

Transportation Network Optimization

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INTRODUCTION

The longevity of transportation networks dates back to the age of ancient civilization, since that time the main objective has in essence remained the same: to *facilitate the transportation of goods from one location to another using the most cost effective mean available*. To rephrase that in modern vernacular, the management and *optimization of transportation networks* in meeting business objectives. While the forces driving the interpretation of most cost effective means available have changed overtime with the introduction of new technologies, global trade links and governmental policies; the general expectation of a transportation network has remained constant. These driving forces have impacted on the perception of optimality; cost is not necessarily the sole objective these days. Optimization objectives such as energy costs and their variability, time, environmental impact but to name a few have growing in importance of late. Many of the existing approaches to supply chain management take a multi-objective optimization approach, combining several (possibly competing) objectives and optimize the network.

As such there is a growing trend to perform balanced optimization across a number of objectives. Transportation networks are rapidly expanding due to the globalization of business and supply chains; as such the size and complexity of transportation networks has increased considerably in the last decade. Transportation network optimization is known to be a difficult and complex problem to solve, a deterministic solution is often not applicable or indeed available for such problems and the problems themselves are therefore categorized as NP-hard problems. In response to the failure of deterministic algorithms to solve NP-hard problems, other optimization techniques have been developed and applied.

The purpose of the paper is to review the current state of art in *transportation network optimization*. The paper is organized in five sections. In the *Background* section, we introduce the transportation problem, consider its theoretical aspects and implications, and perform a detailed analysis of the main contributions made in the field. In the *Main Focus* section, we present a critical analysis of the algorithms used, the objectives optimized and the complexity of the networks analyzed in

the literature, and discuss the main problems that as yet remain to be addressed. In the *Solutions and Recommendations* section, we propose ideas, and possible solutions to these outstanding problems. Finally, in the *Future Research Directions* section, we discuss future and emerging trends.

BACKGROUND

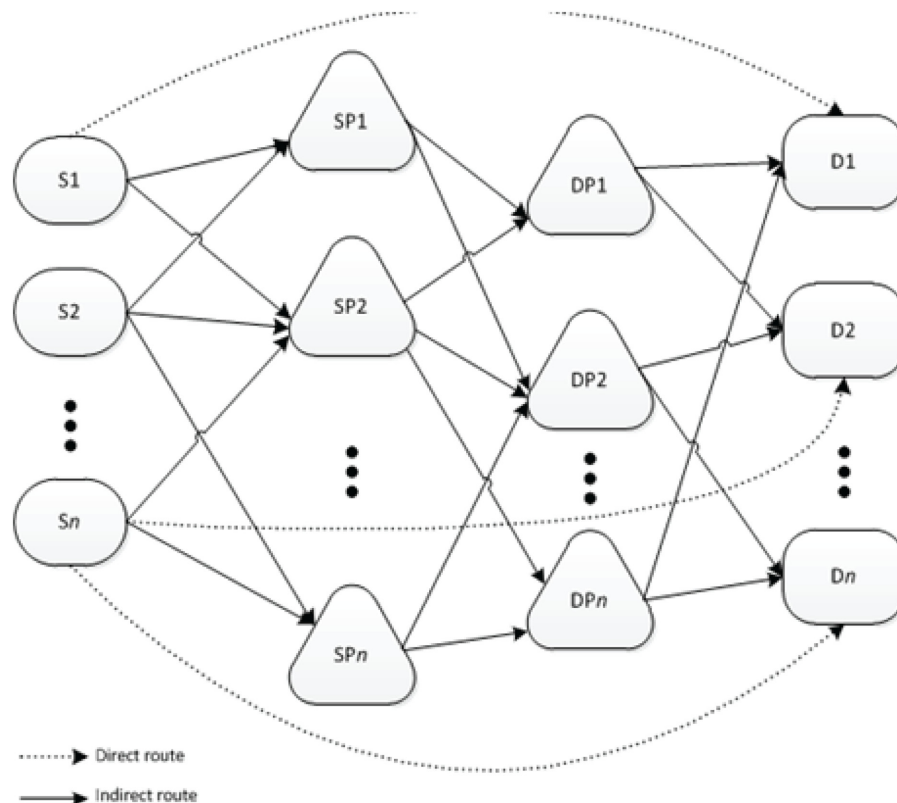
A transportation or distribution network is a *dynamic, stochastic and complex system* that can be modeled as a graph where the nodes (vertices) represent entities that can in general can be categorized as representing producers, distribution centers and end customers (Ding, Benyoucef, & Xie, 2009) or in the more specialist case of manufacturing enterprises as manufacturing and distribution sites that procure raw material, process

them into finished goods, and distribute the finish goods to customers (Ganeshan, 1999) (Figure 1 shows an example of a transportation network).

The optimization of transportation networks is a *specialization of the minimum-cost flow problem*, a well-known optimization model, where the goal is to find a feasible flow of minimum cost in a network with capacity constraints and edge costs (Goldberg & Tarjan, 1987). As a specialization of a linear programming problem, it may be solved by applying the common algorithms from linear programming theory, e.g. the *simplex method*, *branch and bound/cut*, etc. Such methods are exact in the sense that they always terminate with a feasible solution, a solution that is also optimal. While it is desirable to have a solution that is theoretically guarantee to be the best, such *exact methods are not always applicable*. When the problem difficulty is high or the model is too

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Figure 1. Example of transportation network, where S_i are sources, D_j destinations/dealers, and SP_k and DP_l are possible intermediate ports



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