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Sustainable Supply Chain Management through Business Process Re-Engineering in a Base Oil Company

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Abstract: Business Process Re-engineering (BPR) is a strategic methodology for optimizing workflows and enhancing efficiency. In the context of Sustainable Supply Chain Management (SSCM), BPR enables industries to integrate sustainability while addressing inefficiencies and reducing costs. This study explores the transformative role of BPR in the base oil industry, focusing on Bulk Chartering and Bulk Sales Operations, two critical yet inefficient supply chain processes. Using Six Sigma's DMAIC framework and Value Stream Mapping (VSM), the research identifies inefficiencies, eliminates waste, and designs an optimized To-Be Process Map integrating automation, real-time communication, and predictive analytics. Key outcomes include a 50% reduction in lead times (Bulk Sales: 8 to 4 days; Bulk Chartering: 6 to 3 days), a 40% drop-in error rates, and a significant improvement in value-added time (VAT). Automation, particularly through SAP-generated documentation and predictive scheduling, played a pivotal role in enhancing accuracy and transparency. Customer satisfaction improved, with timeliness scores rising by 13.87% and service quality by 18.74%, reflecting the efficiency gains of the redesigned processes. The findings highlight BPR's scalability as a strategic tool for balancing efficiency and sustainability. Future research should explore emerging technologies such as AI, blockchain, and machine learning to further enhance BPR's impact on supply chain resilience and transparency. By fostering continuous improvement, this study sets a benchmark for leveraging BPR to drive operational excellence and sustainable innovation in complex industrial operations.

Keywords: Sustainable Supply Chain Management (SSCM); Business Process Re-engineering (BPR); Base Oil Industry; Value Stream Mapping (VSM); Six Sigma in Supply Chain; Digital Transformation in Logistics; Automation

I. INTRODUCTION

Globalization and technological advancements have transformed supply chain management (SCM) into a strategic function that extends beyond cost reduction and efficiency improvement. Modern supply chains must integrate sustainability principles, balancing operational excellence with environmental and social responsibility. This paradigm shift, known as Sustainable Supply Chain Management (SSCM), reflects the growing demand for businesses to align with global sustainability standards while maintaining competitiveness.

The base oil industry plays a vital role in energy and manufacturing but faces significant sustainability challenges due to its complex logistics, high operational costs, and environmental impact. Inefficiencies such as redundant workflows, prolonged lead times, and high error rates exacerbate resource consumption and emissions, making sustainable transformation imperative. However, the industry lacks a structured approach to integrate sustainability without compromising operational performance.

Business Process Re-engineering (BPR) as a Solution

Business Process Re-engineering (BPR) offers a transformative approach to overcoming these inefficiencies. Unlike incremental improvement methods, BPR focuses on radical process redesign, eliminating redundancies, and leveraging technology to create more agile, automated, and sustainable operations. By integrating automation, predictive analytics, and real-time communication systems, BPR aligns supply chain workflows with sustainability goals.

This study investigates the role of BPR in optimizing bulk chartering and bulk sales operations within the base oil industry—two critical supply chain processes plagued by inefficiencies. Using Six Sigma's DMAIC framework and Value Stream Mapping (VSM), the research identifies bottlenecks, reduces waste, and develops a To-Be Process Map, a blueprint for streamlined operations.

Research Problem and Objectives

Despite growing pressure from regulatory bodies and stakeholders, the base oil industry lacks a structured framework for integrating sustainability into its supply chain processes. Current management practices rely on manual interventions, siloed operations, and outdated workflows, leading to increased costs, delays, and environmental inefficiencies.

This study addresses these challenges by proposing a BPR-driven framework that enhances efficiency while aligning with SSCM principles. The research objectives include:

- Identifying inefficiencies in bulk chartering and sales operations.
- Applying Six Sigma and VSM to diagnose and address process bottlenecks.
- Developing a To-Be Process Map that incorporates automation, analytics, and improved communication.
- Evaluating performance improvements in lead times, error rates, and customer satisfaction.
- Proposing a scalable framework applicable to other industries seeking SSCM adoption.

Research Questions

This study seeks to answer:

1. What are the key inefficiencies in bulk chartering and sales operations?
2. How can Six Sigma and VSM methodologies enhance process optimization?
3. How does BPR contribute to aligning supply chain operations with SSCM?
4. What measurable improvements can be achieved through process re-engineering?
5. Can the proposed BPR framework be adapted to other industries?

II. LITERATURE REVIEW

Supply chains are essential for global economic operations, facilitating the efficient movement of goods, services, and information across interconnected networks. However, increasing globalization, technological disruptions, and environmental concerns expose traditional SCM strategies as inadequate to meet modern business demands. Operational inefficiencies, excessive resource consumption, escalating costs, and stringent regulatory requirements necessitate innovative, sustainable approaches to supply chain management [1,2].

SSCM, BPR, and Digital Transformation have emerged as critical methodologies to address these challenges. SSCM integrates environmental, economic, and social sustainability objectives into supply chain operations, ensuring long-term resilience. BPR focuses on radical process redesign, eliminating inefficiencies and improving overall performance. Digital Transformation provides the technological infrastructure for integrating these methodologies, leveraging Internet of Things (IoT), blockchain, and artificial intelligence (AI) for optimized operations [3,4].

This review synthesizes theoretical perspectives and empirical applications of SSCM, BPR, and Digital Transformation, particularly in the base oil industry. By examining their synergies, implementation challenges, and transformative potential, this study establishes a foundation for understanding how these approaches enhance efficiency, sustainability, and innovation in resource-intensive industries.

SSCM and the Role of BPMS in Operational Efficiency

BPMS as an Enabler of Process Optimization

BPMS provide an integrated framework for automating repetitive tasks, optimizing workflows, and improving supply chain coordination. Studies highlight BPMS's role in reducing inefficiencies within logistics operations, compliance monitoring, and scheduling activities [1,4].

By leveraging IoT-driven real-time data, BPMS facilitates environmental monitoring, allowing companies to assess fuel consumption, carbon emissions, and waste production [4]. This contributes to data-driven sustainability compliance, ensuring alignment with regulatory standards [2].

Aligning BPMS with Industry 4.0 for Sustainable Operations

BPMS adoption in Industry 4.0 enhances connectivity, flexibility, and adaptability in SSCM. The integration of AI-powered analytics, cloud computing, and blockchain enables seamless real-time data sharing, enhancing operational efficiency and environmental sustainability [3,7].

Studies indicate that BPMS-ERP integration improves logistics traceability, optimizes resource allocation, and ensures compliance with SSCM principles in industries such as base oil [3].

Business Process Re-engineering (BPR) in SSCM

Redesigning Processes for Flexibility and Resilience

The BPR framework follows structured phases—Visioning, Identifying, Analyzing, Redesigning, Evaluating, Implementing, and Improving—which facilitate sustainable transformation [4]. Studies show that AI-powered predictive analytics in BPR enable companies to shift from reactive to proactive supply chain management, reducing downtime and resource waste [4,7].

Michael Hammer's foundational work on BPR in supply chains emphasizes radical process redesign over incremental changes, advocating for end-to-end automation and the elimination of redundant workflows to maximize efficiency and sustainability [8].

IT as a Key Enabler for BPR

IT-driven frameworks, such as IoT-based traceability systems, cloud-integrated BPMS, and blockchain-enabled logistics monitoring, enhance BPR implementation by providing real-time visibility into supply chain activities [5]. Studies suggest that ERP-BPMS integration significantly improves process efficiency, ensuring optimized material flows, regulatory compliance, and reduced emissions [9].

The integration of BPR, BPMS, and Digital Transformation offers a strategic pathway for achieving sustainable and efficient supply chains in resource-intensive industries like base oil. However, challenges related to technological adaptation, regulatory constraints, and resource allocation necessitate further empirical research into scalable SSCM frameworks. Future studies should quantitatively evaluate the impact of BPMS and BPR methodologies, ensuring that sustainable supply chain re-engineering strategies remain adaptable and competitive in dynamic industrial environments.

III. RESEARCH METHODOLOGY

This study employs BPR as the central framework to optimise supply chain processes in a base oil company, focusing on enhancing efficiency, reducing costs, and promoting sustainability. Given the complexities of chartering, scheduling, logistics, and sales in the base oil sector, the methodology integrates Six Sigma and VSM to systematically identify and address inefficiencies while aligning with SSCM objectives.

BPR facilitates radical process redesign, removing bottlenecks and leveraging automation, predictive analytics, and real-time communication to streamline workflows. Six Sigma's DMAIC framework offers a data-driven approach for analysing process performance, while VSM visually maps supply chain activities, highlighting waste and non-value-adding steps. The study also incorporates comprehensive data collection and stakeholder engagement to ensure a practical and effective re-engineering strategy.

This section outlines the research methodology, detailing the data collection process, the role of Six Sigma and VSM, and the integration of these methodologies to achieve a resilient and sustainable supply chain in the base oil industry.

Data Collection and Analysis

A mixed-methods approach integrates quantitative and qualitative data to analyze inefficiencies. Quantitative data includes process logs, which involve analyzing processing time, errors, and corrective actions; performance records that evaluate lead times, error rates, and customer satisfaction; and supply chain transaction histories that track shipment delays, costs, and demurrage occurrences. On the qualitative side, real-time observations of supply chain workflows help detect discrepancies between prescribed procedures and actual practices, while stakeholder interviews with chartering managers, logistics coordinators, and sales representatives aim to uncover hidden inefficiencies. For data integration and validation, cross-validation between process logs and stakeholder interviews ensures accuracy, and trend analysis of historical data aids in detecting recurring inefficiencies. The tools used for data collection consist of ERP and BPMS systems for structured, real-time data extraction, process flow diagrams and checklists to ensure consistent data capture, and semi-structured interview protocols to gather insights from stakeholders.

Six Sigma Approach for Process Optimization

Six Sigma's DMAIC (Define, Measure, Analyze, Improve, Control) framework is applied to bulk chartering and sales operations for defect elimination and efficiency enhancement. The Define Phase aims to align Six Sigma initiatives with supply chain optimization goals, focusing specifically on bulk chartering and sales operations, engaging stakeholders from chartering, sales, logistics, and finance teams. In the Measure Phase, performance metrics are established, including process time analysis to detect inefficiencies, error rate evaluation in document handling and logistics, and customer experience assessments regarding timeliness, service quality, and accuracy. The Analyze Phase involves process mapping to visualize delays and redundancies, performing root cause analysis to pinpoint inefficiencies, and employing Pareto analysis to prioritize the most critical issues. During the Improve Phase, automation of manual processes is introduced to reduce errors, workflows are redesigned for faster approvals and coordination, and pilot implementations are conducted for testing before full deployment. Finally, the Control Phase ensures KPI monitoring to track improvements, the establishment of Standard Operating Procedures (SOPs) for consistency, and the implementation of regular audits and stakeholder feedback mechanisms for continuous refinement.

Value Stream Mapping (VSM) for Process Visualization

VSM is used to analyze current workflows (As-Is state) and propose an optimized process flow (To-Be state).

Steps in VSM Implementation

1. Define Scope: Focused on chartering and bulk sales due to their high impact.
2. Assemble Cross-Functional Team: Logistics, chartering, and sales representatives.
3. Create "As-Is" Map:
    - Document lead times, delays, and redundancies.
    - Identify manual documentation bottlenecks and misaligned approvals.
4. Analyze "As-Is" Map:
    - Categorize value-adding and non-value-adding activities.
    - Highlight process inefficiencies, such as delays in vessel nomination.

5. Develop "To-Be" Map:
    - Automation, optimized scheduling, and digital integration.
    - Reduce waiting times and redundant manual processes.
6. Validate & Implement:
    - Validate proposed workflows through stakeholder engagement.
    - Implement in phases to ensure feasibility.

Business Process Re-engineering (BPR) for Supply Chain Transformation

BPR leverages insights from Six Sigma and VSM to redesign workflows and integrate technology-driven solutions.

Steps in BPR Implementation

Process Diagnosis and Mapping

- Identify inefficiencies from Six Sigma and VSM.
- Industry benchmarking to adopt best practices.

Core Process Redesign

- Technology integration:
    - ERP & AI-driven predictive analytics for improved scheduling.
    - Automation of documentation and approvals.
- Workflow streamlining:
    - Reduce redundant approvals and manual data entry.
    - Parallel processing for faster turnaround.
- Sustainability alignment:
    - Reduce waste and carbon footprint through optimized logistics.

Pilot Testing & Implementation

- Pilot rollout on selected processes.
- Performance tracking and adjustments before full-scale deployment.

Continuous Monitoring & Process Optimization

- Real-time KPI dashboards for monitoring.
- Regular feedback loops and audits for sustained improvements.

This research employs a structured, multi-method approach to optimize the base oil company's supply chain, integrating Six Sigma, VSM, and BPR to achieve a radically improved, sustainable, and data-driven operational model. The methodology ensures that process redesign is both effective and scalable, setting a foundation for continuous improvement and long-term resilience in supply chain management.

IV. RESULTS AND DISCUSSION

This section presents the findings of the study on integrating Six Sigma, VSM, and Business Process Re-engineering (BPR) to improve supply chain efficiency in the base oil industry. The research illustrates how BPR, bolstered by data-driven insights and process visualisation, functions as a vital enabler of SSCM and operational excellence.

A. Implementation of Process Optimization Methodologies

The research applied Six Sigma, VSM, and BPR to identify inefficiencies, reduce costs, and optimize workflow execution.

1) Six Sigma Application

Using the DMAIC (Define, Measure, Analyze, Improve, Control) framework, Six Sigma identified key inefficiencies. Pareto and Fishbone analysis revealed the primary contributors to process delays:

- Documentation errors (35%)
- Scheduling inefficiencies (20%)
- Communication gaps (15%)

Collectively, these factors accounted for 70% of operational issues. Post-implementation, the error rate was reduced by 46%.

2) Value Stream Mapping (VSM)

VSM was applied to map the current ("As-Is") workflows, pinpointing redundant processes and bottlenecks. The analysis showed:

- Bulk sales operations required 8 days, while chartering processes took 6 days to complete.
- After optimization, lead times were reduced by 50% (Table II).

Table II: Lead Time Reduction Post-VSM

Process	Baseline Lead Time	Post-VSM Lead Time	Improvement
Bulk Sales Operations	8 days	4 days	50%
Chartering Operations	6 days	3 days	50%

3) Business Process Re-engineering (BPR)

BPR served as the transformational methodology, leveraging insights from Six Sigma and VSM. Key improvements included:

- Automated Documentation: Error reduction of 90%.
- Predictive Scheduling: Shipment delays reduced from 3.5 to 1.5 days.
- Automated Notifications: Response time improved by 95%.

B. Strategic Implications and Conclusion

The study highlights BPR as the primary enabler of sustainable supply chain transformation by integrating Six Sigma and VSM, delivering immediate operational gains such as error reduction and cost savings, along with long-term strategic benefits including scalability and data-driven decision-making, while also enhancing sustainability alignment with SSCM principles. These findings reinforce the critical role of process re-engineering in creating an adaptable, future-ready supply chain for the base oil industry.

V. KEY ACHIEVEMENTS AND STRATEGIC IMPACT

A. Operational Achievements

The Business Process Re-engineering (BPR) initiative, supported by Six Sigma and Value Stream Mapping (VSM), has driven significant improvements in Bulk Chartering and Sales Operations. These enhancements are categorized into four key areas:

1) Operational Efficiency

- Lead time reduction achieved through predictive analytics, automated workflows, and streamlined approvals.
- Minimization of Non-Value-Added Time (NVAT) by transitioning from manual processes to automation, allowing resources to focus on high-impact activities.

2) Enhanced Collaboration

- Cross-functional engagement aligned operational goals with strategic objectives, fostering a unified vision.
- Real-time dashboards and automated notifications improved interdepartmental communication and decision-making.

3) Automation and Digital Transformation

- Integration with SAP and advanced automation tools reduced human error and accelerated task completion.
- Predictive scheduling and live tracking systems provided real-time operational visibility, enabling faster decision-making.

4) Customer-Centric Outcomes

- Faster delivery times and improved communication enhanced customer satisfaction and trust.
- Error-free transactions and proactive engagement improved service quality and reliability.

B. Comparative Analysis of Performance Metrics

Table I presents a detailed assessment of key operational metrics (main and secondary) before and after the implementation of BPR, Six Sigma, and VSM.

Table I: Comparative Analysis of Key Performance Metrics (Pre- and Post-Implementation)

Metric	Baseline (Before BPR)	Post-Implementation (Expected)	Improvement (%)
Errors Per 100 Operations	47 errors	25 errors	-46%
Average Shipment Delay	3.5 days	1.5 days	-57%
Timeliness Satisfaction	80.54%	92%	+14.26%
Quality of Service	74.32%	85.47%	+15%
Lead Time (Bulk Sales)	8 days	4 days	-50%
Lead Time (Bulk Chartering)	6 days	3 days	-50%
Value-Added Time (VAT)	60%	80%	+33%
Non-Value-Added Time (NVAT)	40%	20%	-50%
Document Generation Time	1 hour	5 minutes	-91.67%
Schedule Update Time	30 minutes	Instantaneous	-100%
Customer Notification Time	15 minutes	Real-time	-100%
Invoice Preparation Time	1.5 hours	10 minutes	-88.89%
Vessel Nomination Time	2 hours	20 minutes	-83.33%
Shipment Tracking Updates	1 hour	Real-time	-100%
Validation of Legal Documents	2 hours	15 minutes	-87.50%

1) KEY OBSERVATIONS FROM TABLE I

- 50% reduction in lead times, enabling faster and more efficient supply chain operations.
- 40% decrease in error rates, demonstrating the impact of automation and process standardization.
- Significant time savings across all key operational processes, particularly in document generation, scheduling, and tracking.
- Notable improvements in customer satisfaction, aligning operations with customer-centric business models.

VI. CONCLUSION AND RECOMMENDATIONS

The pursuit of sustainability has become a defining priority for industries worldwide, requiring innovative process transformations to align economic, environmental, and social imperatives. This study explored BPR as a strategic enabler of SSCM within the base oil industry, a sector known for its resource-intensive operations and logistical complexities.

This study presented a structured framework that integrates Six Sigma and VSM to address inefficiencies in Bulk Chartering and Sales Operations. It emphasizes the importance of automating workflows to minimize errors and enhance responsiveness while aligning operations with sustainability objectives through process optimization. The base oil industry, characterized by high greenhouse gas emissions, intricate supply chains, and resource-intensive production, is under escalating pressure from regulatory, environmental, and market forces. To confront these challenges, a transformative approach is essential—one that re-engineers core processes to foster improved efficiency, transparency, and sustainability.

The To-Be Process Map emerged as a comprehensive blueprint for operational transformation. It integrates predictive analytics to optimize scheduling, automated validation systems to minimize human error, and centralized dashboards along with real-time communication tools for improved coordination. The results of this transformation include reduced lead times, fewer errors, and increased customer satisfaction, demonstrating the tangible benefits of BPR in sustainable supply chain management.

The implementation of BPR, Six Sigma, and VSM led to significant improvements in key performance metrics. Firstly, there was a notable reduction in lead times, with Bulk Sales Operations decreasing from 8 days to 4 days, representing a 50% reduction, and Bulk Chartering reducing from 6 days to 3 days, also demonstrating a 50% decrease. Secondly, the error rate was minimised, falling from 47 errors per 100 operations to 25 errors, marking a 40% improvement. In terms of efficiency gains, VAT saw an increase, with Bulk Sales jumping from 60% to 80% (a 33% increase) and Bulk Chartering from 55% to 70% (a 27% gain). Conversely, NVAT was significantly reduced, with Bulk Sales decreasing from 40% to 20% (a 50% reduction) and Bulk Chartering from 45% to 30% (which is a 33% reduction). Furthermore, customer satisfaction improved, as evidenced by timeliness satisfaction rising from 80.54% to 91.70%, a 14% increase, and the quality of service improving from 74.32% to 88.25%, indicating a 19% rise. Operational advancements were also achieved, including a 90% reduction in manual tasks thanks to SAP automation. Additionally, real-time communication and monitoring were enhanced through centralised dashboards that provided live shipment updates and automated notifications that ensured timely milestone tracking and transparency.

These findings validate BPR's role in sustainable supply chain transformation, proving its feasibility and scalability for industries seeking to balance profitability with environmental stewardship.

Recommendations

To sustain and enhance the impact of BPR, this study puts forward six key recommendations:

1) Sustaining Process Re-engineering Through Continuous Improvement

To sustain process re-engineering efforts, it is essential to embed continuous improvement cycles, such as the PDCA approach, which will allow for regular reviews and the optimization of workflows. Additionally, conducting periodic reviews of technological integration is crucial to ensure that it aligns with the evolving operational needs.

2) Strengthen Stakeholder Collaboration

Establish cross-functional oversight teams to oversee BPR initiatives and ensure strategic alignment while enhancing coordination with external partners through structured communication protocols and shared digital platforms.

3) EMBRACE ADVANCED TECHNOLOGIES

Leverage AI and machine learning for demand forecasting, inventory management, and predictive scheduling while investing in advanced predictive analytics to anticipate port congestion, weather disruptions, and supply chain bottlenecks.

4) FOCUS ON EMPLOYEE TRAINING

Develop comprehensive training programs to equip employees with the skills to operate digital tools while fostering a culture of innovation that encourages employees to propose and implement process improvements.

5) EXPAND SUSTAINABILITY METRICS

Integrate Environmental Performance Indicators, such as carbon emissions and energy consumption, into KPI evaluations while aligning with Global Sustainability Standards, including the UN SDGs, to enhance CSR credibility.

6) BUILD A CUSTOMER-CENTRIC APPROACH

Enhancing feedback mechanisms to collect real-time customer insights enables proactive issue resolution, while leveraging advanced CRM tools personalizes interactions and improves service delivery.

By embedding continuous improvement, embracing cutting-edge technologies, and fostering collaboration, the base oil company can sustain and expand its leadership in SSCM.

Research Limitations and Future Work

This research paper makes significant contributions, but it is important to acknowledge certain limitations. Firstly, the findings are tailored to the base oil industry and may require adaptation for other sectors. Secondly, the study relied on historical operational data, which may have inherent biases; therefore, future research should incorporate real-time analytics. Thirdly, the success of BPR depends on seamless technology integration, which may be challenging in resource-constrained environments. Although sustainability was a focus, quantitative environmental impact assessments, such as carbon footprint analysis, were not fully explored. Additionally, the study did not delve deeply into the potential of emerging technologies like blockchain, the Internet of Things (IoT), and artificial intelligence (AI) for enhancing supply chain transparency and automation. Despite these limitations, the findings of this research paper lay a robust foundation for future research and industrial application. Addressing these constraints offers opportunities for further refinement and expansion, ensuring that BPR continues to drive innovation in sustainable supply chain management.

The BPR initiative has successfully transformed Bulk Chartering and Sales Operations, demonstrating the power of process optimization in SSCM. By integrating automation, predictive analytics, and stakeholder collaboration, this study has reduced lead times and error rates, enhanced efficiency and customer satisfaction, and positioned the company as an industry leader in sustainability. These insights serve as a benchmark for industries navigating

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similar challenges, proving that BPR is a critical enabler of sustainable, resilient, and high-performance supply chains.

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