


# Multi-Layer Distributed Constraint Satisfaction for Multi-criteria Optimization Problem: Multimodal Transportation Network Planning Problem

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## ABSTRACT

This article introduces a new approach to solve the multimodal transportation network planning problem (MTNP). In this problem, the commodities must be transported from an international network by at least two different transport modes. The main purpose is to identify the best multimodal transportation strategy. The present contribution focuses on efficient optimization methods to solve MTNP. This includes the assignment and the scheduling problems. The authors split the MTNP into layered. Each layer is presented by an agent. These agents interact, collaborate, and communicate together to solve the problem. This article defines MTNP as a distributed constraint satisfaction multi-criteria optimization problem (DCSMOP). This latter is a description of the constraint optimization problem (COP), where variables and constraints are distributed among a set of agents. Each agent can interact with other agents to share constraints and to distribute complementary tasks. Experimental results are the proof of this work efficiently.

## KEYWORDS

Assignment Problem, Distributed Approach, Multi-Agent System, Multi-Criteria Optimization Problem, Multi-Layer, Multimodal Transportation Network, Planning Problem

## INTRODUCTION

The constraint programming technique is combines techniques from artificial intelligence and operations research. This technique proves their efficiency to solve combinatorial optimization problems. The problems can include various areas as scheduling, timetable, planning, and assignment problems, etc. These problems can be composed of two or more sub-problems. The constraint satisfaction problem (CSP) formalism makes it possible to represent many problems in a simple and effective way.

A CSP is defined by a set of variables  $X$ , a set of domains  $D$  of definition framing values that includes these variables and a set of constraints  $C$  that shapes the values that will make the variables belonging to  $X$ . Formally, the CSP is defined by a triplet  $P = (X, D, C)$  where:

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- $X$  is a finite set of  $n$  variables  $\{X_1, \dots, X_n\}$ .
- $D = \{D_{x_1}, \dots, D_{x_n}\}$ , is a set of  $n$  finite domains for the variables of  $X$ . The domain  $D_{x_i}$  is the set of possible values of the variable  $x_i$ .
- $C = \{C_1, C_2, \dots, C_m\}$ , is a constraints set, where a constraint  $C_i$  is defined by a subset of variables:  $C_i = \{X_{i_1}, X_{i_2}, \dots, X_{i_n}\}$ . These constraints can be expressed in extension by a set of triples which respect the associated constraints, or by predicate or mathematical functions.

In order to solve these problems is interesting to apply the knowledge algorithmic to improve the performance of decision systems. The resolution of a CSP defined by the assigned values to the variables of the problem. The CSP solution is an instantiation that should satisfy all the set of constraints. The constraints can be expressed in different forms as mathematical formulation. These are relationships between variables that define the structure of the problem to be solved.

In a recent paper presented by (Li, Negenborn, & Lodewijks, 2016), authors treat a vessel rotation planning problem (VRPP) of the container as a distributed CSP. The resolution of this problem must plan and assign the rotation of the container using vessels, trains, or trucks. The main goal is to select the rotation plan depending on frequencies of terminals visits, and arrival and departure time of vessels to the terminals in the port area. The case study is characterized by a static data. They have formulated the VRPP as a layered distributed constraint optimization problem (DCOP) structure into two layers: an assignment layer and a scheduling layer. The upper layer defined as the assignment problem to select the sequence of different terminals visited by the vessels. The obtained solutions at the higher layer defined as the lower layer to explain the scheduling problem that plans the arrival and departure times and the waiting time at each terminal. There exists one DCOP in the upper layer that relates to each vessel. Moreover, there are multiple sub-COPs in the lower layer, each one is connected to a single vessel. After finding an optimal solution, the upper layer of the DCOP problem, and the lower layer DCOP solve each problem separately. The multi-layer approach significantly considered to improve the applicability of this approach.

The work focuses on solving the multimodal transport network planning problem that includes the assignment problem and the scheduling problem. The assignment step defined by assigning to the most efficient transport mode and the possible visited nodes. The planning step has given the optimistic shortest path. The main purpose is to find the best multimodal transportation network under to satisfy and minimize the total transport costs and total transports time and meeting deadlines. These objectives considered to better satisfy the requirements and the wishes of the customers and to improve the service quality and to avoid the problems of congestion, which we can meet in the real cases. Among the problems met in the Tunisian ports; on the one hand, is the congestion in the berth when the ship arrives but does not find a free berth. On the other hand, the congestion in the storage area is due to insufficient space that is to say that there is no space to unload containers. In fact, the path chosen for a transport mode is the important basis for measuring the advantages and disadvantages of the solution. Therefore, to solve the multi-objective problem, we contribute by developing an optimization method for the multi-objective problem that achieves the compromise solution. The aim of this work is to develop a new formalism for distributed Multi-objective Optimization in CSPs, called distributed constraint satisfaction multi-criteria optimization problem (DCSMOP). The multi-agent system solves the multimodal transportation network planning problem. In this approach, each agent is responsible for a sub-problem in order to cooperate with others to solve this problem.

## **PLANNING TRANSPORTATION PROBLEM SOLVED AS CSOP: LITERATURE REVIEW**

The constraint problem is a natural fit for solving CSOPs such as scheduling problems. This advanced technique integrates the strengths of both artificial intelligence (AI) and operations research (OR). This technique is proved their efficiency to solve many case studies on CSOPs. (Bu, Zhang, & Luo,

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