Chapter 13
Multi-Objective Optimizer for Multimodal Distribution Networks: Operating Cost, Carbon Footprint and Delivery Time

Mauro Gamberi
University of Padova, Italy

Marco Bortolini
University of Bologna, Italy

Francesco Pilati
University of Padova, Italy

Alberto Regattieri
University of Bologna, Italy

ABSTRACT

A multi-objective optimizer Decision Support System (DSS) to minimize the operating cost, the carbon footprint and the delivery time in the design of multi-modal Distribution Networks (DNs) is presented to overcome the widely adopted methodologies focused on the cost minimization, only. The proposed approach simultaneously assesses three independent objective functions, evaluating the network costs, the Carbon Footprint (CO2 emissions) and the shipping time from the producers to the final retailers. The DSS manages multimodal four-level (three-stage) DN, best connecting the producers to the final retailers, through a set of Distribution Centres (DCs). It allows multiple transport modes and inter-modality options looking to the most effective DN configuration from the introduced multi-objective perspective. The three optimization criteria can be considered independently or solved simultaneously, through the so-called Pareto frontier approach. Finally, the proposed DSS is validated against a case study about the delivery of Italian fresh food to several European retailers.

INTRODUCTION

Distribution Networks (DNs) are the basic link between supply and demand. They include the physical systems and the intelligence tools able to ship products and services from the producers to the final consumers. DN theory belongs to the general Supply Chain Management (SCM) introduced by Lambert et al. (1998) as “the integration of key business processes from end-user through original suppliers, that provides product, service and information that add value for customers and other stakeholders”.

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Such a definition points out the key elements and of all DNs:

- **End-Users**: they represent the target of the SCM activities, to whom the value is directed, appreciated and experienced. They are typically a constraint out of the direct control of the decision makers and express expectations, demand of products, information and auxiliary services;

- **Suppliers**: they represent the active actors of the DNs, feeding it with products, information and services to deliver high value to the end-users. Typical suppliers are the primary resource producers, the process and manufacturing companies, the logistic providers and freight brokers, the last-mile distributors, etc. Such actors are responsible of the DN service level and rising costs and their effective integration and optimization is the primary goal of SCM;

- **Supplied products**: they represent the shipped goods in traditional DNs where the end-users look for physical items. Nevertheless, in this context, products are to be considered from an extensive perspective to include, packages, auxiliary tools, services and complementary products fully satisfying the end-user needs and representing a value for them for which they are ready to pay a monetary offset to have their ownership. Looking at the DN flows, the supplied products move forward from the primary producers to the end-users, i.e. direct logistic flow;

- **Information**: it represents the intangible element of the DNs directly associated to the knowledge moving forward from the suppliers to the end-users and backward from the end-users to the suppliers. The accurate information flow is essential to coordinate the DN stakeholders matching their interests and expectations. The information flow management is an essential part of the value transfer in SCM;

- **Stakeholders**: they represent the group of actors, directly and indirectly operating on the DN, having economic and non-economic interests on it and that are relevant in the decision making process. Stakeholders are from both the private and the public sectors; they include the control institutions and the general public to represent the community interests. SCM interacts with the DN stakeholders, balancing their needs and requirements with the purpose of increasing the overall system value;

- **Business processes**: they represent, by means of a general concept, the bundle of methods, models, practices and rules to be adopted by the stakeholders, at all levels, to reach their purposes, optimizing the DN, and adding value to the supplied products to meet the end-user expectations. Both qualitative and quantitative processes are developed through coordinated and integrated supporting decision tools and actions. Both the scientific community and the practitioners look for the most effective business processes to optimize the existent and the new DNs.

The effective design of DNs deals with and integrated set of actions looking for the whole system optimum. Manzini et al. (2007) highlight the trend of the literature about the importance of adopting an integrated approach not focused on a single element of the DN and based on coordination and information sharing. The authors further propose a reference quantitative approach for the integrated supply chain design.

Among the issues to be considered in the DN design, a basic one is the perspective to be adopted and the targets to look for (Ramaa et al., 2009). Three main perspectives can be followed:

- Single-objective, single-criterion perspective;
- Multi-objective, single-criterion perspective;
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