Universidade do Minho
Escola de Engenharia

Semana da Escola de Engenharia
October 24 - 27, 2011

DESIGN OF WOOD BIOMASS SUPPLY CHAINS

Tiago Costa Gomes, Filipe Pereira e Alvelos and Maria Sameiro Carvalho
Systems and Production Department / Algoritmi Research Center
E-mail: tiago.gomes@dps.uminho.pt, falvelos@dps.uminho.pt and sameiro@dps.uminho.pt

KEYWORDS

Supply Chain, Integer Programming, Wood Biomass.

INTRODUCTION

In an extremely unstable world, an efficient management of energy resources and environment is crucial for a bright future. Societies are each day more convinced of the necessity to change the paradigm of consumption of energy resources. The vast majorities of these resources are non-renewable and not environmentally friendly and have soaring prices that may lead to the collapse of world economies, because they are too dependent on these resources. In order to change the current situation, the vast majority of countries are focusing on increase consumption of renewable and environmentally friendly energies to allow a reduction of the dependence on fossil energy and emissions of greenhouse gases.

There are several types of renewable energy sources such as the wind, hydro, solar, geothermal, wave and biomass. This work deals with one of them, the biomass, and particularly woody biomass. The wood biomass is a clean and renewable energy because it has a carbon neutral cycle. CO_2 is captured from the atmosphere and released when the biomass is burned and the cycle repeats. For this reason, the burning of biomass does not cause more emissions of greenhouse gases. Beyond the environmental benefits, the harvest of forest resources allow the cleaning of forests, reducing fire risk and the proportions of them, as well as the economic development of rural areas. The wood biomass after transformed can be included in various economic activities, such as: in the production of derivatives timber products, for heating, for electricity generation, or in the transport sector. To be profitable the business of biomass it is necessary to optimize the supply chain, from the collection of raw materials until the end-user. Transport costs account for about 50% of total costs, in some cases can reach 65%. The correct definition of the links in the supply chain and the optimal planning of the flow of materials is crucial in order to meet demand at the desired time while minimizing total costs.

DESIGN OF MATHEMATICAL MODEL

In this work we consider a company that collects the raw material in the forest areas and deliveries it to the customer after processing them in chipped products (subrectangular shaped pieces with a defined particle size produced by mechanical treatment with, usually, knives). The company's aim is to deliver the quantity of chipped products desired by customers at the desired time, minimizing the total cost of the supply chain.

The supply chain is formed by forests areas (that serve as suppliers), customers and may have intermediate warehouses. In the forest areas the collection of raw material is made and then resources are stored in the local or are transformed in chipped products. If the material is processed, the chipped products are transported to the customers or to the intermediate warehouses. In this sector of the activity supply and demand is seasonal, varying throughout the year due to climatic variations. Because of this seasonality the use of inventories is more important for a good level of service than in other types of supply chains. The intermediate warehouses serve to improve supply and demand coordination, particularly relevant when seasonality of both supply and demand are an important issue and to better manage of chipped products and transportation operations. The stores can accommodate raw materials, as well as chipped product, and they can also be used to carry out processment operations. The customers receive the chipped product in order to meet their demands.

One important aspect of the problem is the optimal management and good planning of equipment and human resources involved in the tasks of collecting, processing of forest resources, transportation and storage. For tackling all these aspects of the supply chain design, an integer programming model that supports tactical and operational decisions was developed. The model allows the minimization of all the costs involved.

For a given planning horizon discretized in time periods, the model addresses the following decisions:

- Selection of forest areas for being collected;
- Location of intermediate warehouses (if necessary);
- Location where chipping operations are done (in the forest area or in the warehouse);
- Location of the mobile chippers in the periods the time;
- Possible installation of one fixed chipper at each warehouse;
- Storage decisions (quantities to be stored in all periods of time, in different warehouses);
- Decisions related to transportation between different links in the chain.

RESULTS AND CONCLUSIONS

A mixed integer programming model that supports tactical and operational decisions was developed and implemented on Cplex.

We obtained the following results:

- For instances of small and medium size (for 7 and 30 time periods, for 5 and 150 forest areas, for 1 and 4 warehouses and 3 and 7 customers, for 1 and 4 products) was almost always possible to obtain quality solutions in time for a very acceptable time, whose value is close to the value of solution (in most cases the difference is less than 1% of GAP);
- For instances with 90 time periods, with less forest area (5) has always been possible to reach quality solutions;
- For instances with 150 forest areas, with 90 time periods was still possible to reach some quality solutions in the time available, but with 150 time periods solutions are not obtained because the model has an unfeasible dimension for Cplex.

To obtain good solutions in reasonable amounts of time for larger instances, we intend to combine decomposition techniques and metaheuristics.

In the future, besides improving the results for larger instances, we plan to deal with some extensions to the model to make it even closer to reality.

AUTHORS' BIOGRAPHIES

TIAGO GOMES was born in Braga, Portugal and went to the University of Minho, where he studied Industrial Engineering and Management and obtained his degree in 2004. He worked some years for some companies before returning to the University of Minho where he is PhD Student.

FILIPE ALVELOS is Associate Professor at the Department of Production and Systems Engineering, of University of Minho, Portugal. He is also a researcher of the Systems Engineering, Optimization and Operations Research Group of the Algoritmi Research Center. He received his Ph.D. degree in 2005 in Operations Research from University of Minho, his M.Sc. degree and his B.S. degree both in Electrical and Computers Engineering from Faculty of Engineering of University of Porto, Portugal. His current research interests are exact and heuristic methods for integer and combinatorial optimization with applications to network design and routing, production planning and scheduling, and cutting and packing problems. He has authored several papers in refereed international journals and conferences and has been involved in several Portuguese and European Union funded projects.

MARIA SAMEIRO CARVALHO was born in Braga, Portugal. She graduated in Computer and Systems Engineering in the University of Minho, Portugal. She holds an MSc degree in Transportation Planning and Engineering and a PhD degree in Transportation Planning from the University of Leeds, UK. She is Associate Professor at the Department of Production and Systems Engineering, of University of Minho, Portugal. She is also a researcher of the Systems Engineering, Optimization and Operations Research Group of the Algoritmi Research Center Her main research interests are in Operational Research, Transportation and Logistic.