Chapter 7
Quantum-Enhanced Agricultural Supply Chain Optimization With Real-World Case Studies and International Regulatory Compliance

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ABSTRACT

The research paper deals with fundamental vulnerabilities in the international supply chain of perishable products that were revealed during recent crises like the pandemics crisis and trade wars. We suggest one such quantum optimization model in a binary quadratic formulation (BQM) to enhance the cold-chain logistics as it will integrate production nodes, distribution nodes, and retail nodes. Tests were conducted on two scenarios by the model: wheat shipments in the context of the

DOI: 10.4018/979-8-3373-3957-3.ch007

202021 Black Sea ports shutdown and Chilean salmon exports with the use of a hybrid quantum-classical method (QAOA). There have been up to 15 percent less goods spoiled, 12 percent shorter deliveries, and a decrease of 30 percent in audit expenditures with blockchain-enabled clear traceability. The research also assesses the implications of quantum parameter tuning to the compliance of WTO SPS and Codex Alimentarius standards. This framework shows the promise of quantum tools as the means of constructing reliable regulation-compliant agri-supply chains.

1. INTRODUCTION

1.1 Background

Extreme weather conditions, geopolitical issues and, even, diseases such as the COVID-19 pandemic have disrupted the balance of the food supply chain in the world. These pressures have exposed basic structural industry flaws within the logistical networks through which the agricultural commodities flow, particularly those commodities that are perishable (think fresh produce, seafood and dairy), which rely on time-sensitive temperature-sensitive cold-chain logistics that cross national boundaries and have to be highly coordinated among a wide range of players (Ivanov, 2020). Although in the recent past there has been advancement in matters concerning digital supply chain platforms, the situation remains unusually susceptible with regard to farming and food production. Perishable products are very much sensitive to even the smallest mishaps or temperature change: a medium weather disruption of one mechanical failure and spoilage, wastage, economic loss, and regulatory infraction can occur. The standard optimization models designed to be used in traditional logistics have proven to perform well under stable conditions, but international trade is not that stable and in that, it is a part of the world where optimization models fail to perform well. In addition, the majority of these models fail to incorporate the compliance requirements, namely the food safety standards and regulations mandated by the organizations such as the World Trade Organization (WTO) and the Codex Alimentarius Commission, in a baking sort of manner (Ben-Daya, Hassini, & Bahroun, 2019).

New technology has provided a new horizon in supply chain optimization. The power of quantum computing allows breaking combinatorial problems, the scale of which is unprecedented, and therefore it is possible to build logistics models that are fit and ready to comply with regulations. Meanwhile, blockchain-based traceability brings traceability and audit expectations with real-time, unchangeable record of environmental conditions and products locations, which is exactly what the regulators require (Preskill, 2018). In aggregate, these developments may transform

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