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STRATEGIC DECISIONS IN LOGISTIC OF SUGAR BEET CAMPAIGN

Abstract: Managers of sugar beet processing companies need to decide which parcels will become part of the campaign, as well as the time when the beets will be collected from it. Such decisions have far-reaching consequences in a logistic chain. The company strives to optimize transportation costs, but at the same time, that the goods are collected at optimal quality, and processed timely. Simultaneously, an effective transport plan implies the use of minimal amounts of fuel, as well being environment friendly. We will present a mathematical model to support the decision-making process.

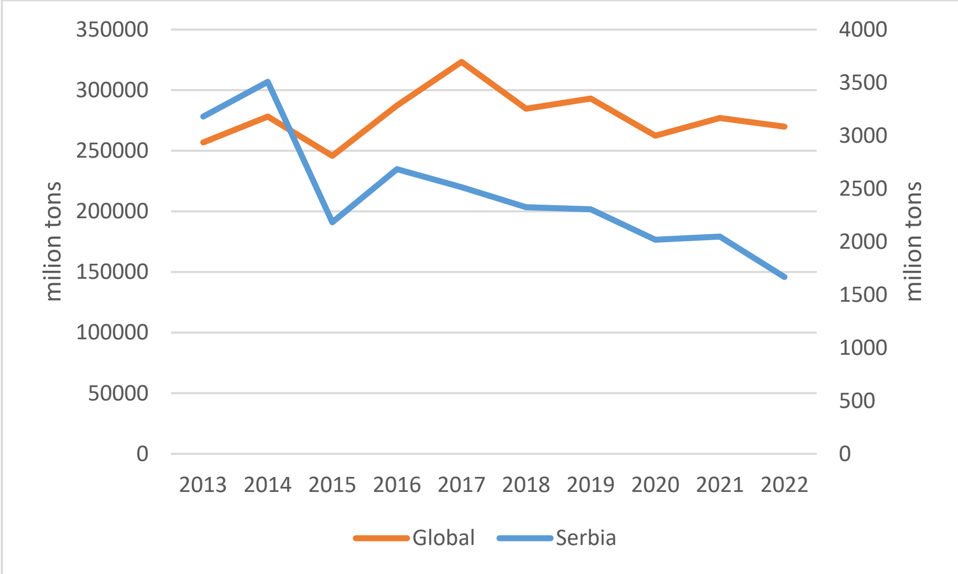
Keywords: Sugar beet, logistics, supply chain, planning, transportation

1. INTRODUCTION

The agro food supply chain is imbued with a large number of activities, including seeding, irrigation, harvesting, processing and distribution to final consumers. Each of these processes are accomplished and especially linked with some form of transport activities. Therefore, adequate planning and synchronization is necessary to achieve a desired value chain. The sugar industry is by no means an exception. Moreover, the raw materials sugar beet and cane are often grown on a large and sparse parcels. In order to increase the profit, companies seeks for a tool capable to optimize processes and transportation plans.

According to FAO database, in 2022 the worldwide production of sugar beet and sugar cane was approximately 2296 million tons. By analyzing a period between 2013. and 2022, we found that shares of sugar beet and sugar cane are 12% versus 88%, and that these figures are without significant variations. Largest producer of sugar beet is Russia, holding a share of 13-18% total sugar beet production, while largest producer of sugar cane is Brazil with a share of 36-39% of total sugar cane production. This puts a Brazil as largest sugar producer. Analyzing agricultural yield data from sugar beet plants, we found that the best is Chile with 102 tones/ha, while Russia with 42 tones/ha ranks as a 36. In the paper Kolfschoten et al. (2014). authors mark that "sugar beet is currently the cheapest sugar source and lowest in water usage, as well as being an effective biomass source".

In Serbia there are no sugar cane plants, complete production of sugar is based on sugar beet. On picture 1 is shown sugar beet production in period 2013-2022 compared with a global production. We can see a small depreciation of production in Serbia over a given period. With average production of 2,4 million tons, Serbia shares less than 1% of worldwide sugar beet production. With a 47807ha, Serbia ranks as a 19th country with a soil seeded with sugar beet. Average agricultural yield over a 10-year period is 51 tones/ha.



Picture 1: Sugar beet production in period 2013-2022.

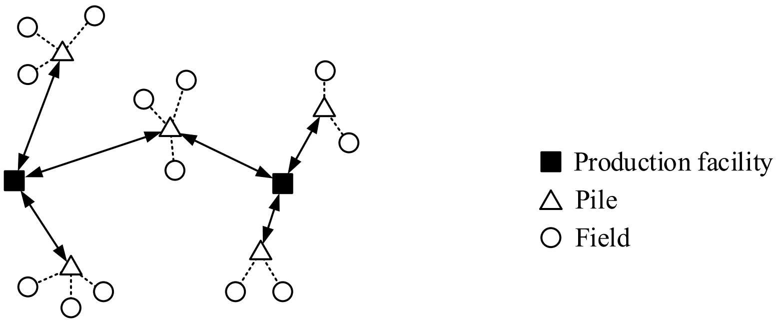
In this research we deal with a mixture of strategic and tactical decisions regarding the sugar industry supply chain. The rest of the paper is organized as follows. Section 2 is devoted to a literature review, in Section 3 we present a problem description and results in section 4.

2. LITERATURE REVIEW

In the work of Higgins (2006), author emphasize the influence of decreased sugar prices on international level to the role of optimizing the agro logistic chain, especially the synchronization of harvesting and transporting activities.
In López-Milán, Plà-Aragonés (2014), authors stress the complexity and multicriteria of the optimization problem. Namely we confront two very often opposed goals: minimization of transportation costs and maximization of resources quality. To make a decision process traceable and optimization doable, most often research is directed to cost minimization. Regardless of the complexity of the problem itself, harvesting campaign is often accompanied with a poor transportation possibilities namely the heterogeneity of the fleet. Therefore, synchronization becomes even more important. That characteristic can be seen in many logistics problems, from newspaper delivery problem Bala et al. (2010), multi-echelon distribution Bala et al. (2017), but also in scheduling of the vehicles in a harvest season, Gvozdenović, Brcanov (2018).
As indicated in many papers, for example see Behzadi et al. (2018), many activities in agro supply chain have to deal with supply spikes. Also, the nature and long lead time of supply material can have a large impact on planning activities. In the research of Rong, et al. (2011), or van der Vorst, et al. (2009), authors signify degradation of resources over time stressing the endowment of logistics activities.
In Grunow et.al. (2007), authors hierarchically structure the problem into three levels: cultivation, harvesting and dispatching. Authors represent MILP model for the first two phases and use a commercial software to solve transportation level. The solution is applied to case study of sugar cane in Venecuela.
In Higgins (1999) author deals with strategic to tactical harvest planning and provide a non-linear MIP model. The main direction of the research was on harvest date and crop cycle length. The application of the model on sugar cane producers in Australia led to 7% net revenue increase.
The work of Higgins (2006) represents a model that schedule vehicles from farms to loading pads. Case study where findings are adopted comes from Australia. Authors apply the metaheuristic approach – tabu search and variable neighborhood search. As it is already known, metaheuristic algorithms are often applied when a decision maker does not set optimality as a prime goal of optimization. Common phrase that metaheuristic finds reasonably good solution for a reasonably amount of time plays its role in this case. Managers point that each solution needs some fine tuning before being adopted, since many practical constraints have to be accounted in solution. Also, real time scheduling was set as priority thus applying any solution that reduce the costs was satisfactory.
In Gvozdenović, Brcanov (2018) authors represent a model and a heuristic algorithm including a large fleet of vehicles, loading machines, where a high degree of synchronization has to be adopted to maintain the efficient employment of all participants. The main idea was the minimization of waiting times, which leads to higher degree of utilization. A solution is modeled on a time-space network which was explored via metaheuristic simulated annealing. A fast and competitive solutions were constantly improved and updated with new information.

3. PROBLEM DESCRIPTION

The planning of sugar beet harvesting has to be done in such a manner that enables reaching the optimal profit. However, profit is influenced with many factors, such as fuel costs, crew and vehicle fleet, available machinery for extraction of beet and loading on transportation vehicles, but also on maturity and quality of beet, and finally the necessity of continuous activity in production facility. As a biggest problem in this chain, managers point the lack of raw materials in production facility. Therefore, continuous processing can be seen as the highest goal or as a constraint in an optimization process.
In this paper we will omit the decisions regarding the time when the beets are harvested. We rather focus on the transportation process of collecting the sugar beet to the factory. The sugar beet are combined form several fields, and scattered piles are located close to the solid paths. There the loading machines throw the beet to the transporting vehicle and the quantities of beet are transported to the manufacturing objects. Since there are few manufacturing objects, one of the arising questions is to which production facility goes a particular truck of the raw material. On Picture 2 are shown two production facilities, and 5 piles of sugar beet. All the beet from the fields is transported tracing the dotted lines to the piles. Transportation that is analyzed in this work is the represented with solid lines, operating between piles and production facilities. Although the assignments of two leftmost and two rightmost piles seems to be obvious, the position of central pile can rise a question to which mill the beets should be assigned, the left or the right production facility.



Picture 2: Typical transportation scheme.

Since location of production mills are given, and their positions cannot be altered without excessive investments, the locations of fields and piles have a great impact on total transportation costs. Further, the quality of the roads can deviate a plain geographic view, since moving of the vehicles on a normal roads, rather than on a country roads between the fields, can be more time and fuel costly. To include the weather conditions, total capacities of vehicles can be fully utilized if the truck moves on the asphalt roads instead of dirt roads. All of these peculiarities are taken into account when a manager calls a certain route to be conducted.

4. MODEL AND RESULTS

Let P be a set of indices denoting the set of piles. For each $p \in P$ let q_p denote the quantity of accumulated sugar beet at pile p. With F we denote the set of production facilities. Let d_{fp} denote the distance between each $f \in F$ and $p \in P$. We can assume that distance matrix is symmetric, that is $d_{fp} = d_{pf}$. The cost of transport between two locations is given and denoted as c_{fp}. Further, suppose that capacity of each production facility, including the space for accumulating resources, is C_f. Let us introduce the binary decision variables t_{fp} that equals 1 if beet is transported from pile p to production facility f, and 0 otherwise.
Regarding the introduced notation, the goal of each campaign, to achieve an optimal transportation costs can we written as:

$$\min \sum_f \sum_p d_{fp} c_{fp} q_p t_{fp}.$$

Following the capacity of production facility, that can handle the maximum quantity of the beet at any time, we write the constraint:

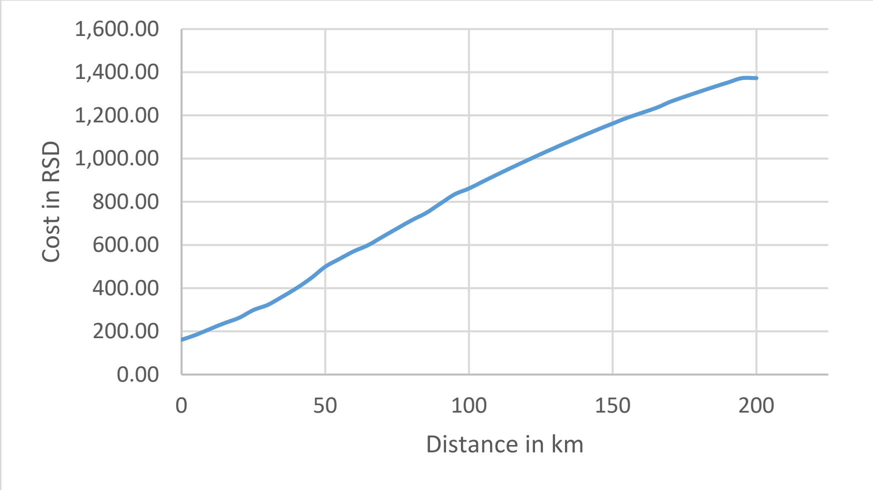
$$\sum_p q_p t_{fp} \leq C_f, \text{ for each } f \in F.$$

With respect to all contracts between producers of sugar beet and production company, we expect that all extracted sugar beet resources are transported to some production facility, that is:

$$\sum_f t_{fp} = 1.$$

In the case study considered within this research, there are three production facilities, with total capacity 85646720, 55341560, 112313460 tons respectively. The number of piles is 222 accumulating total 253301740 tons of sugar beet.

Cost of transportation is given in tones per km. Relationship between transportation costs and distance is depicted in Picture 3, from where we can see that there exists almost linear form.



Picture 3: Relationship between transportation costs in RSD and distance in km.

To obtain an optimal solution, we use LP solve version 5.5.2.11. By comparing the optimal solution and realization plan, we have found that transportation costs are higher by 11%. Result comes from different pile-facility allocation, which was found in 55 pairs, that is in 25%.

To make an insight on influence of production facility capacity constraint, we made additional tests with higher capacities. More precisely:

- If the capacity of production facilities is increased by 10%, the transportation costs can be reduced by 6%, summing to total reduction of 17%.
- If the capacity of production facilities is increased by 20% in total, the transportation costs can be additionally reduced by 4%, summing to total reduction of 21%.

5. CONCLUSIONS

By analyzing the transportation costs generated in the harvesting season with an optimal plan, we came to conclusion that there is a significant gap and space for improvement. In allocation piles to production facilities there was 25% of mismatch enabling 11% of savings in transportation costs. Benefits on environment are not taken into account, but we believe that there is a significant correlation between the two. However, transportation distance is not the only aspect that managers account in decision making process. Safety stocks, maturity and quality of sugar beets also play important role in the allocation process. Also, weather conditions can have a strong impact on dynamics of collecting the beets, but also on the transportation phase. The significant share of transportation activities is taken on a dirt roads, and as such, decision makers have to achieve their functionality.

In future work we will address a more comprehensive approach that will require more sophisticated data. As noted by many authors, the key in savings can be found in more collaborating actors, thus leaving more space to reduce total costs of the entire value chain.

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