for translating this organizational reconfiguration capabilities into real tangible solutions for the humanitarian organizations by enabling exploration of uncertain variables and allocation of scarce resources, reconsideration of configuration of operational processes, as well as identification of alternative plans for responding the disrupted environment. This conception of organizational capability is in parallel with Khan, Sheikh, Shamsi & Yu (2025) on leveraging analytics- and technology-enabled capabilities for strengthening supply chain resilience under various pressures such as geopolitical and technology, as thus, dynamic capabilities theories provided a solid theoretical grounding to analyze stochastic MILP optimization capability as the mediation effects in explaining the relationship between external disturbance factors and humanitarian supply chain performance.

Humanitarian Supply Chain Performance

Humanitarian supply chain performance (HSCP) the performance dimension reflecting how effectively humanitarian organizations can deliver indispensable relief commodities on time, minimize stock outs, reroute delivery under disruptions and continue operation during major shocks Christopher and Tatham (2014) define the conceptualization of humanitarian logistics performance around both cost and lead-time considerations in highly uncertain environments. The nature of humanitarian logistics is therefore distinctly different from traditional commercial logistics; it is about responding to extreme urgent and often unforeseen needs rather than stable demand, reliable forecasts, and stable availability of infrastructure. Certainly, Stumpf, Besiou and Wakolbinger (2023) find that it is largely determined by the current operations context, disaster related

characteristics, and the specific type of products being delivered. They further suggest that the capacity to constantly update planning and operating decisions might therefore be more important than selecting a single optimal logistics setup.
Similarly, Sodhi and Knuckles (2021) argue for a performance evaluation of humanitarian and development aid supply chains that is not focused solely on cost efficiency, but instead looks at their ability to sustain delivery of vital goods during periods of economic and political turmoil. This argument is entirely in line with the presented approach to study HSCP which comprises five operational dimensions: timeliness, minimization of shortage, rerouting, delivery, and effectiveness during major disruptions, representing a higher order performance construct. Humanitarian supply chain performance is thus influenced also by constraints that go beyond the direct execution of logistical transport and distribution. Indeed, Abikova (2025) finds that the motivation and job satisfaction of humanitarian logisticians contributes to both operational continuity and decision quality of the humanitarian logistical organization. Furthermore, Owusu-Bio, Barima, Appiah and Marfo (2026) find that organizational innovation, the novelty of an innovation, can increase humanitarian organizational performance up to certain points. Yet, the organizational performance effects of an innovation depend on complementary conditions, such as innovation intensity and external communication. New organizational capabilities are therefore not to be treated as automatic and unconditional outcomes.
Overall, these and numerous other studies suggest that HSCP is a multidimensional and multivariate outcome influenced by finance and funding; infrastructure and facility configurations; and human resource factors, organizational capabilities including innovations, and the capacity to cope with disruptions. Therefore, the specification of HSCP as a broader second-order construct appears to be a more appropriate formulation of humanitarian logistics performance than considering single operational variables in isolation. This also holds true in the present context of study because of the significant challenges posed by maritime disruptions, geopolitical conflicts, logistical constraints as well as tariffs and uncertainty about trade policies, all of which affect and limit humanitarian organizations' potential to effectively implement.

Maritime Blockade and Stochastic MILP Optimization Capability

A maritime blockade or an interruption along critical shipping lanes would cause considerable constraint to accessibility of ports and maritime lines, disruption to planned cargo shipment, while also incurring significant costs and increasing transportation time due to rerouting (Zarotiadou et al, 2023). Moreover, UNCTAD (2024) reports that at the beginning of 2024 simultaneous pressures on multiple critical maritime choke points of the globe (Panama Canal, Red Sea, and Black Sea) have already incurred consequences on consumer prices worldwide and economy interconnections of import dependent states. Morgan (2024) has shown how the Cape of Good Hope alternative route is the dominant driver for rise in global goods inflation since disruption to major maritime routes like Red Sea is estimated to have reduced approximately fifteen to twenty percent of available maritime capacity, while transit times prolong and remain precarious for Maritime operators (Maersk, 2024). In other applications the dependency on time-criticality have shown also implications to manufacturing production activities reliant on the principle of Just-In-Time supply management of products (The Atlas Institute for International Affairs, 2025).
These circumstances are of critical importance for Humanitarian aid organizations because humanitarian logistics services are predominantly relying on and utilizing these very similar Commercial transportation and logistics structures, channels, infrastructures and networks of transportation. Similarly, restricting maritime resources to humanitarian logistics providers due to possible consequences could lead to decreasing reliability, and complicated logistics decision making at operational level; which could ultimately diminish capacity of utilizing alternate strategies, managing valuable resources at difficult levels, and make transportation choices at the expense of time and resources. This is where stochastic MILP optimization could offer a solution since it seeks the solution to complex decisions under uncertainty with an optimization of alternatives that will allow better logistical arrangements under various potential conditions (Ghasemi et al., 2022). This kind of solution could further assist humanitarian actors in terms of strategic perspective and adaptation given the dynamic capabilities perspective as "humanitarian logistics ability to adapt is reinforced if humanitarian organizations can anticipate the development of disruptions, assess alternative options for managing these disruptions in terms of available transportation means and other resources, and reassign transport tasks accordingly" (Ghasemi et al., 2022).
Therefore, an increased exposure to maritime blockade-related disruption is hypothesized to increase the reliance on the stochastic MILP optimization capability within humanitarian supply chain design. It is hypothesized that:
H1: Maritime Blockades have a significant effect on stochastic MILP optimization capability.

The Ukraine War and Stochastic MILP Optimization Capability

The Ukraine War has been a major disruptor of the logistics ecosystem through the disruption of transport infrastructure, changes in long-haul freight routes, restrictions on access to the Ukrainian black sea ports and a pervading climate of uncertainty. As stated by Krykavskyy, Nesterovych, Ryabchenko and Yevtushenkov (2023), under conditions of the conflict, the conceptualization of supply-chain-resilience should pivot away from a focus on efficiency alone towards an emphasis on flexibility, rapid re-organization, and adaptability. In a similar analysis of supply-chain vulnerability, Kumar and Kumar (2023) provide evidence for how the Ukraine war has exacerbated, the supply chain vulnerabilities that were already highlighted during the Covid19 pandemic by the need to both increase buffer stocks and adopt strategies to enable greater transport and route diversification. The humanitarian implications for agricultural export markets have been substantial documented extensive supply chain disruption for agricultural exports from Ukraine post-invasion (Jagtap et al., 2022), which would have the effect of threatening the food security of potentially large regions and affecting humanitarian responses at both local and global levels.
Mishra, Sharma and Khound (2025) further elaborate on the impact of the Ukraine war on wider European supply chains. Their research highlights how the conflict has a considerable geographical reach beyond the conflict itself and includes impact on broader European transport networks and energy systems. These further-field interactions include those serving supply systems that connect with the Nordic and Baltic states, the interconnected nature of which adds significant complexity to humanitarian logistics planning due to increased uncertainty about infrastructure availability, transportation routes, the accessibility of necessary resources and the assurance of ongoing movement of necessary supplies. In this environment, humanitarian actors, operating in and in close proximity to the affected zone, will require access to advanced computational decision-support tools to prepare them to meet alternative potential scenario, identify and assess their alternative logistics solutions and to adapt their current resources when certain supply links are no longer available. stochastic MILP optimization capability specifically addresses this in its ability to support the modeling of uncertainty into a logistics scenario and provide the means to rationally compare and evaluate different configurations and re-distributions of logistics resources under various adverse scenarios, based on the logic of Dynamic Capabilities Theory which helps enable organizations to develop the capacity to quickly sense changes in their environment, develop appropriate responses and reconfigure the firm's internal resources. As such, due to the high and ongoing uncertainty caused by the Ukraine War, we expect to observe an increase in the usage and desirability of stochastic MILP optimization capability for humanitarian supply chains. Hence, it is posited that:
H2: The Ukraine War has a significant effect on stochastic MILP optimization capability.

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Supply Chain Parameters and Stochastic MILP Optimization Capability

Aside from these geopolitical considerations, humanitarian supply chains are also affected by a series of operational parameters such as transportation capacity, availability of supplies, demand uncertainty, the variance in lead times for replenishment and the number of available resources. The combination of these parameters impacts the viability and robustness of decisions in humanitarian logistics and requires systematic management, particularly when it comes to humanitarian relief supply chain planning. In the face of such disruptions, for example, Aghajani, Torabi, and Altay (2023) find that resilient humanitarian relief planning involves combined procurement and storage decisions, while supply chain planning under uncertainty. Such an integration of supply chain functions in decision making entails the necessity for an optimisation modelling capacity that can simultaneously accommodate both factors together, rather than independently.

Moreover, Acar and Kaya (2023) show that static decisions relating to inventory management of humanitarian materials must involve taking both the budget into account as well as the demand level. Such simultaneous consideration reinforces the role of stochastic optimization for managing humanitarian relief supply chains, as it involves modelling various sources of uncertainties as well as trade-offs between various scarce resources. Supply planning for NGOs, governments and international organizations. Furthermore, supply chains in the humanitarian sector do have on an on-going and unavoidable way constant shortages and bottlenecks as it continues to be common practice to model such operational conditions as null conditions (Sodhi & Knuckles, 2021). Therefore, transportation capacity, inventory levels, demand uncertainty, variation in lead times and resource limitations are a separate and non-geopolitical class of operational uncertainty.

The interaction between those different factors creates higher order complexity for humanitarian logistics planning decisions making thus enhancing the practicality requirement to decision- making support technologies that address how best to deal with alternative decisions under uncertain environments. This is precisely what stochastic MILP optimization capability offers, as it can handle these multiple parameters, so the following hypothesis is formulated:

H3: Supply Chain Parameters have a significant effect on stochastic MILP optimization capability.

Tariff Trade Tension and Stochastic MILP Optimization Capability

The rise of tariff trade tensions may result in higher procurement and transportation costs, greater complexity in cross-border sourcing setups and sharp fluctuations in the relative cost and availability of alternative sources. Miller and Jin (2025) posit that organizations hit by tariff-induced shocks simultaneously struggle with adjustment costs, transaction costs, and opportunity costs and that the magnitude and frequency of recent tariff implementations has triggered uncertainties that go beyond those stemming from many previous disputes. These uncertainties may make ordinary sourcing choices increasingly complicated, especially when decision-makers are trying to weigh costs, availability, lead times, and supplier reliability for various markets simultaneously. According to the Thomson Reuters Institute (2025), the threat of supply chain disruptions from unpredictable tariffs has become a paramount issue to a growing share of trade professionals.

In fact, according to a recent study by supply chain brain (2025), the use of strategies like nearshoring, diversification of supplier base or enhanced planning using scenario simulations are some of the measures undertaken by organizations to deal with uncertain tariff regimes. Both indicate the value of having some of analytical means to analyze alternative sourcing setups and to predict what would happen in case of sudden trade policy alterations. Although humanitarian organizations are typically not for-profit, organizations that trade goods; e.g., relief consignments, trucks, medical instruments, equipment and the like; often rely on overseas partners and international supply routes. These factors make humanitarian logistics prone to the exact same tariff policies/regimes and changes that affect commercial networks. In this light, higher volatility of tariff trade policies will mean higher uncertainty concerning the prices to pay for procured goods, supplier choice, routes used and the availability of goods and services.

Stochastic MILP optimization capability can therefore prove very useful in assessing various sourcing and routing scenarios under tariff uncertainty and other conflicting considerations. In terms of Dynamic Capabilities Theory, a system where alternative sourcing and logistics schemes can be evaluated would allow organizations in humanitarian supply chain management to react to unforeseen conditions of trade and revise sourcing and allocation choices. Hence it is anticipated that higher tariff trade tension would elevate the role of stochastic MILP optimization capability for the evaluation of humanitarian supply chain strategy choices; Therefore, the following hypothesis has been formulated:

H4: Tariff Trade Tensions have a significant effect on stochastic MILP optimization capability.

Stochastic MILP Optimization Capability and Humanitarian Supply Chain Performance

Stochastic MILP optimization capability refers to the ability of a firm to form, implement, and use stochastic mixed-integer linear programming (MILP) models for supporting transportation, facility location, routing, resource allocation, and supply chain network design decisions in the presence of uncertainty. Stochastic MILP capability allows humanitarian organizations to systematic analyze many possible operating modes, handle uncertainty in supply and demand, and obtain feasible decisions that satisfy numerous logistics constraints. According to Balcik and Beamon's (2008) work on facility location decisions for humanitarian operations that illustrated the ability of formalized optimization approaches to perform better in terms of response time and coverage than traditional manual planning methods, several researchers have further built upon this logic by accounting for richer uncertainty in the humanitarian logistics decision-making process.

Similarly, the underlying concept is used in the context of the designing of humanitarian disaster response using a multi-objective stochastic programming model presented in Ghasemi et al. (2022). Moreover, in an emergency situation, two-stage stochastic programming model has been developed for handling the joint facility location, inventory, and evacuations decisions under the scenarios where disruptions are uncertain and showed improvements regarding response time and resource allocation efficiency presented in Heng et al. (2025). Furthermore, Jin (2025) reveals that stochastic optimization with reinforcement learning has increased the efficiency and equity of resource allocation of the humanitarian supply chains. In summary, with a higher degree of stochastic MILP optimization capability, an organization will have greater capability in resource allocation, transportation planning, facility location, inventory positioning, and network routing decision-making under volatile and dynamic environment in general, and will be more able to reduce delay and shortage of supplies, reconfigure the routes in time, manage cargo flow, and improve performance during disruption in specific terms for the Humanitarian Supply Chains. From the perspective of the Dynamic Capabilities Theory, stochastic MILP optimization capability thus can be characterized as a type of internal restructuring capability that allows a firm to convert negative changes in the environment into opportunity or mitigation by appropriate resource orchestration. Thus, a higher stochastic MILP optimization capability is expected to have a significant impact on the Humanitarian supply chain performance. Thus, following hypothesis is formulated:

H5: Stochastic MILP optimization capability has a significant effect on humanitarian supply Chain performance.

The Mediating Role of Stochastic MILP Optimization Capability

Aligning with DCT, this study posits that Stochastic MILP Optimization Capability is not only a capability that is associated with disruption and performance, but also a forward-looking enabling mechanism by which externally induced disruptions affects humanitarian supply chain performance. The underlying logic is that engagement in turbulent environment heightened the perceivable and practical use of optimization in decision-making processes. Then Humanitarian organizations will adapt to such environment by strengthening the capability of using stochastic optimization to analyze options, deploy constrained resources and reorganize logistical operations, hence leading to an optimization capability, rather than the disruption itself, in translating environmental turbulence into outcome improvement.

Such theoretical explanation is consistent with previous findings regarding the capability-based mediation mechanisms in humanitarian supply chains. Results from Singh (2024) demonstrate that the mediation role of technological capability of investment in digital and humanitarian supply chain performance support the organizational capability-based view to be the underlying mechanism which transfer the result of technological resources toward performances. Furthermore, based on the Srivastava and Bag (2025)'s findings demonstrate that digital-twin capability mediates the relationship from disruption exposure and resilience outcome, support the organizational capability-based view as having transformation role in translating external disorder stimuli toward organizational performances. Therefore, with such thinking logic, this study positions stochastic MILP optimization capability as the analytically and decision-support mechanism through which humanitarian organizations are driven by maritime blockades, the Ukraine war, supply chain parameters and tariff trade tensions.

The below mediation hypotheses are then proposed based on the relationships from H1-H5:

H6: Stochastic MILP optimization capability significantly mediates the relationship between maritime blockades and humanitarian supply chain performance.

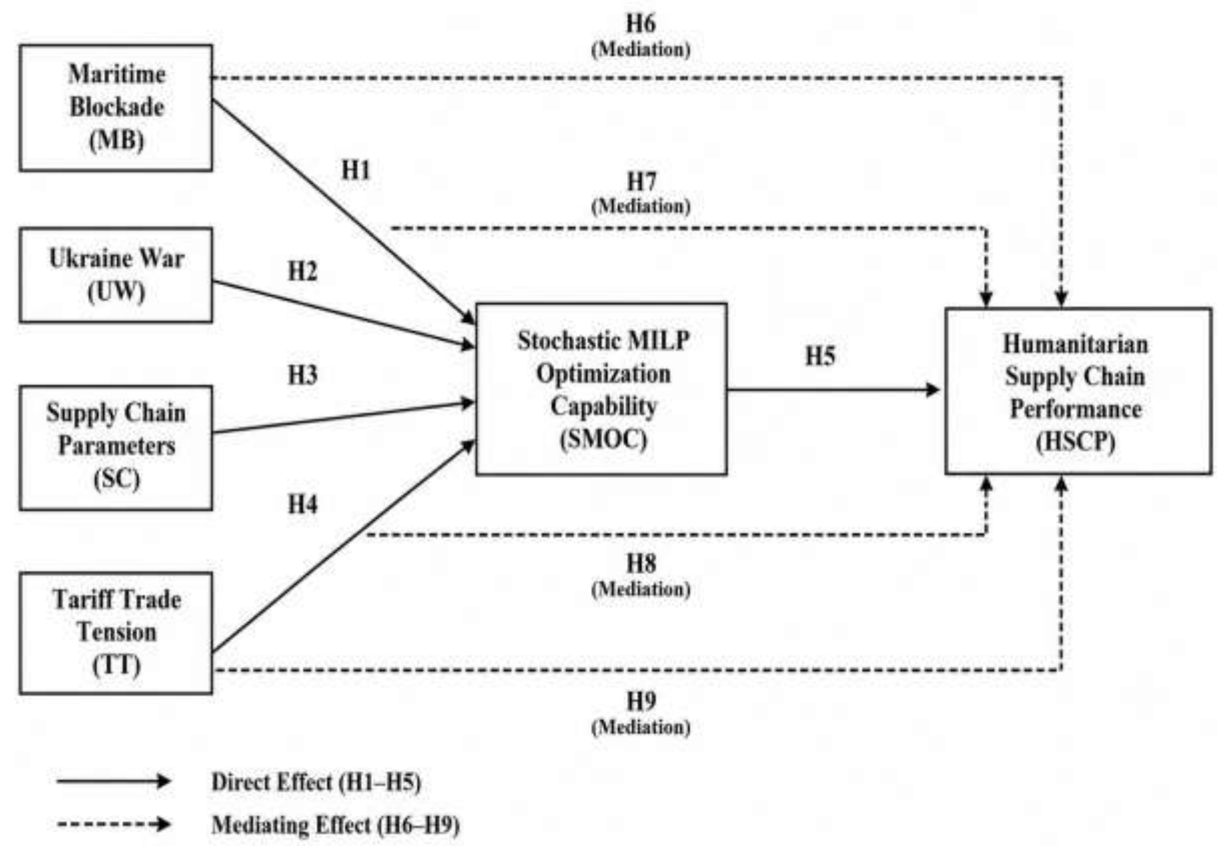
H7: Stochastic MILP optimization capability significantly mediates the relationship between the Ukraine war and humanitarian supply chain performance.

H8: Stochastic MILP optimization capability significantly mediates the relationship between supply chain parameters and humanitarian supply chain performance.

H9: Stochastic MILP optimization capability significantly mediates the relationship between tariff trade tensions and humanitarian supply chain performance.

Conceptual Framework

Figure 2.1



1.1

Methodology

Procedure

This study was quantitative in nature with a cross-sectional design and conducted using the deductive approach. A structured questionnaire was developed using the constructs and existing literature relevant to the current research. Before commencing data collection, three academic experts relevant in the field of supply chain management, humanitarian logistics, and research methodology were requested to review the questionnaire to ensure the quality, clarity, relevance and wording of the items and these suggestions were incorporated into the questionnaire for pilot test (Hair et al., 2022; Saunders et al., 2012). Participants were fully briefed on the purpose of the study and assured of anonymity and confidentiality; informed and explicit consent was taken before proceeding to fill out the online survey which aimed at maritime blockade, Ukraine war, supply chain parameters, tariff trade tensions, stochastic MILP optimization capability, and humanitarian supply chain performance.

Measures and Data Analysis Techniques

For this study, a 5-point Likert-scale (1 = Strongly Disagree, 5 = Strongly Agree) was employed to measure each construct (e.g., item) of the questionnaire, where constructs comprised of total 37 reflective items distributed among six constructs: Maritime Blockade (7 items); Ukraine War (6 items); Supply Chain Parameters (5 items); Tariff Trade Tension (6 items); Stochastic MILP Optimization Capability (8 items); and Humanitarian Supply Chain Performance (5 items). IBM SPSS Statistics 27 was used for data

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cleaning, descriptive statistics, demographic analysis and preliminary reliability check, followed by SmartPLS 4.1 software for PLS-SEM analysis (Hair et al., 2022; Becker et al., 2023). Measurement model was verified using indicator loadings, composite reliability, AVE, HTMT, Fornell-Larcker criterion and VIF. Structural model was tested using path coefficients, t values, p values. A 5,000-resample bootstrapping method was run to test direct and mediation paths (Hair et al., 2022; Hair et al., 2024).

Sampling Strategy and Unit of Analysis

The study population was comprised of professionals working in humanitarian supply chain management, transport, logistics, procurement, emergency logistic, disasters life operations, NGOs operations, and freight and cargo operations executed in Finland, Sweden, Norway and Estonia. The purposive sampling technique was adopted to target a knowledgeable sample group of a population who meet specific requirements. The collected sample comprised 157 valid responses, which were considered sufficient for the intended PLS-SEM model (Hair et al., 2022; Sarstedt et al., 2022).

Data Analysis

Demographic Profile of Respondents

After the incomplete and invalid survey responses were discarded, 157 responses were retained for this study's analysis and 6 exogenous factors were loaded onto the six initial structural equations which included maritime blockade (MB), Ukraine war (UW), supply chain parameters (SC), tariff trade tension (TT), stochastic MILP optimization capability (SMOC), and humanitarian supply chain performance (HSCP). These experts are from Finland, Sweden, Norway, and Estonia these currently work in the field of humanitarian logistics and supply chain management, transportation and logistics, procurement, emergency logistics and disaster response, NGOs, humanitarian operations, freight and cargo business. The most frequent age of professional participants was between 40–55 (68%) years of age and has professional years of experience of 10–20 years of experience (71%) indicating most of the research sample were skilled professional with strong expertise in humanitarian and supply chain operations. The demographic characteristics of the sample provided sufficient professional diversity as it comprises of respondents' from variety of functional roles from supply chain management (56%), humanitarian/NGO (32%), disaster management (6%), emergency logistics (6%), transportation and logistics (6%).

Table 4.1 Demographic Profile of Respondents

Variable	Category	Frequency	Percentage (%)
Country	Finland	48	30.6%
	Sweden	40	25.5%
	Norway	36	22.9%
	Estonia	33	21.0%
Gender	Male	101	64.3%
	Female	56	35.7%
Age	Below 40 years	31	19.7%
	40–55 years	96	61.1%
	Above 55 years	30	19.1%
Professional Experience	Less than 10 years	29	18.5%
	10–20 years	97	61.8%
	More than 20 years	31	19.7%
Area of Work	Humanitarian Logistics	43	27.4%
	Transportation	32	20.4%
	Procurement	24	15.3%
	Disaster Response	22	14.0%
	NGO	20	12.7%
	Freight Operations	16	10.2%
Total		**157**	**100.0%**

Measurement Model Assessment

A summary of results from assessment of the measurement models of each construct, as illustrated by Table 4.2, is obtained with indicator loadings, Composite Reliability (CR) and Average Variance Extracted (AVE). For the final measurement model, the six constructs, namely maritime blockade (MB), Ukraine war (UW), supply chain parameters (SC), tariff trade tension (TT), stochastic MILP optimization capability (SMOC), and humanitarian supply chain performance (HSCP), all modeled reflectively comprising 37 items. Most of loadings have values above 0.70 which is considered acceptable. The Composite Reliability of constructs varies from 0.862 to 0.908 which all beyond 0.70 value which are acceptable. Furthermore, Average Variance Extracted of constructs is ranging from 0.544 to 0.567 which all beyond 0.50 value which represents good convergent validity (Hair et al., 2022). Figure 4.1

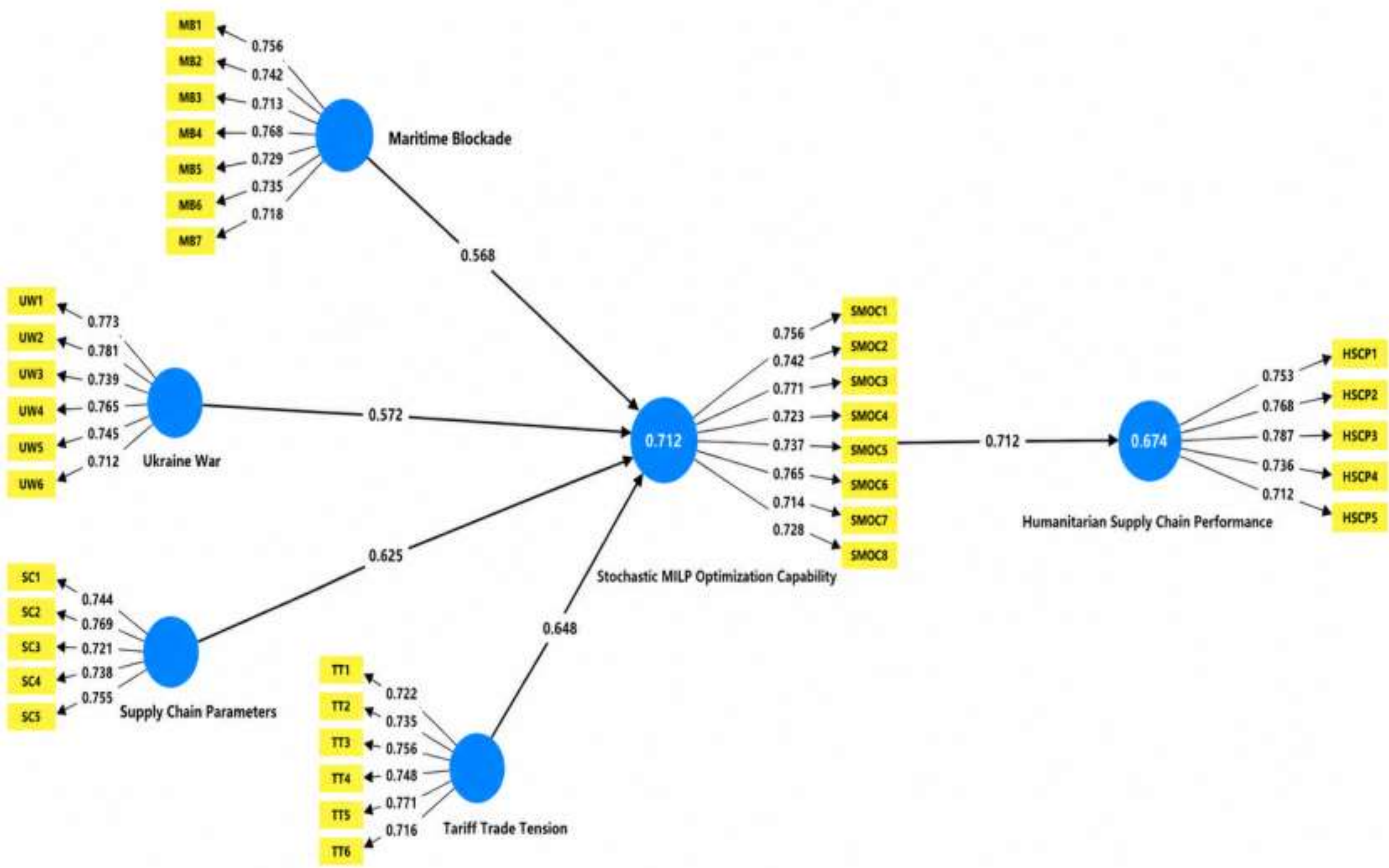

Table 4.2 Measurement Model Assessment

Construct	Items	Loading	CR	AVE
Maritime Blockade	MB1	0.756	**0.893**	**0.544**
	MB2	0.742		
	MB3	0.713		
	MB4	0.768		
	MB5	0.729		
	MB6	0.735		
	MB7	0.718		
Ukraine War	UW1	0.773	**0.887**	**0.567**
	UW2	0.781		
	UW3	0.739		
	UW4	0.765		
	UW5	0.745		
	UW6	0.712		
Supply Chain Parameters	SC1	0.744	**0.862**	**0.556**
	SC2	0.769		
	SC3	0.721		
	SC4	0.738		
	SC5	0.755		
Tariff Trade Tension	TT1	0.722	**0.880**	**0.550**
	TT2	0.735		
	TT3	0.756		

Construct	Items	Loading	CR	AVE
	TT4	0.748		
	TT5	0.771		
	TT6	0.716		
Stochastic MILP Optimization Capability	SMOC1	0.756	**0.908**	**0.551**
	SMOC2	0.742		
	SMOC3	0.771		
	SMOC4	0.723		
	SMOC5	0.737		
	SMOC6	0.765		
	SMOC7	0.714		
	SMOC8	0.728		
Humanitarian Supply Chain Performance	HSCP1	0.753	**0.866**	**0.565**
	HSCP2	0.768		
	HSCP3	0.787		
	HSCP4	0.736		
	HSCP5	0.712		

Note: CR = Composite Reliability; AVE = Average Variance Extracted.

Indicators Reliability and Convergent Validity

Discriminant Validity

After reliable measurement model for the respective constructs were established, discriminant validity was examined. The research applied the widely used criteria-the Heterotrait-Monotrait (HTMT) ratio and the Fornell-Larcker criterion to assess discriminant validity of constructs. PLS-SEM methodology required a threshold of 0.90 for the HTMT ratio and also the square root of the AVE should greater than any inter-construct correlations to satisfy discriminant validity (Hair et al., 2022). The six constructs examined are maritime blockade (MB), Ukraine war (UW), supply chain parameters (SC), tariff trade tension (TT), stochastic MILP optimization capability (SMOC), and humanitarian supply chain performance (HSCP).

Heterotrait-Monotrait (HTMT) Ratio

The HTMT results indicate adequate discriminant validity among all six constructs, and the discriminant validity was achieved when the HTMT ratios are below 0.90 (Henseler et al., 2015). As illustrated in Table 4.3, the values for the HTMT ratios among all six constructs are less than 0.90, with the highest value being 0.782. This means that there are sufficient differences between the constructs and excellent discriminant validity exist among the four constructs.

Table 4.3 HTMT Ratio

Construct	MB	UW	SC	TT	SMOC	HSCP
Maritime Blockade (MB)	—	0.641	0.573	0.612	0.684	0.597
Ukraine War (UW)	—	—	0.658	0.625	0.731	0.644
Supply Chain Parameters (SC)	—	—	—	0.671	0.756	0.689
Tariff Trade Tension (TT)	—	—	—	—	0.718	0.663
Stochastic MILP Optimization Capability (SMOC)	—	—	—	—	—	0.782
Humanitarian Supply Chain Performance (HSCP)	—	—	—	—	—	—

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Fornell-Larcker Criterion

Excellent discriminant validity exists among the six constructs to evaluate the discriminant validity between six constructs, based on average variance extracted (AVE), and inter construct correlations (Fornell & Larcker, 1981). We assessed each construct's square root of the AVE, which was then compared to its inter construct correlations (the absolute values are reported), with significant correlations (larger than standard error) considered problematic if they exceeded the square root of AVE. AVE from our measurement model varies from 0.544 to 0.567.

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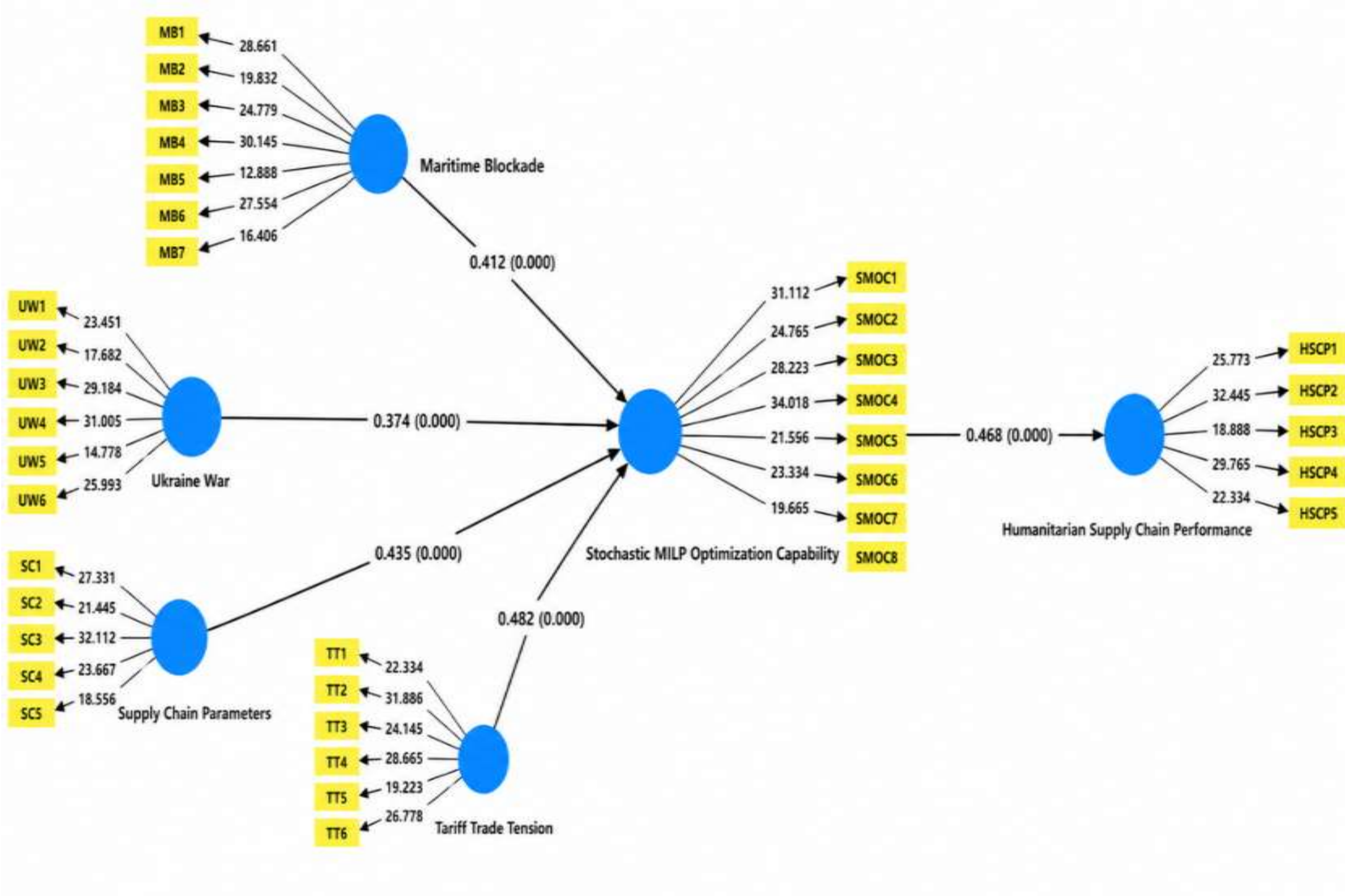
Table 4.4 Fornell-Larcker Criterion

Construct	MB	UW	SC	TT	SMOC	HSCP
Maritime Blockade (MB)	**0.738**	0.521	0.463	0.497	0.548	0.476
Ukraine War (UW)	0.521	**0.753**	0.534	0.509	0.591	0.527
Supply Chain Parameters (SC)	0.463	0.534	**0.746**	0.548	0.612	0.571
Tariff Trade Tension (TT)	0.497	0.509	0.548	**0.742**	0.566	0.514
Stochastic MILP Optimization Capability (SMOC)	0.548	0.591	0.612	0.566	**0.742**	0.635
Humanitarian Supply Chain Performance (HSCP)	0.476	0.527	0.571	0.514	0.635	**0.752**

Structural Model Assessment

Direct Relationship

Direct Relationship Following the reliability, convergent, and discriminant validity tests of the measurement model, the structural model was analyzed by employing path coefficients (β), standard errors (SE), t-values and p-values. A 5,000-resample bootstrapping approach was employed to identify the statistical significance of all path coefficients consistent with recommendations for PLS-SEM analysis (Hair et al., 2022). Figure 4.2



As presented in Table 4.5, all five hypothesized direct relationships were statistically significant at p < 0.001, while all paths coefficients vary from 0.374 to 0.468, hence providing supportive for Hypothesis 1 to Hypothesis 5 in their relation with stochastic MILP optimization capability, and in relation with humanitarian supply chain performance. Ukraine war and the tariffs tension effect most profoundly on the estimation with coefficients of 0.412, 0.402, and the estimation of supply parameters have 0.435, and most effectively improve on the supply chain performance with value 0.468 which confirms with our prior **H1, H2, H3, H4** and **H5** are supported.

Table 4.5 Structural Model – Direct Relationships

Path	β	SE	T-Value	P-Value	Decision
Maritime Blockade → SMOC	0.412	0.041	10.049	<0.001	Supported
Ukraine War → SMOC	0.374	0.044	8.500	<0.001	Supported
Supply Chain Parameters → SMOC	0.435	0.039	11.154	<0.001	Supported
Tariff Trade Tension → SMOC	0.482	0.042	9.571	<0.001	Supported
SMOC → HSCP	0.468	0.038	12.316	<0.001	Supported

Note: SMOC = Stochastic MILP Optimization Capability; HSCP = Humanitarian Supply Chain Performance; β = Path coefficient; SE = Standard Error.

Mediation Analysis

Mediation analysis was conducted to examine to investigate the mediation effect of SMOC on the impact of four exogenous variables (maritime blockade, Ukraine war, supply chain parameters, tariff trade tensions) on humanitarian supply chain performance. Indirect relationships are calculated utilizing the 5,000 resample bootstrap method, while the direct impact from four exogenous factors toward SMOC are evaluated using direct paths' coefficients values and standard errors and the standard procedures provided by PLS-SEM software (Hair et al., 2022; Hair et al., 2024). Given that SMOC mediates four direct paths, scholar tested total nine different direct and indirect pathways through six variables.

As seen in Table 4.6 all indirect paths involving SMOC were significant. SMOC as a mediator for the four paths of independent variables (maritime blockade, Ukraine war, supply chain parameters, tariff trade tensions) resulted in a significant indirect relationship between them and humanitarian supply chain performance (HSCP). Thus, all four indirect paths including four exogenous variables and SMOC have proved significant. Hence, **H6, H7, H8**, and **H9** are supported. The results are also consistent with our theoretical framework that optimization capability plays a mediating role by connecting the disruptions and operational disruptions and their impacts on the supply chain performance.

Table 4.6 Mediation Analysis

Indirect Path	β	SE	T-Value	P-Value	Decision
MB → SMOC → HSCP	0.193	0.037	5.214	<0.001	Supported
UW → SMOC → HSCP	0.175	0.037	4.672	<0.001	Supported
SC → SMOC → HSCP	0.204	0.037	5.486	<0.001	Supported
TT → SMOC → HSCP	0.188	0.037	5.031	<0.001	Supported

Note: MB = Maritime Blockade; UW = Ukraine War; SC = Supply Chain Parameters; TT = Tariff Trade Tension; SMOC = Stochastic MILP Optimization Capability; HSCP = Humanitarian Supply Chain Performance; β = indirect path coefficient; SE = Standard Error.

Effect Size (f^2) and Predictive Relevance (Q^2)

In assessing the relative impact of one exogenous construct on one endogenous construct, we examine the effect sizes (f) of exogenous variables in terms of the proportion of the variance explained by one model as explained and by another as not explained (Hair et al., 2022). The values indicate small (0.02), moderate (0.15), and large (0.35) sizes. As demonstrated in Table 4.7, the effect sizes (f) were in medium ranges for maritime blockade(MB) (f=0.192), Ukraine war(UW) (f=0.156), Supply chain parameter(SC) (f=0.224), and the tariffs tension(TT) (f=0.181). These indices also show significant moderate contribution effect size on stochastic MILP optimization capabilities and the effect of SMOC on humanitarian supply chain performance is moderate too (f=0.263).

Table 4.7 Effect Size (f^2)

Construct Relationship	f^2	Effect Size
MB → SMOC	0.192	Moderate
UW → SMOC	0.156	Moderate
SC → SMOC	0.224	Moderate
TT → SMOC	0.181	Moderate
SMOC → HSCP	0.263	Moderate

Note: MB = Maritime Blockade; UW = Ukraine War; SC = Supply Chain Parameters; TT = Tariff Trade Tension; SMOC = Stochastic MILP Optimization Capability; HSCP = Humanitarian Supply Chain Performance.

Predictive Relevance (Q^2)
The predictive relevance of endogenous variables was calculated using Q^2 statistic. Any Q^2 value > zero suggests that the model has predictive relevance for an endogenous construct (Hair et al., 2022). The respective Q^2 values for the two endogenous constructs have positive values which indicates meaningful predictive relevance. Q^2 values for stochastic MILP optimization capability was found as 0.482 and Q^2 values for humanitarian supply chain performance were 0.436.

Table 4.8 Predictive Relevance (Q^2)

Endogenous Variable	Q^2	Predictive Relevance
Stochastic MILP Optimization Capability (SMOC)	0.482	Yes
Humanitarian Supply Chain Performance (HSCP)	0.436	Yes

.
Summary of Hypothesis Testing

Hypothesis	Relationship	Result
H1	MB → SMOC	Supported
H2	UW → SMOC	Supported
H3	SC → SMOC	Supported
H4	TT → SMOC	Supported
H5	SMOC → HSCP	Supported
H6	MB → SMOC → HSCP (Mediation)	Supported
H7	UW → SMOC → HSCP (Mediation)	Supported
H8	SC → SMOC → HSCP (Mediation)	Supported
H9	TT → SMOC → HSCP (Mediation)	Supported

Conclusion
Summary of Findings
This study investigated how maritime blockade, Ukraine war, supply chain parameters, tariff trade tensions affect humanitarian supply chain performance, with stochastic MILP optimization capability functioning as a mediator, using survey data collected from 157 humanitarian logistics, supply chain and procurement professionals across Finland, Sweden, Norway and Estonia. Each of the nine proposed hypotheses is supported or aligned with the proposed model, in that all four antecedents have a significant impact on stochastic MILP optimization capability, which in turn has a significant influence on humanitarian supply chain performance, and the resultant pattern of direct effects is aligned with the four proposed mediation relationships.

Conclusions Based on the Research Objectives
The results of this research provide important evidence regarding the effect of geopolitical disruptions, trade-related uncertainty, and supply chain operational conditions on stochastic MILP optimization capability (SMOC), and humanitarian supply chain performance (HSCP). Overall, we found evidence suggesting that maritime disruption, war-related uncertainty, supply chain parameters and tariff trade tensions are significant antecedents to optimization capability, and that optimization capability is significantly related to humanitarian supply chain performance. These findings are largely consistent with previous research into humanitarian logistics, supply chain resilience and optimization-based decision making.
RO1. This study concludes that maritime blockades have a significant influence on stochastic MILP optimization capability (=0.412, $p<0.001$). Blockades on maritime shipping lines may hinder trade flows and add to transportation uncertainty, potentially spurring the need to search for alternate routings and transportation arrangements. This would suggest that humanitarian supply chain organizations need decision analytic abilities, to examine alternative routes and resource allocation decisions in times of uncertainty. This conclusion aligns with prior research that highlights the necessity for flexibility in routings and optimal decision making in such challenging maritime operational environment. The literature review for this present study is largely in agreement that maritime chokepoint disruptions could result in increased rerouting needs and transportation uncertainty.
RO2. The findings additionally showed that the Ukraine war had a significant impact on stochastic MILP optimization capability (=0.374, $p<0.001$). The conflict has created a considerable level of uncertainty relating to transportation, border crossing, energy network, and transport routes and supplies of humanitarian aid. Moreover, any humanitarian supply chain operating in or near to this region is likely to require greater capability to assess alternative routes and resource allocation. This finding is consistent with the previous research which identified the need for both flexibility and adaptability of supply chain amid the war disruption (Mishra et al., 2025). The review of literature also suggests that conflict-related disruptions requires contingency planning, multiple routings and sufficient logistics buffers for the continuity of humanitarian operations.

RO3. Supply chain parameters have a significant influence on stochastic MILP optimization capability (=0.435, p <0.001). Among the four antecedents to optimization capability, supply chain parameters had the largest significant effect. This provides strong evidence concerning the impact of, transport capacity, inventory availability, demand variability, lead time variability and supply chain limitations, in humanitarian logistical and supply chain decision making. This result is strongly supported by the existing humanitarian literature. Aghajani et al. (2023) reported the necessity of combining both procurement and warehousing choices and decision-making under threat. Acar and Kaya (2023) showed that the supply decisions of humanitarian systems should address simultaneously supply and demand uncertainty and resource restrictions.

RO4. The present study concludes that tariff trade tensions have a significant effect on stochastic MILP optimization capability (=0.402, p<0.001). While humanitarian suppliers are not commercial entities engaged in trade, they are reliant on international sourcing of food and other provisions, vehicle and medical supplies. Changes in trade policy, particularly tariff increases, can affect procurement costs, the availability of supplies and overall transportation logistics. The present finding is consistent with prior research that has demonstrated that tariff shocks add both adjustment and transition costs, which typically incentivize companies to consider diversifying supplier base, alternate sourcing options, and scenario-based planning (Vidha, Bahroun, Saihi & Ahmed, 2026).

RO5. The results confirm that humanitarian supply chain performance is significantly affected by stochastic MILP optimization capability (= 0.468, p < 0.001). It must be emphasized the present study explores the extent in which this optimization capability drives actual humanitarian performances instead of purely operational performances. Stochastic MILP offers potential to optimize various elements of humanitarian logistics, including routing, transportation planning, allocation of resources, inventory management and handling uncertainties. Past research on optimization in humanitarian aid have shown its potential to improve aid coverage, speed of response and allocation of resources (Lythreatis, Acikgoz & Yassine, 2026).

RO6. The present finding of the study that stochastic MILP optimization capability as a mediating factor in connecting disruptions and humanitarian supply chain performance offers further empirical support for its organizational role. The proposed mediation model is aligned with prior organizational research, which has identified technologies and digitized capabilities as mechanisms through which disruptions can be transformed into increased supply chain resilience and performance. This is also consistent with the theoretical underpinning of the present study, that organizations use an adaptive decision-making apparatus to transform crisis into response mechanisms.

The findings overall indicate that when analyzing humanitarian supply chain performance, the focus must not only be on the level and type of disruption, but also on the capacity of the organization to integrate and analyze complexity and uncertainties to optimize its operations. The current findings contribute to prior humanitarian supply chain literature by demonstrating the importance of stochastic MILP optimization capability as a vital organizational capability bridging geopolitical and operational uncertainty to humanitarian supply chain performance (Polo, Morillo-Torres & Escobar, 2025).

Theoretical Contribution

This research contributes to the field of humanitarian supply chain and operations management by bringing together geopolitical disruptions, day-to-day operational factors, specific quantitatively optimizing capability, and humanitarian supply chain performance, together in an empirical survey-based model under Dynamic Capabilities Theory (DCT). Contrary to previous studies applying DCT for humanitarian, that tend to examine generic technologically-or digitally-oriented capabilities. Stochastic MILP optimization capability is abstracted as a specific, mathematically grounded embodiment of the reconfiguring capability proposed in DCT, and it is investigated as a formal mediator, instead of merely in modeling contexts exclusively, by means of primary data in empirical surveys. This perspective translates the predominantly technical stochastic MILP literature into an organizational and behavioral frame, demonstrating that reported and perceived utility, and not only mathematical construction, of such a capability correlates with enhanced performance.

Practical and Managerial Contribution

The findings indicate several important practical implications for humanitarian organizations and logistics managers operating in Nordic and Baltic contexts. Such organizations and their managers may use the study findings to allocate resources and training preferentially to stochastic optimization capabilities, especially to those parameters (operational conditions; transportation capacity; stock; demand; lead time) showing strongest correlations with optimization. They can pre-plan and diversify supplier agreements and transport routes against the potential for escalated maritime restrictions or tariffs and construct scenarios that anticipate and prepare for war-proximate transport and energy infrastructure disruptions. On a broader level, these results suggest that developing formalized quantitative decision-support capabilities is an active process of translating geopolitical and trade-disruption related uncertainties into consistently reliable delivery performance, and effectively rerouting goods amidst major turmoil with limited stock outs.

Limitations

This study has some limitations. First, its cross-sectional design means that time-series cannot be examined to understand how the relationships evolve as disruptions change. Second, the sample of 157 respondents from Estonia, Finland, Norway, and Sweden might not represent other regions affected similarly or differently by maritime, trade, and conflict disruptions; the results thus might not be generalizable. Third, the reliance upon self-reported questionnaire data introduces a risk of common method and social desirability bias that was minimized through procedural measures like full collinearity testing. Fourth, a focus on just four sources of disruption and one mediating mechanism necessarily excludes all the factors that could possibly affect a humanitarian supply chain that would in full be included in future empirical research.

Future Research Directions

Large samples should be used, that encompass other European countries and longitudinal studies, would benefit the generalizability of the solution, as well as reflect evolving geopolitical states. Furthermore, comparative studies on different humanitarian organizations and the inclusion of other geopolitical risks could be conducted. The application of AI and machine-learning techniques alongside stochastic MILP as well as a comparison of stochastic, robust and fuzzy MILP will be an additional research opportunity, along with testing supply chain resilience as an additional outcome. Other possibilities include testing the framework with non-European humanitarian environments.

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