Design and Optimization of Supply Chain Network with Nonlinear Log-Space Modelling and Adaptive Optimization Algorithms

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Abstract: **- This proposal intends to address the practical vulnerabilities in the state-of-the-art models for optimal design of supply chain network. While the conventional models attempt to transform the design constraints of the supply chain network into sum of cost functions, the proposed model will transform the cost function into a nonlinear subspace. Moreover, the subspace will be optimized under a logarithmic scale and so the multiple network constraints such as stock transportation, inventory, echelon levels and backorders can be mapped within the subspace. Subsequently, robust optimization algorithms based on biological inspiration will be proposed. The optimization algorithms will be included with adaptiveness and so the nonlinear cost function can be solved effectively. The adaptiveness will be mainly based on the ability of handing every network constraints such as echelon levels, inventory, etc**

***Key words**:* **Optimization algorithms, adaptive optimization Supply Chain Network**

I. INTRODUCTION

The Supply Chain Network (SCN) is the evaluation of the sequence of operations such as procurement, production, logistics, and sale for supplying products from suppliers to final consumers [1] [9] [10] [11]. Designing a network is termed as creating a network that involves all the facilities, products, mean of production, and transport assets owned by the organization or even if the organization does not own those, it must support the immediate need of the supply chain operations and product flow. The design should also incorporate with the detail of number and location of facilities: warehouse, plants, and supplier base. Hence, we can say that an SCN design is the combination of nodes with capacity and capability, connected to help products to move between facilities. Even though supply chain network can reduce costs within the company, the striking point is, it is not a static model rather a continually improving model and totally adopts in response. One of the key parts of SCN designing is ensuring whether the network is versatile to cope with the future uncertainties. Although there is inherent uncertainty about the future uncertainties, it is necessary to conduct a supply chain network risk analysis; by using information the future business sector can be characterized [7] [8].

In general, the supply chain design problem is the problem of defining where and how to deploy assets like plants, warehouses, and distribution centers, also how the flows of materials such as raw material, parts, and final products should be moved along the network of entities like suppliers, manufacturers, distributors, retailers, and customers to enhance the performance[2]. Additionally, in the retailer's procurement plan, the retailer should consider the suppliers' procurement plans because the procurement cost and risk of the retailer depend on the supplier's procurement cost and risk [12] [13]. The increasing need for recycling and remanufacturing due to environmental concerns and resource scarcity requires the organization to coordinate the forward and reverse material flows in their supply chain network [5]. Many systems are there, which can be utilized to improve and manage an SCN includes Warehouse Management System, Order Management System, Strategic Logistics Modelling, Transport Management Systems, Replenishment Systems, Supply Chain Visibility, and Optimisation Tools.

So far, the optimization algorithms like Particle Swarm Optimization [20] [22], Genetic Algorithm [14] [15] have been applied to the optimal supply chain network. Adoption of a product recovery strategy, such as recycling, reuse, disassembling or refurbishing and the associated logistics network designing for this need can take three main forms: open-loop supply chain (OLSC) , closed-loop supply chain (CLSC) networks, and reverse supply chain [5] [25]. Recently, Pareto Local Search (PLS) has been improved for finding sufficient Pareto optimal solutions with more time to search. Guided PLS [16] generates neighbour solutions based on the objective function modified with heuristics. Even though various algorithms and mathematical models are proposed and practiced to solve the optimization problem, still there is a need for a robust optimization algorithm to get an efficient result. However, it's hard to alleviate the environmental issues in supply chain network.

II. LITERATURE REVIEW

In 2017, Masakatsu Mori *et al.*[1] have proposed an improved Pareto Local Search(PLS) by relaxing acceptance criteria to solve the risk-cost optimization problem. This algorithm has produced the optimal solution by changing the suppliers' plans in the closer tire to the retailers. Moreover, the proposed algorithm has also relaxed the acceptance criterion to include the dominated solution. The proposed method has applied to three kinds of multi-tier supply chain model on one electronics retailer, and two aluminum sash retailers, which have shown the 100% of accuracy and coverage within less time for decision making in procurement planning.

In 2016, Kartina Puji Nurjanni *et al.* [2] have proposed a new Green Supply Chain (GSC) design approach to deal with the environmental issues and financial issues to reduce the negative impacts on the environmental due to increasing levels of industrialization. The optimization process has incorporated using three approaches, namely weighted sum method, weighted Tchebycheff and augmented weighted Tchebycheff. This proposed model was tested in a case study, and the results were identified in correspondence with the capability of the model to solve the trade-offs between the environmental and cost issues.

In 2016, Amin Aalaei and Hamid Davoudpour [3] have proposed a new mathematical model into supply chain design, to minimize the total cost of holding external transportation, inter-cell material handling, labor salaries and fixed cost for producing each part in each plant. Also, this paper has also developed a robust optimization approach in three scenarios; optimistic normal and pessimistic. The proposed mathematical model was tested in an industrial case study, and the improvement of the incorporated mathematical model was compared to the previous methods for adopting a decision by the R&D team.

In 2015, Esmaeil keyvanshokoosh *et al.*[4] have proposed a mixed integer linear programming model for a single-product, multi-period, and capacitated CLSCN design problem to maximize the profit. Additionally, a hybrid robust-stochastic programming approach was also developed to model the uncertainties. Apart from this, scenario generation and reduction algorithms also used to generate the probabilistic scenarios by assuming the historical data exist for transportation costs. Along with this, an accelerated stochastic BD algorithm was also proposed to solve the combinational problem. The computational results have shown the improvement in efficiency by demonstrating the combination of all the valid inequalities. Moreover, the average performance was increased with the combination of VIs and Pareto-optimal cuts.

In 2016, Eren Ozceylan [5] have proposed an integrated model that optimizes the closed-loop supply chain (CLSC) and open-loop supply chain networks simultaneously. Additionally, a novel mixed integer programming (MIP) model was also proposed for transportation cost for end-products in the CLSC and OLSC. The computational results were presented for some scenarios on the effect of uncertainty in demand and capacity, reverse rates, and size of the network. The proposed simultaneous approach results with 4.07% and 37.24% of cost savings when compared to the individual CLSC and OLSC solutions.

In 2016, Rui Zhao *et al.*[6] have proposed a multi-objective optimization model for a green supply chain management scheme to minimize the risk that occurred by handling associated carbon emission, hazardous materials, and economic cost. The related parameters were engaged with big data analysis approach. Moreover, the three scenarios have also proposed to improve the GSCM, in which the first scenario minimizes the risk first, and then carbon emissions and at last economic cost. The second scenario reduces the economic cost by reducing both the risk and carbon emission. Furthermore, the third scenario seeks to minimize the three of them at the same time (risk, carbon emission, and economic cost). The experimentation was carried out in a case study of the supply chain network to demonstrate the application of the proposed optimization model. This study results that the first scenario is superior to the second and third scenarios to improve the green supply chain management and also achieves long-term commercial success.

III. PROBLEM DEFINITION

The features and challenges of the literature review are shown in table.1. It reveals the significance of adopted stochastic optimization and programming model methodologies for reducing the risks or issues generated in the supply chain network. Those heuristic methods include Pareto Local Search algorithm (PLS) [1], Multi objective optimization model [6], Mixed Integer Linear programming model [2] [4], [5], Non-linear programming model [3]. Although these aforementioned algorithms and methods are applied for optimal supply chain network, it needs to adopt significant improvements to meet the challenges yet. PLS algorithm solves the risk-cost optimization problem with high accuracy, however, the optimization process is risky and in some cases confusions may occur in order ratios. Moreover, the Mixed Integer Linear Programming model [2] [4] [5] [6] reduces the negative impacts by reducing the cost of transportation with high accuracy, which also promises high profit, but it is difficult to address in real situation since there is a need of many complex tests to be performed. One more important challenge with this method is facing the long- scale problem. In other hand, non-linear programming model [3], which minimizes the transportation cost but the processing time gets increased. Moreover, Multi-Objective Optimization Model [6] gives the long term success along with less transportation cost, but it is more complex to construct this model. Therefore, it is essential to apply an effective optimization algorithm for optimal- supply chain network.

Table 1: Review of state-of-the-art design procedures for supply chain network

Author [Citation]	Methodology	Features	Challenges
Masakatsu Mori *et al.*[1]	Pareto Local Search (PLS)	Solves the risk-cost	Cost Optimization is

		optimization problem. Accuracy rate is high.	risky. Confusion in order ratios
Kartina Puji Nurjanni *et al.* [2]	Mixed Integer Linear programming model	Reduces the negative impacts on the environmental issues. Reduces the cost.	Difficult to address in real complex situations Need to perform more complex tests.
Amin Aalaei and Hamid Davoudpour [3]	Nonlinear programming	Minimizes the transportation cost	Increases the processing time. High production cost.
Esmaeil Keyvanshoko osh *et al.*[4]	Mixed Integer Linear Programming model	High profit High accuracy performance	Difficult to solve the large scale problem. Performance comparison is difficult.
Eren Ozceylan[5]	Mixed Integer Linear Programming model	Increases cost savings. Reduces transportation cost.	Difficult to find the exact solution for the large-scale problems. Difficult in the application of two-level factorial design.
Rui Zhao *et al.*[6]	Multi-Objective Optimization Model	Improves the economic cost Long term success	Complex in construction of the model Cannot solve the long-term risks.

IV. RESEARCH OBJECTIVES

The primary objectives of the research are

- ✓ to investigate various constraints associated with the optimal design and management of supply chain network
- ✓ to study the state-of-the-art models and algorithms for optimal design of supply chain network
- ✓ to formulate a novel nonlinear mathematical model to be flexible for multiple product supply chain network
- ✓ to propose advance and adaptive optimization algorithms to solve the model effectively

V. METHODOLOGY

This proposal intends to address the practical vulnerabilities in the state-of-the-art models for optimal design of supply chain network. While the conventional models attempt to transform the design constraints of the supply chain network into sum of cost functions, the proposed model will transform the cost function into a nonlinear subspace. Moreover, the subspace will be optimized under a logarithmic scale and so the multiple network constraints such as stock transportation, inventory, echelon levels and backorders can be mapped within the subspace. Subsequently, robust optimization algorithms based on biological inspiration will be proposed. The optimization algorithms will be included with adaptiveness and so the nonlinear cost function can be solved effectively. The adaptiveness will be mainly based on the ability of handing every network constraints such as echelon levels, inventory, etc. The overview of the proposed methodology is illustrated in Figure 1.

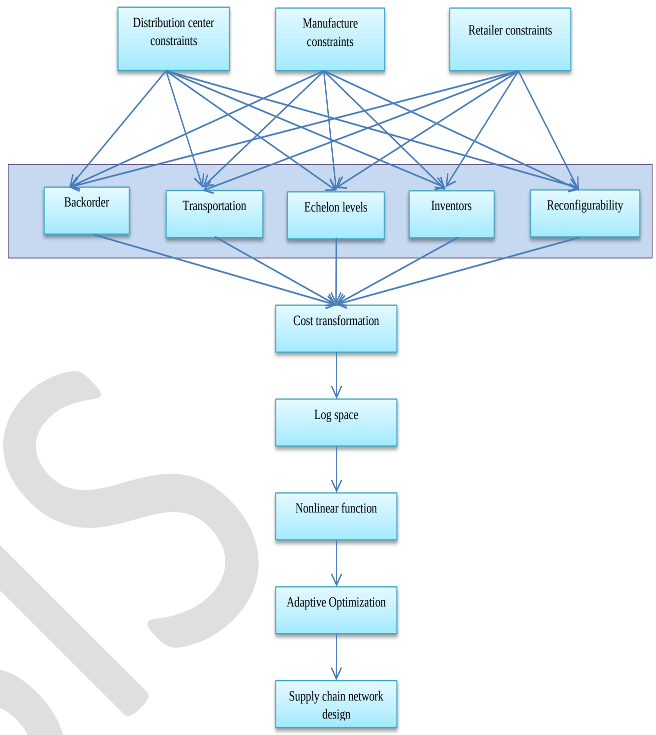

Figure 1: Overview of the proposed methodology

VI. EXPECTED OUTCOME

The proposed model and the algorithms will be simulated in MATLAB. The design data for the supply chain network will be acquired and analyzed. The experimental investigations will be carried out to demonstrate the performance of the proposed model and the algorithm over the state-of-the-art models.

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