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Applying Action Research in Operational Management - Simulating Volvo Car Reaction to Suez Canal blockage 2021

Wael Ghazi Shaaban[1*]

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ABSTRACT

This paper applies Action Research (AR) and the DMAIC quality-improvement framework to examine how the March 2021 Suez Canal blockage disrupted global supply chains and to propose a structured operational response. Using the Plan-Act-Observe-Reflect cycle, the study diagnoses production delays caused by shortages of critical inbound materials and weak multi-tier supplier visibility, and develops a prioritised portfolio of planning, action, monitoring and reflection activities. The role of simulation as an operations-research method for modelling supply chain disruption is then reviewed, comparing Discrete Event Simulation, Agent-Based Modelling and System Dynamics, and drawing on existing simulation-based studies of the Suez Canal event and broader supply-chain resilience research. These insights are applied to a focal case, Volvo Cars, whose electric-vehicle battery and component after-sales supply chain is highly exposed to maritime corridor disruption between Asia and Europe. A DMAIC-based improvement project - Define, Measure, Analyze, Improve, Control - is used to diagnose and address quality, continuity and responsiveness issues in Volvo's replacement-parts supply. Pareto analysis of baseline measures shows that two of eight problem categories (25%) account for 85.2% of the observed burden, identifying incoming material quality and replacement stock availability as the dominant drivers of performance. Root-cause (fishbone) analysis and a prioritised set of interventions are then proposed, coordinated through an integrated DMAIC-PDSA-Agile framework for ongoing control. The paper concludes that the Suez Canal disruption should be treated as a continuity and quality problem, not solely a transport problem, and that combining AR, simulation and DMAIC gives organisations a structured, evidence-based route from disruption to long-term supply chain resilience.

INTRODUCTION

Analyzing Suez Canal disruption 2021

The Suez Canal disruption of March 2021 (See Figure_1) was not only a big accident in one of the world's most important maritime corridors, but also a major operational problem that exposed the fragility of global supply chain (SC) and the degree to which many firms depend on interruptible trade flows (Özkanlısoy & Akkartal, 2022). Global supply chains remain vulnerable to external disruptions because of their dependence on interconnected transportation networks, international trade flows and geographically dispersed supply bases (Qian & Arkadievna, 2024).

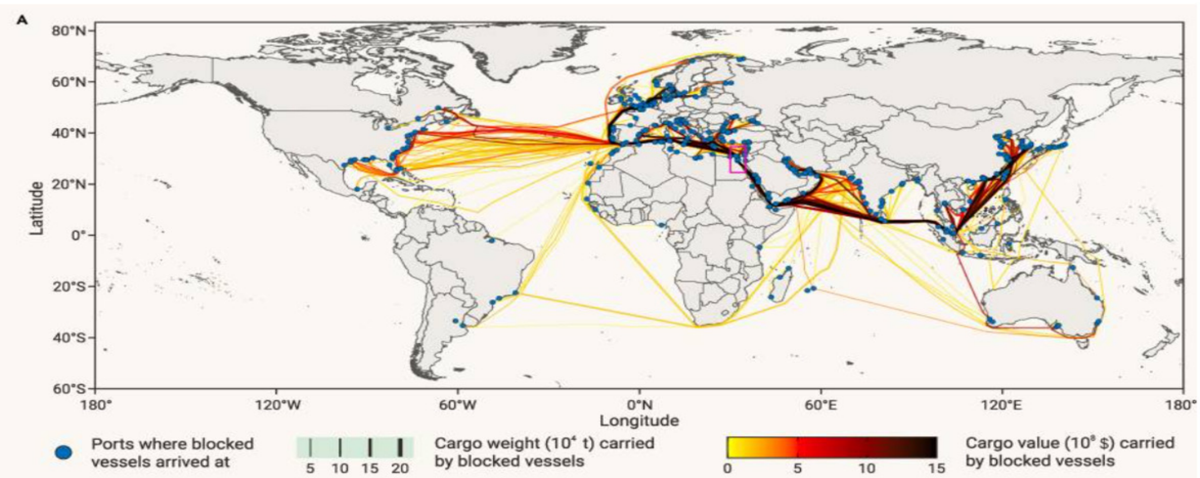


Figure 1: Logistics trajectory during Suez Canal blockage
Source: (Qu, et al., 2024)

Restricting this dual corridor (See Figure_2) for 175 hours affected around 12%-15% of global trade through disproportionate impacts of operations (Qu, *et al.*, 2024). This showed the vulnerability of businesses when lean inventory supply systems, which are efficient routes and upstream dependencies, converge in one disruption (Wan, *et al.*, 2023).

[1] London Metropolitan University, Saudi Arabia
[*] Corresponding author's e-mail: waelghazishaaban5@researchpublication.co

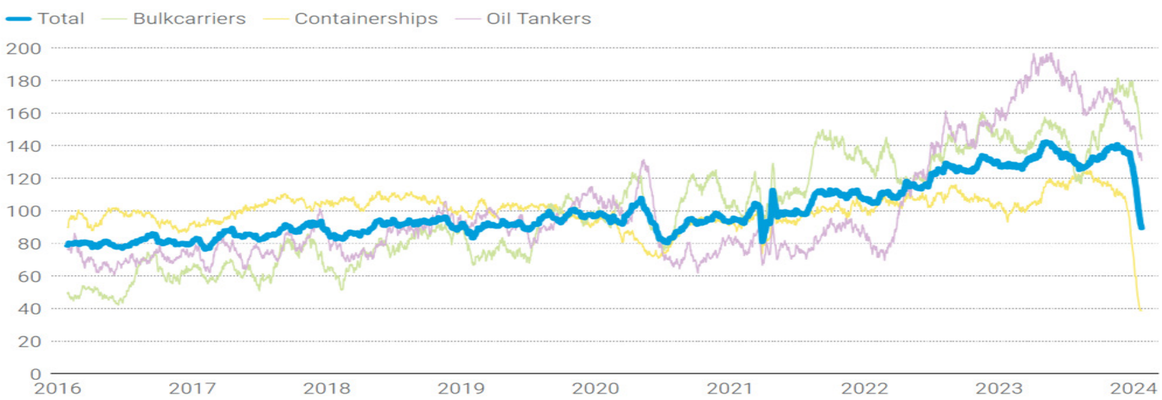


Figure 2: Suez Canal daily transit
Source: (UNCTAD, 2024)

The blockage acted as a triggering event of multiple, interconnected problems preventing firms from identifying vulnerable components quickly or activating alternative responses with sufficient speed (Taghizadeh, Venkatachalam, & Chinnam, 2021). In this sense, the core issue was not only transport interruption, but continuity failure across the whole supply system (Christopher, 2018).

One of these operational problems, selected for deep analysis using Action Research (AR), is "Production delay caused by shortages of critical inbound materials, compounded by weak visibility across multiple supplier tiers".

AR helps addressing such a problem because it is practical, collaborative, contextual, and cyclical (Çakar, Tronco, & Şimşek, 2010). AR facilitates multi-layer investigation while simultaneously testing improvements (Royal Education Council, 2018). Additionally, in this disruption case, the cycle of "Plan, Act, Observe, and Reflect" (PAOR) is especially suitable because information is incomplete, circumstances change rapidly, and stakeholders across procurement, logistics, warehousing, production, and customer service all hold different pieces of the status picture.

AR therefore offers a disciplined way to move from disruption to continuity (COPE, 2005).

LITERATURE RIREVIEW

Simulation as a method

Simulation is one of those most suited operation research (OR) methods to the SC disruption which creates multidimensional uncertainty and difficult-to-apply alternatives (Petropoulos, *et al.*, 2023). This method involves constructing a model of a real system and then testing how that system behaves under different conditions and/or rules, and what likely outcomes are expected before implementation (Petropoulos, *et al.*, 2026). More broadly, Snyder *et al.* (2016) describe simulation as a natural tool for evaluating disruption effects in complex SCs because it can capture multiple interacting risks and mitigation strategies in ways that simpler models often cannot (Snyder, *et al.*, 2014). For the Suez Canal event, three simulation forms (see Figure_5) were considered from the perspective of their contributing variables: (a) Discrete Event Simulation (DES) capturing event-based variables, (b) Agent-Based Modelling (ABM) focusing on actor interactions, and (c) System Dynamics (SD addressing broader feedback effects. On this basis, DES can be recommended because the blockage was a discrete operational event with immediate process-level consequences across the SC system.

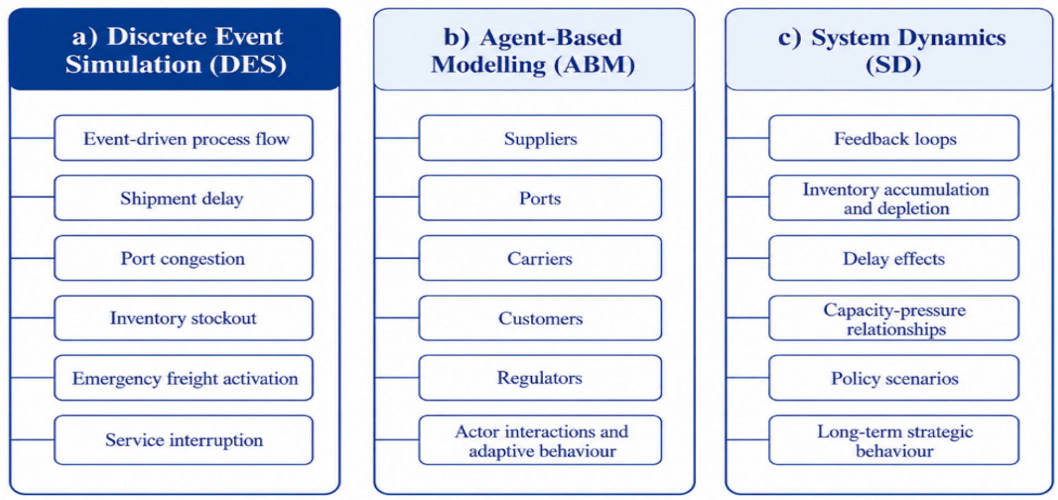


Figure 3: Three simulation forms of SC disruption analysis.
Source: (Author Findings)

Still, the other simulation forms are feasible (and present) in recent OR on the Suez Canal disruption. For instance, Qu *et al.* (2024) developed an agent-based model to simulate the effects of the canal blockage on global SCs. Their findings addressed $136.9 billion global loss with consequences extended beyond directly affected countries (See Figure_4).

This simulation revealed indirect ripple effects that managers may overlook if they rely only on immediate freight delays or intuition (Qu, *et al.*, 2024).

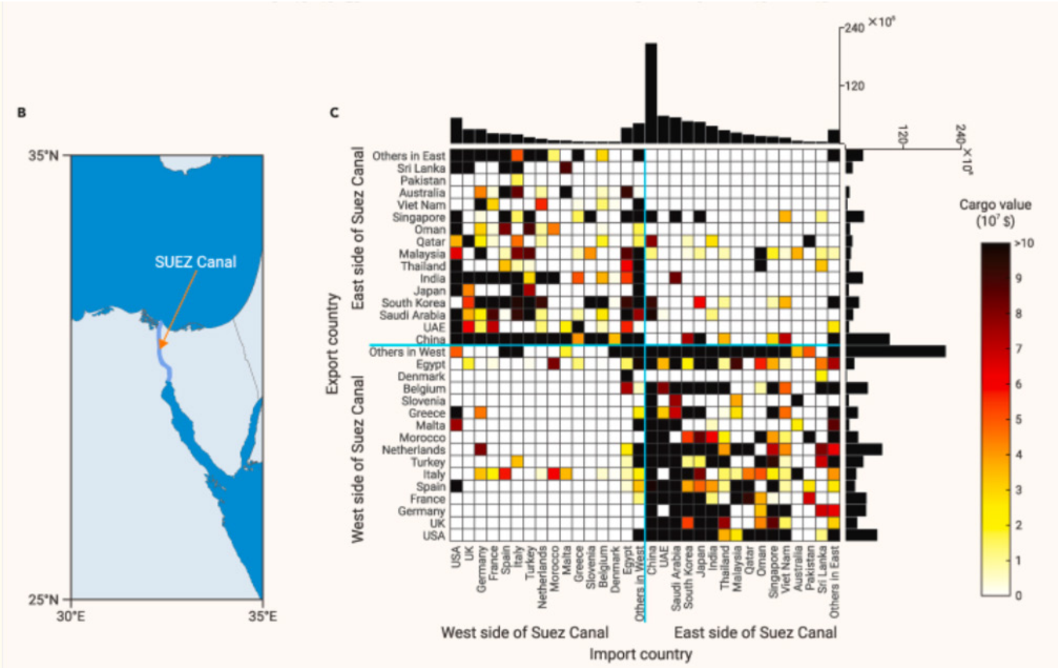


Figure 4: International matrix of blocked cargo value.
Source: (Qu, et al., 2024).

Simulation has also proved useful in wider supply-chain resilience research. Moosavi *et al.* (2021) developed a simulation-based method to assess resilience strategies in a multi-stage SC during pandemic disruption and argued that simulation can convert resilience from a general concept into a measurable, quantitative assessment (Moosavi & Hosseini, 2021). In decision-making terms, this means that managers are not limited to discussing options in abstract terms; instead, they can compare the probable effects of different interventions before committing resources. Contemporary supply-chain management research emphasizes the importance of integrating theoretical perspectives to understand coordination, interdependence and performance across supply-chain actors (Emmanuel *et al.*, 2024). The impacts of transport and infrastructure interruptions may reach far beyond logistical interruptions and even affect the continuity of businesses which are dependent upon the uninterrupted flow of their inputs and other resources (Emeke & Mansi, 2026).

Applied to the Suez Canal blockage, a DES simulation model could have tested several operational scenarios and associated alternatives based on SC risk evaluation (Chen, Sohal, & Prajogo, 2013) considering variables like demand, products, customers, transportation, suppliers, production and distribution centres (Figure-5).

Options that may be simulated can be as follows:

- Waiting for the reopening of the canal,
- Routing ships through the Cape of Good Hope,
- Distributing shipments among multiple routes, and
- Accelerating shipments that are urgent.

Inputs to DES modeling can be the following:

- Disruption duration,
- Port congestion,
- Cost of transportation,
- Inventory coverage,
- Shortage costs, and
- Customer service implications.

It should be noted, therefore, that the power of simulation is not just in its technical accuracy, but its capacity to facilitate decision making through comparison (Qu, *et al.*, 2024).

Of importance, however, is that simulation also has its own weaknesses. Credibility of the output from simulations relies on the validity of the assumptions made, data inputs and model boundaries (Hosseini, Ivanov, & Dolgui, 2019; Ivanov & Dolgui, 2022; Petropoulos, *et al.*, 2023).

As Robinson notes, "Simulation models are not judged on their absolute accuracy; rather, they are judged by whether they are accurate enough for the intended application. Verification and validation provide the foundation for confidence in simulation" (Robinson, 1997).

This implies that if the assumptions relating to delayed distributions, demand patterns, or inventory situations are not realistic, the output produced will be rigorous yet misleading for the decision makers.

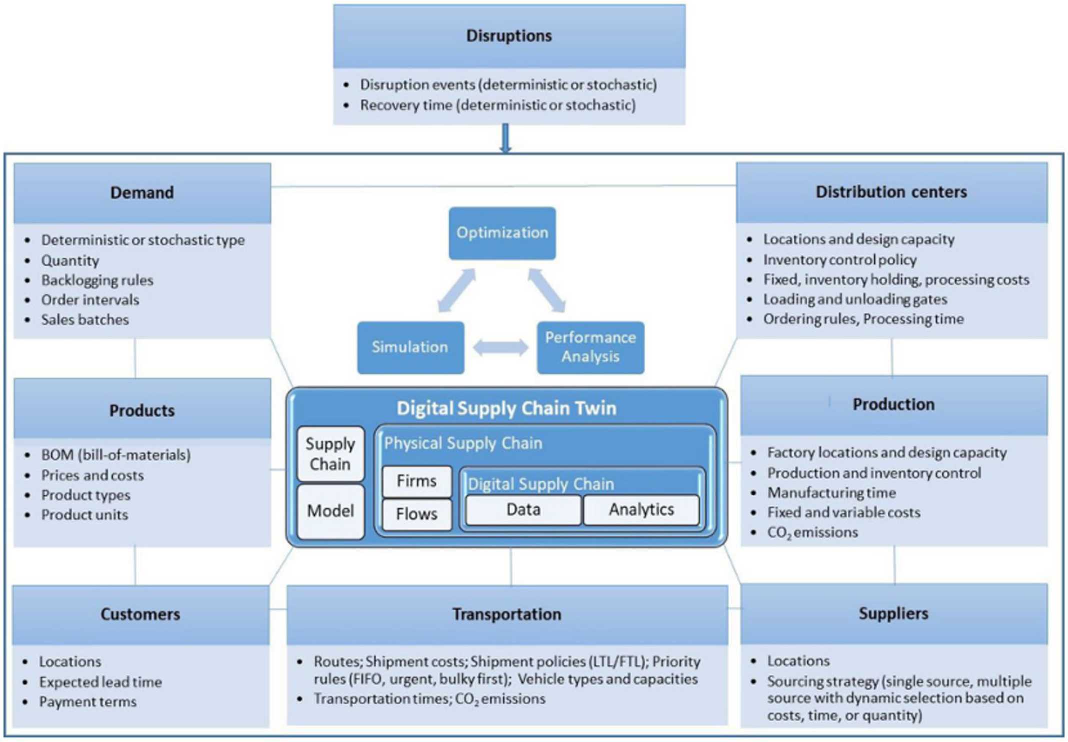


Figure 5: Digital SC design for disruption analysis.
Source: (Ivanov & Dolgui, 2022)

Considering that quality input data are essential for successful discrete-event simulations, this problem is even more acute when the underlying data are incomplete, contradictory, or unvalidated. Thus, simulation can be considered an extremely useful decision-supporting tool, but its usefulness is contingent on proper modeling and data validation. (Bokrantz, Skoogh, Lämkull, Hanna, & Perera, 2018).
However, with regards to disruption similar to that of Suez, it brings significant benefits since it helps to make uncertainty visible, quantify the trade-offs between cost, service, and delay risk, and allows decision-makers to explore contingencies systematically (Moosavi & Hosseini, 2021).
This is why simulation may be considered an absolutely relevant OR approach not only to alleviate the consequences of the Suez Canal blockage but also to allow management judgement enriched with insight and to optimize supply chain performance through better decision-making.

MATERIALS AND METHODS

Plan

AR enables organizations to apply iterative planning cycles to move from disruption to improvisation (Çakar, Tronco, & Şimşek, 2010).
Planning begins with disciplined diagnosis before jumping to any immediate solution (ASQ, 2026). Fishbone analysis can help identify possible causes of the problem and organize them into categories to distinguish their effect or symptom (ASQ, 2026). See Figure_6.

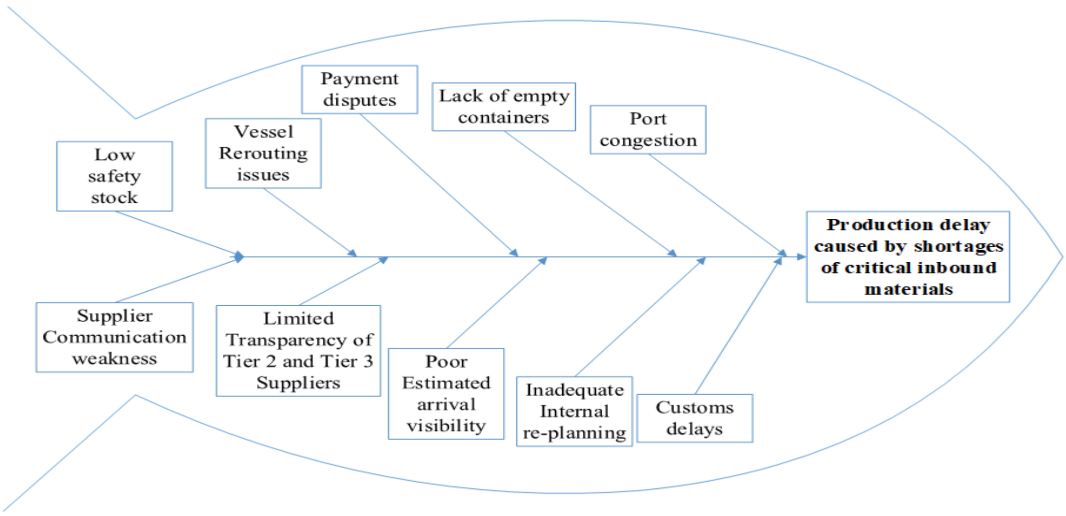


Figure 6: Production delay main causes.
Source: Author Findings

Each cause may have different implications; for example, UNCTAD notes that container shortages were generating higher freight rates (UNCTAD, 2021). In parallel, resilient risk mitigation requires visibility not only of immediate suppliers but also of second- and third-tier suppliers (Christopher, 2018).
Once the causes are mapped, the planning stage should define a 3W response portfolio focusing on the system performance as a whole (Thakur-Weigold & Miroudot, 2024).
Table_1, below, shows the most relevant planning activities.

Table 1: AR Planning Activities.

Stage	Planning Activity
A	Identify critical materials needed for vulnerable products.
A	Identify exposed suppliers.
A	Identify priority customer segments that are most sensitive to potential delay.
B	Contact Tier 1, Tier 2, and even Tier 3 suppliers to validate the problem exposure.
B	Assess altering the product mix to reduce dependency on constrained inputs.
B	Scan local or regional markets for alternative materials.
B	Plan for evaluating substitute inputs.
C	Study the possibility of fast-tracking essential cargo.
C	Study reprioritizing production schedules.
D	Plan to trigger a customer-care communication campaign.

Source: Author Findings, (Berthou, Haramboure, & Samek, 2024), (Guo, Liu, Song, & Wang, 2025), (Kesen, Kanchanapiboon, & Das, 2010), and (Vakil, 2018)

This planning effort may range from finding alternative sources to performing reputation recovery (OCED, 2025). However, firms also plan to adopt controlled risk acceptance, as far as some causes may not be directly treated if the response cost is excessive, and their consequences are still managed.

Act

Phase "Act" entails the selection and execution of the most practical interventions in short operational loops. This can be done using either an adaptable method that uses several actions at once, or by strictly adhering to the playbook approach (Azadegan, Mellat Parast, Lucianetti, Nishant, & Blackhurst, 2020).
A cross-functional continuity team should coordinate procurement, logistics, production, warehousing, finance, and customer service. Table_2 shows the most relevant actions.

Table 2: AR Prioritized Actions.

Priority	Action
A	Contact suppliers at multiple tiers to verify actual stock positions, in-transit shipments, substitute sourcing options, realistic replenishment times, and any fast- tracking options of new shipments.
B	Scan local or other markets quote alternative input materials and compare the time and cost of those alternatives against the consequences of production delay and any potential fines or negative financial implications.
B	Review whether the product mix can be altered since some products may count heavily on constrained components, while others may remain totally or partially produceable with available inputs. Change as much as seemed feasible and necessary.
C	Perform cost-benefit analysis and/or comparisons to determine the cheapest or the least damaging options. This includes comparing cargo fast-tracking against cost of stoppage, contractual penalties, or reputational damage. Then adjust needed logistics.
C	Review contractual compensation rights and whether delayed shipments, supplier non-performance, or customer delivery failures constitute non-performance and whether there is liability for delay. Then manage any penalties or liquidated damages.
D	Protect cash flow through reprioritizing the product mix, changing configurations, or temporarily promoting substitute products to preserve output when certain material shortages cannot be eliminated quickly.
D	Run a customer-care campaign especially if order delays cannot be avoided. Try proactive communication, revised delivery commitments with or without discounts, and transparent explanation to reduce customer dissatisfaction and preserve trust.
E	Examine whether business interruption insurance or similar cover may support recovery of part of the loss via pursuing contractual and insurance remedies to offset disruption costs while reinforcing accountability across the wider supply network.

Source: Author Findings, (Russo, Masorgo, & Gligor, 2022), and (UNIDROIT, 2010).

It is summarised that during the action phase, emphasis should not only be on procurement cost but should consider continuity, time, impact on customers, and cost exposure. In practice, organizations manage both disruption cause and consequence, which is often more realistic than solving just one.

Observe

The third phase, "Observe", is where AR becomes evidence-based rather than merely reactive (McNiff, 2002). The firm should monitor, using appropriate Key Performance Indicators (KPIs), whether the selected interventions are reducing disruption in practice (Karl, Micheluzzi, Leite, & Pereira, 2018). See Figure_7.

Figure 7: Suggested KPIs.
Source: Author Findings and (UNIDROIT, FAO and IFAD, 2015).

Accordingly, KPI judgement should be based on comparison between scenarios. For example, by comparing the cost of delay, the cost of alternative sourcing, and the cost of logistics fast-tracking. This may require additional qualitative feedback from planners, warehouse staff, buyers, suppliers, and customer-facing teams to shape the recovery effectiveness by coordination quality and execution realism.

The observations should also entail competitor analysis, which would enable us to see how they have reacted to the same disruption and what are their sources and logistics strategies. The goal is to find response solutions that will protect our position in the market and not delay decision-making processes (Dubey, Gunasekaran, & Papadopoulos, 2024).

Reflect

Phase five, "Reflect," involves key stakeholders assessing what actually worked, what merely moved the problem somewhere else, and what put an undue burden on the organization (Coghlan, 2019; Daudelin, 1996).

Reflection should extend beyond crisis management itself, yet must assess what could be improved during the period of disruption as well as weaknesses exposed regarding the structural strengths of the company, like reliance on one route, lack of multilevel supply chain visibility, poor inventory segmentation, and bad continuity governance (Coughlan & Coghlan, 2002). Certain measures may end up being appropriate only for stabilization in times of emergency, while others may warrant adoption on a long-term basis, including enhanced supplier mapping, categorization of critical material, dual sourcing of specific inputs, contractual agreements, or disruption playbooks. Through this approach, the disruption at the Suez Canal is not just an experience to survive but one that provides an opportunity to learn.

AR is particularly valuable here because it turns practical intervention into systematic and continues organizational improvement.

Simulating the case of Volvo Cars.

The Suez Canal blockage has different complex effects on both manufacturing and service firms which have excessive dependence on long, global maritime supply systems. For instance, it disrupted inbound raw materials, and production scheduling. This led to inventory shortages, production interruption, and higher logistics costs. In parallel, service and retail firms were suffering from delayed merchandise replenishment, reduced product availability, and pressure on replacements and returns lead-time (Wan, *et al.*, 2023).

Within this context, Volvo Cars represents a suitable focal firm for study and improvement (Volvo Cars, 2026).

As an automotive manufacturer undergoing electrification, Volvo's electronical vehicle (EV) is fully dependent on battery-related components and technologically advanced spare parts linked to international supply networks. Such dependence makes the company particularly sensitive to corridor disruption between Asia, mainly China, and Europe (UNCTAD, 2024).

The Suez Canal blockage contextually triggers an SC improvement aiming to strengthen Volvo's system in a way that reduces vulnerability to future maritime disruption.

The recommended scope focuses on a predictive spare-parts and replacement supply for batteries and selected critical components, especially those linked to warranty and after-sales maintenance service.

The flow of warranty replacement involves manufacturing, logistics, quality management, customer service, and cost control (Murthy, Solem, & Roren, 2004).

When a battery or another sensitive EV's component fails prematurely, the effect is not limited to one defective part, but it may create workshop congestion, delayed service appointments, dissatisfied customers, repeated visits, emergency freight costs, warranty expense, and maybe brand damage (Kurata & Nam, 2010).

In a maritime-dependent system, these problems can become more severe because replacement units may originate from distant suppliers and travel through vulnerable trade corridors.

The recommended improvement project utilizes DMAIC to improve the quality, continuity, and responsiveness of a high-impact after-sales SC (George, 2002).

Define

The issue can be stated as: Volvo's existing replacement supply system for the batteries of EVs as well as certain other key components is susceptible to: a) Quality source risk; b) Long lead times for replenishment; and c) Poor response capability to disruptions, leading to higher cost of quality and lower reliability of service. The goal of the research effort would be to ensure continuity of supply, lower repeat failure rate of replacements, minimize response time to the customer, and manage costs of prevention, appraisals, and internal/external failure costs.

Measure

Baseline general measures (See Table_3) should first be established to understand the current performance of the replacement flow.

To assure comprehensiveness, Figure_8 below shows the main dimensions of the above-mentioned measures and their connection to time, cost and quality.

Table 3: Suggested measures for DMAIC.

Measure	Measure Description
Critical part defects	Count of incoming materials which do not fulfil the quality specification or fail to meet the design requirements.
Stock unavailability cases	Count of warranty cases facing stock shortage in Sweden and nearby European hubs.
Repeated replacements	Count of material replacements concerning same item in the same vehicle according to the cause of failure.
Warranty case caused excessive costs	Times of extra cost beyond average of service cost of warranty services including car towing, logistics, material, and manpower.
Service level agreement (SLA) breaches	Count of warranty cases needed to replace an item (e.g., a battery) which fails to meet service completion SLA.
Customer complaints	Count of complaints raised from customers impacted by the delay in replacements of spare part in-scope of the study.
Emergency freight incidence	Count of cases requiring emergency logistics because service lead time is affected or customer complaint risk is created.
Service workshop idle situations	Count of times a car stays idle within a workshop during replacement of spare part in-scope of study.

Source: Author Findings and (UNCTAD, 2022)

To assure comprehensiveness, Figure_8 below shows the main dimensions of the above-mentioned measures and their connection to time, cost and quality.

These measures create a foundation for diagnosis and combine information from difference perspectives. However, the list can be improved by adding more detailed measures like corridor-related volatility, such as shipment delay by route, variability in transit time, and rejection rates of incoming material by batch and supplier (UNCTAD, 2022).

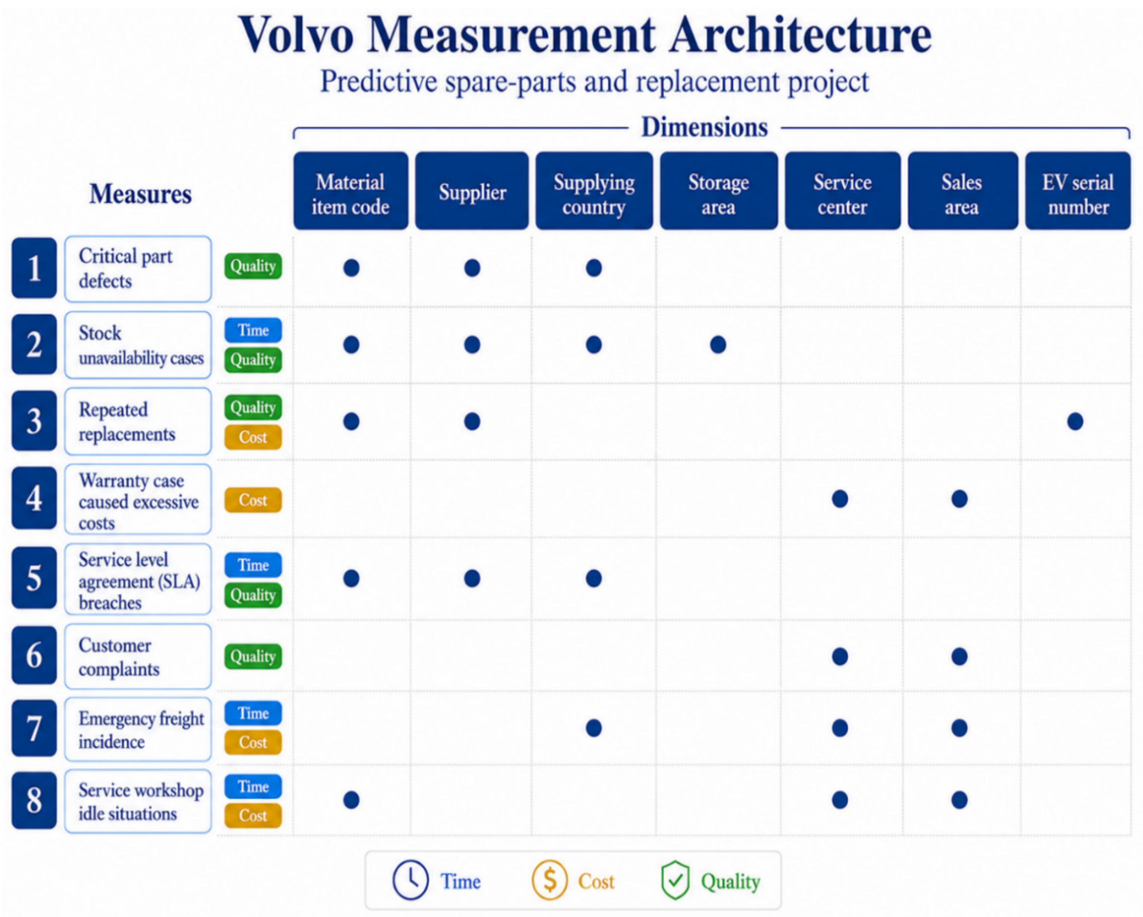


Figure 8: Suggested measures for DMAIC.
Source: Author Findings

RESULTS AND DISCUSSION

Analyze

Once the baseline is available, Pareto analysis can be used to determine which categories create the greatest share of quality loss, delay, or undesirable cost (Alkiayat, 2021). Table _4, Functions as a decision-modelling device.

Table 4: Illustrative annual scenario data used within the proposed DMIAC framework.

Measure	Annual Count	Contribution
Critical part defects	9,852	64.1%
Stock unavailability cases	3,245	21.1%
Repeated replacements	985	6.4%
Warranty case caused extra excessive costs	654	4.3%
Service level agreement (SLA) breaches	324	2.1%
Customer complaints	221	1.4%
Emergency freight incidence	51	0.3%
Service workshop idle situations	38	0.2%
Total	15,370	100%

Source: Author Findings

Using the given measurements, the Pareto analysis indicates that two out of eight categories (i.e., 25%) represent 85.2% of the total observed burden, confirming the 80/20 principle. This finding suggests prioritized focus on a) incoming material quality, and b) replacement stock availability, being dominant drivers of system performance. See Figure_9.

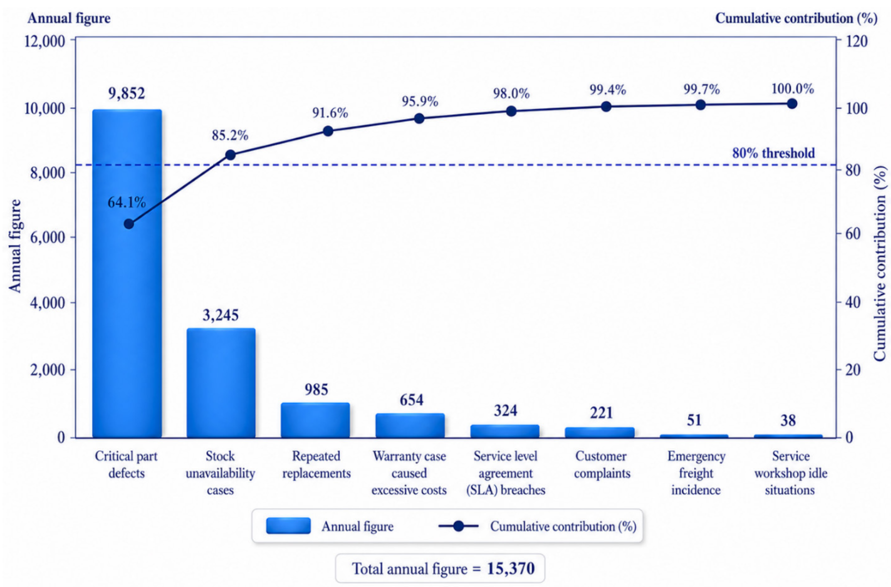
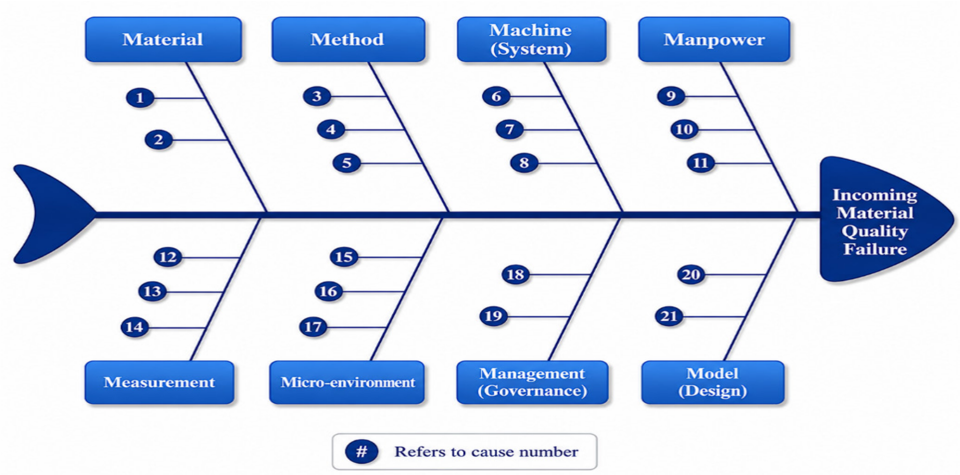


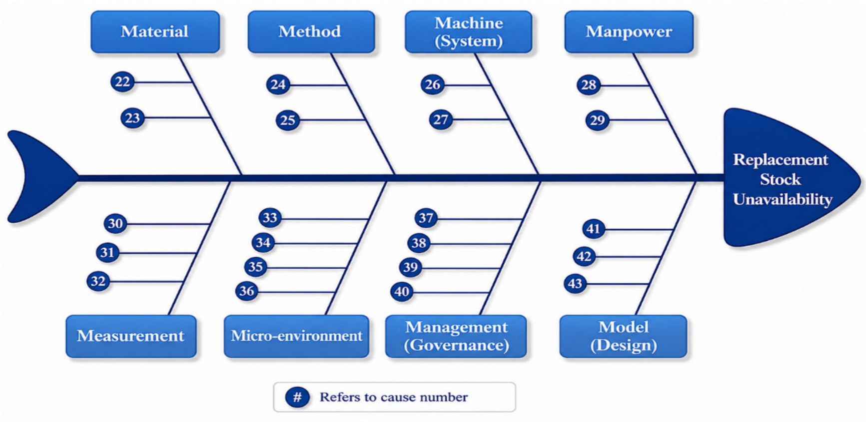
Figure 9: Pareto Analysis.
Source: Author Findings

Based on Pareto analysis results root cause analysis, using fishbone method, should be applied to the highest-priority issues to examine all underlying reasons. See figure_10 and Figure_11.



Fishbone	Potential causes leading to failure of **material quality failure**
Material	1) Inconsistent raw material composition across supplier batches. 2) Substandard packaging or protection causing damage in transit.
Method	3) Weak inspection procedure of incoming material. 4) Inappropriate sampling plan. 5) Supplier process changes are not formally approved before shipment.
Machine (System)	6) Weak testing capability at the supplier premises. 7) Inadequate calibration of supplier production testing equipment. 8) Poor traceability tools linking lot, batch, serial number, and defect history.
Manpower	9) Insufficient operator discipline. 10) Lack of appropriate training. 11) Quality engineers do not escalate recurring deviations quickly enough.
Measurement	12) Acceptance criteria too are broad and not specific to each material model. 13) Testing check list is inconsistently interpreted across teams. 14) Test data are not shared in a timely or comparable format with Volvo.
Micro-environment	15) Temperature, humidity, vibration, or contamination during transport. 16) Wrong storage conditions. 17) Mixed storage conditions at ports, consolidation hubs, or receiving areas.
Management (Governance)	18) Supplier quality audits are too infrequent (e.g., for high-risk parts). 19) Commercial pressure to ship on time despite known minor nonconformities.
Model (Design)	20) Tight tolerance design makes the part highly sensitive to process variation. 21) Design changes are not fully cascaded through lower-tier suppliers.

Figure 10: Potential causes leading to failure of material quality failure.
Source: Author Findings



Fishbone	Potential causes leading to failure of **availability of replacement stock**
Material	22) Long replenishment lead time of souring critical parts from overseas. 23) Batch rejection of incoming replacement stock reducing usable inventory.
Method	24) Stock reorder point is not linked to real defect / warranty failure rates. 25) No differentiated stock policy for urgent warranty parts versus routine parts.
Machine (System)	26) Poor inventory visibility across Sweden and nearby European hubs. 27) Lack of systematic flag of disruptions and/or replenishment risks.
Manpower	28) Teams do not update demand signals quickly after field failures increase. 29) Weak coordination between procurement, warehousing, and service centers.
Measurement	30) Forecasts rely on historic averages only and ignore live warranty trends. 31) Lack of clarity of marketing discount campaign effects. 32) Lack of KPI linking stock cover to route disruption and in-transit delay.
Micro-environment	33) Port congestion. 34) Customs delay. 35) Corridor disruption. 36) Storage constraints in local hubs reduce effective availability.
Management (Governance)	37) Overdependence on one supplier or one maritime route. 38) No pre-approved contingency rule for emergency freight. 39) Lack of clear stock transfer procedure. 40) Lack of alternative routing procedures or emergency souring protocols.
Model (Design)	41) Design consists of too many part variants. 42) Low standardization is fragmenting stock and lowering availability. 43) Warranty replacement demand is not reduced through local repair.

Figure 11: Potential causes leading to availability of replacement stock failure.
Source: Author Findings.

Fishbone analysis (ASQ, 2026) shall be then supported by team collaboration to address one or more improvements that can be initiated to eliminate [or mitigate] multiple root causes, while the measurements get regularly repeated to check the results and adopt any necessary changes.

Improve

Based on the root cause diagnosis, team collaboration can be performed to recommend a coordinated set of quality interventions using brainstorming techniques or focus groups, but they need to be prioritized as objectively as possible.

Table_5 shows an example of prioritization criteria.

In the Volvo EV case, Table_6, below shows suggested ideas.

Table 5: Example of prioritization criteria.

Criteria Dimensions (1 to 10 scale)	Criteria Description
Impact on root-cause reduction	How strongly does the intervention address the diagnosed root cause?
Effect on customer service continuity	How much is it expected to reduce waiting time and complaints?
Cost effectiveness	Is it likely to produce immediate meaningful benefits in cost?
Feasibility of implementation	How realistic is it in terms of data, supplier cooperation, time etc.?
Speed of implementation	How quickly can it be deployed and begin producing results?
Sustainability and control	Can it be maintained over time and embedded into operating practice?

Source: Author Findings and (Kurata & Nam, 2010)

Table 6: Improvement suggested for Volvo EVs.

Improvement	Full Description
Source Quality Gate	This is an additional quality verification for warranty batteries and selected sensitive components before import to Sweden. This could include third-party validation at source, especially in major supply locations, to test performance, verify specification compliance, and reduce the risk of defective units being shipped over long maritime distances.
Re-Order Point System	This is an inventory control mechanism designed for high-risk replacement items. The re-order points should be linked to actual defect rates, replacement demand patterns, lead-time variability, and disruption risk. This would ensure that the system responds to real failure behavior rather than generic inventory assumptions.
Emergency Stock Trigger	This is a disruption response model designed to avoid waiting until service failure becomes visible to customers. Triggers may include inventory dropping below the reorder threshold, incoming shipment delay beyond a pre-defined number of days, abnormal defect spikes, workshop backlog exceed a pre-defined limit, or corridor disruption alerts affecting Asia-Europe maritime routes. Once triggered, predefined countermeasures should be activated, such as emergency stock release, route reallocation, premium freight approval, stock transfer between European sites, or urgent supplier escalation.
Predictive Data-Driven Controls	This is a monitoring system which connects vehicle real-time data, workshop diagnostics, and warranty records to monitor battery condition, temperature exposure, abnormal degradation, and recurring fault patterns. These insights feed into demand forecasting, identify weak supplier batches earlier, and refine reorder-point logic. However, this should be implemented selectively and with proper governance so that data capture remains cost-efficient and compliant with privacy requirements such as GDPR.

Source: Author Findings

By applying the criteria, the priorities shown in Table_7, below, get addressed:

Table 7: Prioritized improvements for Volvo EVs.

Improvement Criteria (1 to 10)	Source Quality Gate	Re-Order Point System	Emergency Stock Trigger	Predictive Data Driven Controls
Impact on root-cause reduction	8	6	7	5
Effect on customer service continuity	9	4	6	8
Cost effectiveness	6	5	7	8
Feasibility of implementation	7	9	4	5
Speed of implementation	6	9	8	3
Sustainability and control	9	8	8	7
Total Score	45	41	40	38

Source: Author Findings

Still, within the proposed framework, DMAIC functions as the quality improvement roadmap by structuring the project into the stages. However, the improvement stage is not treated as a single implementation event. Rather, each selected intervention (in Table_7) is developed through its own PDSA (Plan, Do, Study and Act) cycle. Agile methodology (See Figure_12) can be integrated here allowing planned actions to be refined, and either standardized or adjusted based on evidence.

Control

When several improvement projects are operating in tandem, agile project management approach is used to coordinate and control these PDSA streams via iterative planning, execution, review, and prioritization. (IHI, 2026). DMAIC is used for governance at a higher level, PDSA is used for learning at a lower level, while agile approach is used for implementation. Table_8 illustrates five different control activities that can be used.

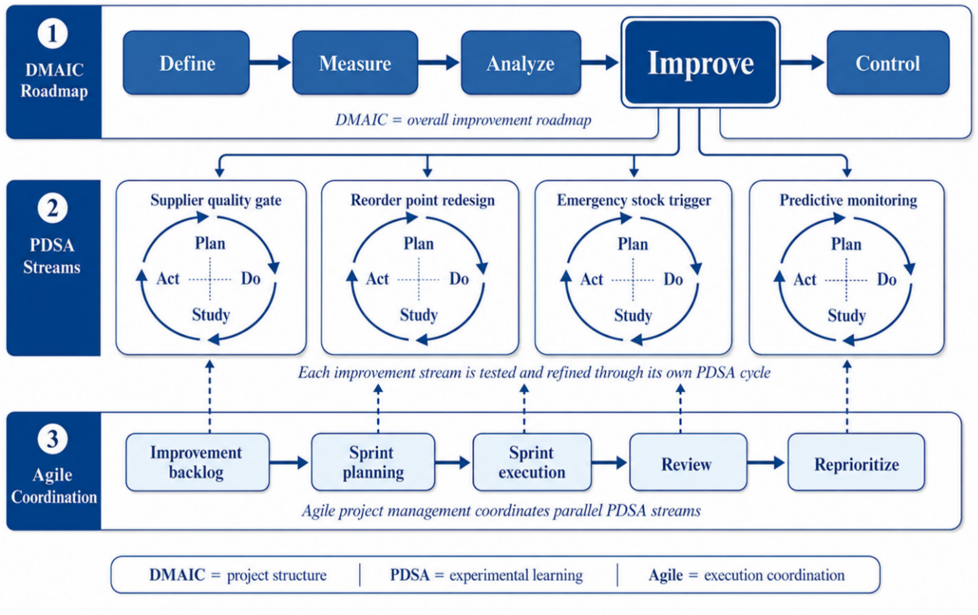


Figure 8: DMAIC – PDSA – Agile framework.
Source: Author Findings and (NHS England, 2019)

Table 7: Suggested Control Activities.

Area of Control	Control Description
Policy and Procedures	It is very important that the company adopts new policies and procedures along the improvement progress to sustain the results.
	Volvo shall establish a quality review process across procurement, logistics, after-sales service, quality, finance, and legal teams to promote compliance and capture difficulties.
Quality Measure	Volvo should monitor a defined dashboard of KPIs including: 1) stock fill rate for replacement parts, 2) defect recurrence, 3) average customer waiting time, 4) emergency freight usage, 5) batch rejection rates, and 6) route-delay indicators.
Risk	Volvo shall review the customs of its supply, insurance coverage, and contractual compensation rights to improve accountability and reduce the financial burden of disruption.
Cost	Volvo system shall also be supported by premium battery-care or extended warranty offerings, provided these are framed as customer-value services rather than simple cost recovery.

Source: Author Findings

CONCLUSION

In general, the suggested framework proves that disruption on sea routes cannot be considered solely an issue of transport. With respect to Volvo EV, one may observe how disruption causes a larger quality problem with regard to predictive spare parts planning, warranty service, inventory management, suppliers' reliability, and customer reaction. Through the use of the DMAIC methodology, Volvo can transition from replacement logistics to replacement supply.

Such an approach improves not only maturity and readiness to disruption, but also the overall performance and quality of the firm's existing SC.

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