

## **Extended abstract for the lecture on the 12th of February**

In distribution and logistics operations some combinatorial optimization problems arise. In these operations, the goods must be delivered while considering an effective distribution. This is done in order to reduce the distribution costs and to insure that the quality of the packing and the transport meet the costumers' needs. The distribution's main goal is that the products must be: delivered to the costumers' locations on time and undamaged; in the exact quantities that were ordered; and the unloading process of the goods can be accomplished easily and in a time-saving manner, in order to reduce the costs distribution process and the dissatisfaction of the clients. To accomplish this, some well-known combinatorial optimization problems are used; such as, the vehicle routing problems (VRP) and the cutting and packing problems (C&P). Regarding the latter, one will be addressing the pallet loading problem, bin-packing problem and the container loading problem in particular.

Basically, the main objective is to minimize the total transportations costs, ensuring that the costumers' demands are met and that the vehicle's loading capacities in terms of volume and weight are not exceeded. To accomplish this, the packing and transportation operations must be carried out efficiently and in an integrated basis. In ground transportation, using trucks, the Vehicle Routing and Loading Problem (VRLP) could be solved. If the transport of goods must be carried out by sea, the Container Stowage and Ship Routing Problem (CSSRP) must be addressed. This problem is an integration of the Container Stowage Problem (CSP) and the VRP, applied to short sea shipping. The advantages of short sea shipping are well known and recognized by the EU member states and it has experienced tremendous growth in the last decade.

Despite the fact that both the VRLP as the CSSRP are NP-Hard problems, it could be possible to solve them using exact approaches, as a result of the integration of the classic NP-hard problems, depending on the size of the problems. This allows for optimal solutions or at least good upper bonds, which can be used to evaluate the results obtained by other non-exact approaches.

The problems previously mentioned and related formulations will be presented. Some exact and non-exact approaches will also be presented as a case study, in order to solve them in a real application context.

### **Case Study introduction**

OLI-Sistemas Sanitários S.A., founded in 1954 in Aveiro (Portugal), is the largest cistern producer in Southern Europe and owns OLI, a global brand of bath solutions, present in 80 countries on five continents. In the large and modern industrial complex, with a total area of 82 thousand square meters and 389 employees, the entire value chain is controlled - from idea to industrialization, production and commercialization. The factory, recognized for innovation and awarded for efficiency, works 24 hours a day, 7 days a week, and ensures weekly production of 43 700 flushing cisterns and 64 000 mechanisms.

In the last decade, OLI has created products with the goal of becoming more efficient and environmentally friendly, comfortable and accessible. Since 1993, the company has been part of the Silmar Group, headquartered in Italy.

### **Decision support system - Packing and Routing Optimizer (PRO)**

The company OLI ships its goods to national and international customers. While most of the customers are in Portugal, there are also other European customers and costumers in the African continent, Malaysia and Australia. All receive deliveries more or less periodically. Most of the customers get their goods delivered by trucks, while some are delivered through standard containers (by land or by sea).

Until the start of this project, in 2012, the daily packing and routing decisions were done manually (i.e. guided by human experience and not supported by computer programs). A decision support system was developed through the project, to support the daily decision making on packing goods and routing trucks. The system is called "Packing and Routing Optimizer", also known as "PRO". The following goals are pursued using the PRO system:

G1 - Improving quality of daily distribution decisions, supporting all packing and routing operations at OLI.

G2 - Flexible planning by strengthening flexibility in negotiations with customers. Daily costumer orders could be adapted or deliveries could be postponed in order to guarantee a sufficient efficiency of the distribution process.

G3 - The PRO system should be easy to operate with a simple user interface.

G4 - It supports, rather than replace the staff. The PRO system is meant to help the company staff when making suitable decisions regarding the distribution of goods and managing relevant data (e.g., customer demand data).

### **The distribution process**

The daily distribution of the goods is done in two places, from now on called Factory and Store. Both are located in Aveiro, Portugal.

All foreign customers are supplied from the factory. The distribution is made by land or by sea. The goods shipped in trucks must be first loaded onto pallets. So, a two-stage packing problem has to be solved. In the first stage, boxes are to be packed onto pallets; in the second stage, these pallets are loaded into one or more trucks. The boxes have to be transported to different customers and the main goal is to guarantee a sufficient utilization of the truck loading space. In this case, only the Packing Problem is addressed.

The goods shipped by sea, must be loaded into containers. Those goods, also packed into boxes, could be loaded onto pallets or directly into the container. Afterwards, those containers must be stowed onto the ships, in order to be sent to their destination. In these cases, one always has a packing problem to solve and depending on the costumers' location, a CSSRP or a CSP are addressed.

The Store supplies all Portuguese customers. The Portuguese costumers are supplied by trucks and the goods are also packed into boxes, which are either directly placed into the truck or first onto pallets, which are then stored in the truck. In this case, a VRLP is solved.

In any case, the loading of pallets, trucks, ships and containers has to be done in such a way, that the capacity of these means of transportation is used efficiently (i.e. wasted or unused space should be avoided). On the other hand, additional constraints, e.g. regarding stability of the cargo, load bearing constraints, time windows and deadlines, must be met.

The description of these different types of distributions, leads to a complete definition of the decision problems to be solved with PRO: Pallet Loading Problem, Container Loading Problem, Bin-packing Problem, Vehicle Routing with time windows and the Container Stowage Problem.