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A HEURISTIC APPROACH TO THE DAILY DELIVERY SCHEDULING PROBLEM. CASE STUDY: ALCOHOL PRODUCTS DELIVERY SCHEDULING WITHIN INTRA-COMMUNITY TRADE LEGISLATION

Mariusz Grajek, Paweł Zmuda-Trzebiatowski

Poznan University of Technology, Poznan, **Poland**

ABSTRACT. Background: Delivery scheduling plays a significant role in business activities of enterprises which operate on EU market, especially the ones which deal with production and trade of alcohol products. The character of such activities requires to take into consideration various regulations which determine many guidelines and constraints in storing and transporting of such products between EU countries. On the other hand, these issues are not well recognized in the literature.

Methods: Authors proposed a heuristic algorithm for solving the problem of scheduling this type of deliveries. Basing on the constraints and input data, which includes demand for deliveries in wider planning horizon, the algorithm creates a daily delivery schedule from one or many suppliers to one consignee. The algorithm takes into consideration the consignee's, suppliers' and carrier's interests. This is done by including their constraints as well as by including three criteria in the scheduling process, i.e. minimization of the stock in transit and minimization of the dispersion of loadings and unloadings in consignee's and each supplier's warehouses.

Results: The proposed algorithm has been implemented in spreadsheet with solver extension. It was applied for solving the real delivery scheduling problem in one of alcohol products importing companies, in which manually filling of DRP matrixes method was previously used. The results show that algorithm works correctly and efficiently in comparison to previously used method.

Conclusions: The results show, that there is a need for further research on the field of determination suppliers order in the scheduling process. The possibility of implementation of multiple criteria analysis or optimization methods for solving such problems may be also a good direction of further research.

Key words: delivery scheduling, Intra-Community Trade, importation of alcohol products, heuristic approach, spreadsheet implementation, optimization.

INTRODUCTION

Delivery scheduling plays a significant role in business activities of enterprises which operate on EU market, especially the ones which deal with production and trading of alcohol products. The character of such activities requires to take into consideration various regulations which determine many guidelines and constraints in storing and transporting of such products between EU countries. More extensive description of such issues may be found in authors' previous works [Grajek 2011a, 2011b, 2012, Grajek and Żak 2012]. The key issues which should be considered are as follows:

1. The excise warehousing regime for excise-duty suspended goods: very limited number of warehouses is available on the market. There are also legal and technical

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difficulties in changing capacities of such warehouses.
2. Very difficult or in practice impossible to introduce transshipments of excise goods.
3. Homogenous and full truck loadings are desired due to tax & customs requirements.
4. No necessity to conduct customs clearance. However there is necessity to declare in advance the exact time and place of delivery.
5. International transport, specific distances, time of transportation and means of transport characteristic for EU.

The aim of this work is to solve the daily delivery scheduling problem in which alcohol products are delivered from one or many suppliers to one consignee within Intra-Community Trade regulations. In order to fulfill this aim authors proposed a heuristic algorithm which was implemented in spreadsheet software and then applied to solve the real problem in one of alcohol products importers.

MATERIAL AND METHODS

Delivery scheduling is an activity in which the size and future dates of deliveries are determined on the basis of inventory level forecast [Fertsch 1996]. Delivery scheduling problem is a subclass of wider class of scheduling problems. Scheduling problems applies to such areas as: management, production, transportation, computer systems and others [Zinder, Shkurba 2001]. Scheduling problems are usually formulated as P or NP-hard combinatorial problems [Lenstra, RinnooyKan 1978]. There are many different approaches to solving of such problems in the literature. These approaches are depended on the character and complexity of solved problems. Very often dynamic programming method is used for solving such problems, e.g. in works authored by Chen and Chung-Yee [2008], Cheng, Wang [2010], Hall and Potts [2005], Kovalyow and Cheng [2001] or Lixin and Hua [2009]. Approximation techniques, which are less time and resources consuming, are utilized in case of more complex instances of the problem. Some examples of such techniques are: genetic algorithms [Cha et al. 2008], fuzzy logic [Xue et al. 2001], tabu search [Garcia and Lozano 2005, Herka 2004], simulated annealing [Gupta et al. 1999] as well as other heuristics [Tang et al. 2008]. The problem considered in this work is a specific instance of delivery scheduling, as many stakeholders are involved in the decision process, i.e. consignee (e.g. alcohol products importer), suppliers (e.g. alcohol products exporters) and carriers. It should be noticed, that in case of alcohol products Intra Community Trade market, the consignee and suppliers are often associated within one consortium. Interests and constraints of each stakeholder should be meet in order to create an effective supply chain which will be able to satisfy the final consumers' needs. Also all regulations related to trade of excise goods between various EU countries should be meet [Grajek 2011a, 2011b, 2012, Grajek, Żak 2012]. Authors have not managed to find any article scoped on solving this type of scheduling problems. They develop a heuristic algorithm for solving such problem. The algorithm and its implementation are presented in the next paragraphs of this paper.

The proposed algorithm utilizes the following criteria: stock in transit minimization and minimization of the daily dispersion of loadings and unloadings in supplier's and consignee's warehouses. Stock in transit minimization is related to the transport cost minimization. There are a lot of constraints related to excise goods transport under Intra Community Trade regulations. For example, from practical point of view if transport is done under excise-duty suspended procedure it is very complicated to join excise and non-excise goods in one trailer. Thus transport cost of excise goods may be higher than transport cost of non-excise goods and much higher than logistic cost related to the warehouses operations, such as loadings and unloadings. Therefore the criterion of stock in transit minimization is considered as more important than two other used within algorithm. The two other criteria are related to the cost of warehouses' operations. Authors make an assumption that consignee is the decision maker in the scheduling process. The consignee is interested more in optimization its own operations, than in optimization its suppliers operations. Furthermore very often consignees do not manage its suppliers operations, so it is only capable to propose them a delivery schedule. Such situation occurs in the case presented in 'Results' chapter. Therefore the criterion of minimization of the dispersion of unloadings in consignee's warehouse is considered as more important than the criterion related to the dispersion of loadings in suppliers' warehouses.

The algorithm requires the following input data: defined quantity of deliveries from suppliers to the consignee within wider planning horizon (e.g. one week or month), the minimal transport time between each consignee-supplier pair as well as possible dates:

- of loadings in each supplier's warehouse;
- unloadings in consignee's warehouse;
- of transporting shipments.

The second group of constraints is related to days in which loadings, unloadings or transport activities are not possible due to national or company's regulations, e.g. weekends, public holidays, stocktakings, days of increased sales and others. Third group of constraints, which is optional, defines warehouses and carrier capabilities, i.e. the maximum number of loadings, unloadings and shipments per day as well as the maximum capacities of consignee's and suppliers' warehouses. The algorithm allows also to define the number of predefined loadings and unloadings in consignee's and each supplier's warehouse for each day. So it is possible to model shipments delivered from/to other suppliers/consignees.

The algorithm is consisted of five main phases, i.e.:

6. Determination the optimal dates of loadings for each consignee-supplier pair.
7. Determination the order of suppliers in delivery scheduling process. Selection the first supplier.
8. Creation the best possible unloading schedule in consignee's warehouse for selected consignee-supplier pair.
9. Creation the best possible loading schedule in selected supplier's warehouse which does not worsen the schedule created in phase 3.
10. Updating loadings and unloadings schedules. Checking whether the schedule has been created for all suppliers. If "yes" then the algorithm ends. Otherwise the algorithm selects the next in order supplier and returns to phase 3.

In the first phase of the algorithm the optimal dates of loadings are determined. The optimal dates are these for which the stock in transit is minimal, i.e. there is no waiting for loading or unloading caused by non-working period of the warehouse and the transport time is not extended by days when transport of goods is not allowed. The algorithm check for each possible day of unloading whether the transport time equals to the minimal transport time and whether there is a possibility to load the shipment in supplier's warehouse at the day, when the transport should begin. Only dates that meet these conditions are taken into account in further phases of the algorithm. The optimal dates are determined separately for each consignee-supplier pair.

In the second phase of the algorithm the order of suppliers in delivery scheduling process is determined. In business practice, this order may be a result of cooperation conditionings between consignee and each supplier. These conditionings may be related to political or technical issues, such as lead times. Thus the situation, where there is only one possible order, may occur. However, one cannot exclude that the decision maker is able to change this order. In this case the decision maker may use such criteria as: the total quantity of shipments delivered from each supplier, the duration of transport between consignee and each supplier, the number of days when loadings are possible, the number of optimal dates of loadings or others.

In the third phase of the algorithm the best possible unloadings schedule in consignee's warehouse is generated for selected consignee-supplier pair. The optimization criterion here is the minimization of the dispersion of unloadings. The measure of the dispersion is the sum of squared subtraction of the number of unloadings in consignee's warehouse at day di minus the mean value of unloadings in consignee's warehouse in the planning horizon. So the goal function is nonlinear (see. eq. 1). This form of the goal function is better than the mean dispersion from the mean value of unloadings in consignee's warehouse. In the first case any dispersion from the mean value worsens the goal function more noticeably. There are following constraints in the optimization process in this phase: the maximum number of loadings in consignee's warehouse and unloadings in selected supplier's warehouse.

$$GOAL = \min(R^2) = \min\left[\sum_{di=1}^{x}(U_{di} - \bar{U})^2\right] \quad (11)$$

where:

R^2 - dispersion of the number of unloadings in consignee's warehouse within the planning horizon,

U_d - number of unloadings in consignee's warehouse at day *di*.

$\bar{U}$ - mean value of unloadings in consignee's warehouse within the planning horizon.

di - index of optimal day of unloading, di∈{1,2,…,xi} where *xi* is the last optimal day in the planning horizon for the consignee-supplier *i* pair.

There may be more than one optimal unloadings schedule. Thus in the fourth phase of the algorithm the optimization of the loading schedule for selected supplier is done. The goal function (see eq. 2) is formulated analogously as in phase 3 of the algorithm as the dispersion of the number of loadings in supplier's *i* warehouse within the planning horizon. There are the same constraints as in phase 3 of the algorithm. One additional constraint related to the dispersion of the number of unloadings in consignee's warehouse within the planning horizon, which cannot be worse that the dispersion computed in phase 3 of the algorithm, is added.

$$GOAL = \min(R_i^2) = \min\left[\sum_{li=1}^{y}\left(L_{li}^i - \bar{L^i}\right)^2\right] \quad (2)$$

where:

R_i^2 - dispersion of the number of loadings in supplier's *i* warehouse within the planning horizon,

L^i_{li} - number of loadings in supplier's *i* warehouse at day *d*,

$\bar{L^i}$ - mean value of loadings in supplier's *i* warehouse within the planning horizon.

li - index of optimal day of loading in supplier i warehouse, li∈{1,2,…,y} where *yi* is the last optimal day of loading in supplier's *i* warehouse in the planning horizon.

In the last phase of the algorithm predefined loadings and unloadings schedules are updated by the results obtained in phase 4 of the algorithm. Then the algorithm checks whether all of the suppliers have been considered in the delivery scheduling process. If the answer is "yes", then the algorithm ends. Otherwise the algorithm selects the next in order supplier and returns to phase 3. It should be noticed that the unloading schedule for the newly selected supplier includes scheduling results for all earlier suppliers.

RESULTS

The presented algorithm has been implemented in MS Excel 2010 software. The standard version of the solver, which is delivered with this software, is utilized in optimization phases of the algorithm. The implemented algorithm was tested by authors on the real data obtained from one of the alcohol product importers. Due to the necessity to maintain full confidentiality, some random changes had to be applied to the data set which is utilized in the computational example presented in this paper. However these changes were applied in the manner, which does not affect the major characteristics of the considered problem.

The considered company is located in Poland. It is associated in one of the international corporations of alcohol products producers. Thus the company is the exclusive distributor of corporation's products on Polish market. Alcohol products are imported mainly from three EU countries, but there may be more than one supplier or more than one loading location in each country. Depending on the period of time, from a dozen to several dozen of various SKU's are imported from some or all suppliers. Transport is done exclusively by external carriers, which utilize fleets consisted of side-loading semi-trailers. Goods are transported as palletized unit loads. Assumed distances between loading and unloading places are relatively long. Therefore shipments are considered as full truck loads (homogenous or heterogeneous). Due to Intra Community Trade regulations transport takes place in excise duty suspension procedure using eAD document. So all deliveries are unloaded in company's excise warehouse. EXW Incoterms rule is applied in the transport process.

Delivery scheduling of products imported from other EU countries was previously conducted with the usage of typical DRP matrixes which were manually filled by planners hired by the company. The computational tools were utilized by planners only for data analysis and automatic recalculations of DRP matrixes. The decision about the quantity of pallets, which have to be delivered to the company each day, is made by planners and manually entered into DRP matrixes. Therefore the delivery scheduling process requires a lot of time, knowledge and experience from planners, while the results are not reproducible nor optimal.

The planning horizon in the considered problem is set to 56 days (8 weeks). The shipments are delivered from three suppliers. The quantity of shipments, which have to be delivered from each supplier every week, is determined on the basis of sales forecast and current stock. Detailed input data related to suppliers is presented in table 1.

Table 1. Input data related to suppliers
Tabela 1. Dane wejściowe dotyczące dostawców

Parameter	Supplier 1	Supplier 2	Supplier 3
No. of deliveries at week 1	3	10	8
No. of deliveries at week 2	3	9	2
No. of deliveries at week 3	4	5	8
No. of deliveries at week 4	5	8	10
No. of deliveries at week 5	5	7	5
No. of deliveries at week 6	5	10	2
No. of deliveries at week 7	8	5	9
No. of deliveries at week 8	4	10	6
Total no. of deliveries	37	64	50
Transport time [days]	2	1	3
Days, when loadings are not possible	6, 7, 13, 14, 20, 21, 26, 27, 28, 34, 35, 41, 42, 48, 49, 55, 56	6, 7, 10, 13, 14, 18, 19, 20, 21, 24, 26, 27, 28, 34, 35, 38, 41, 42, 48, 49, 52, 55, 56	none
Total no. of days without loading possibility	17	23	0

Source: own work

Table 1 shows that supplier's 1 warehouse does not work in the weekends and in one additional day which is reserved for stocktaking. In case of supplier's 2 warehouse, the non-working days are in each weekend. Two more days are non-working due to national holiday in supplier's 2 country. One more day is reserved for stocktaking and four more days for other activities related to fulfillment of sales plans. The consignee's warehouse does not work at days no. 6,7,13,14,20,21,25,26,27,28,34,35,41,42,48,49, 54,55,56, i.e. 19 days in total. Supplier's 3 warehouse as well as carriers do not have any constraints related to working days within the planning horizon. The scheduling process is conducted within pull system. Also consignee's, suppliers' and carrier's capabilities related to warehousing and transport processes are much higher than needed in this case. Thus there is no need to use constraints related to these aspects.

The consignee's fiscal warehouse does not have predefined any other shipments planned to be delivered within the planning horizon. Table 2 shows loadings in suppliers' warehouses realized for other consignees within the planning horizon.

The results generated by the proposed algorithm are shown below. Optimal dates of unloadings were calculated at the 1st phase of the algorithm. The results are shown in table 3.

Table 2. Schedule of predefined loadings to other consignees in supplier's warehouses
Tabela 2. Dchemat załadunków do innych odbiorców w magazynach dostawcy

Suplier 1															
	Day (d)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SUM
d+0	4	7	9	3	2	0	0	5	6	1	5	4	0	0	46
d+14	5	5	8	6	2	0	0	2	4	5	7	0	0	0	44
d+28	5	4	5	4	3	0	0	4	5	2	3	5	0	0	40
d+42	5	2	0	3	5	0	0	6	3	5	4	4	0	0	37
Suplier 2															
	Day (d)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SUM
d+0	8	7	5	4	3	0	0	6	6	0	9	8	0	0	56
d+14	2	9	7	0	0	0	0	1	3	0	1	0	0	0	23
d+28	1	6	5	8	1	0	0	4	9	0	4	7	0	0	45
d+42	7	4	5	0	8	0	0	2	1	0	1	8	0	0	36
Suplier 3															
	Day (d)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	SUM
d+0	8	5	2	3	9	0	4	5	5	6	4	3	10	2	66
d+14	6	0	0	7	0	2	8	2	3	9	9	7	0	6	59
d+28	6	5	7	5	7	9	9	6	7	8	6	1	10	0	86
d+42	10	0	4	2	3	4	10	0	6	9	6	9	0	6	69

Source: own work

Table 3. Optimal days of unloadings for each supplier
Tabela 3. Optymalne dni rozłunku dla poszczególnych dostawców

Parameter	**Supplier1**	**Supplier 2**	**Supplier 3**
Optimal days of unloadings	3,4,5,10,11,12,17,18,19,24,31, 32,33,38,39,40,45,46,47,52,53	2,3,4,5,9,10,12,16,17,18,23,24,30, 31,32,33,37,38,40,44,45,46,47,51,52	All with the exception of days 1, 2, 3 and these resulting from consignee's constraints
Total no. of optimal days	21	25	34

Source: own work

In the second phase of the algorithm the order of suppliers in the delivery scheduling process was determined. Due to the cooperation conditionings between consignee and suppliers, the following order was determined: supplier 1 -> supplier 2 -> supplier 3.

Due to the nonlinearity of the goal functions, the solver extension was configured to use Generalized Reduced Gradient method in 3rd and 4th phase of the algorithm. The optimization was conducted for each consignee-supplier pair on Intel Core i7 Q720, 4GB RAM system. The final results generated by the algorithm are shown in tables 4 and 5.

Table 4. Schedules of loadings and unloadings in suppliers' and consignee's warehouses generated by the algorithm
Tabela 4. Schemat załadunków i rozładunków w magazynach dostawców i odbiorców wygenerowany przez algorytm

Supplier 1														
	Day (d)													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	**GOAL**
d+0	5	8	10	3	2	0	0	6	7	2	5	4	0	0	137,71
d+14	6	7	9	6	2	0	0	7	4	5	7	0	0	0	140,86
d+28	7	6	6	4	3	0	0	6	6	4	3	5	0	0	89,14
d+42	7	5	3	3	5	0	0	8	5	5	4	4	0	0	90,86
														sum	**458,57**
Supplier 2															
	Day (d)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	**GOAL**
d+0	11	10	7	6	3	0	0	10	9	0	11	8	0	0	279,14
d+14	5	10	8	0	0	0	0	7	5	0	1	0	0	0	164,24
d+28	4	7	6	10	1	0	0	9	11	0	7	7	0	0	224,86
d+42	10	5	5	1	8	0	0	8	5	0	1	8	0	0	179,71
														sum	**848,00**
Supplier 3															
	Day (d)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	**GOAL**
d+0	12	9	2	3	10	0	4	6	5	6	4	6	10	4	166,29
d+14	6	3	0	7	8	4	8	2	3	9	9	10	1	6	156,86
d+28	6	6	7	5	8	9	9	7	7	8	6	5	11	2	60,57
d+42	11	1	4	2	7	4	10	2	6	9	6	9	0	6	157,43
														sum	**541,14**
Consignee															
	Day (d)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	**GOAL**
d+0	0	3	4	7	7	0	0	1	4	4	2	3	0	0	60,00
d+14	3	3	4	3	4	0	0	8	8	7	0	0	0	0	18,00
d+28	3	4	3	3	4	0	0	1	5	4	2	5	0	0	17,71
d+42	4	4	5	4	5	0	0	4	6	6	4	0	0	0	101,43
														sum	**320,29**

Source: own work

Table 5. Results generated by the scheduling algorithm
Tabela 5. Wyniki wygenerowany przez algorytm harmonizujący

Parameter	**Consignee**	**Supplier 1**	**Supplier 2**	**Supplier 3**
Number of planned loadings/unloadings	151	204	224	330
Number of scheduled loadings/unloadings	151	204	224	330
Value of the goal function before optimization conducted in phase 4	320,29	464,57	874,00	551,14
Value of the goal function after optimization conducted in phase 4	320,29	458,57	848,00	504,57
Phase 4 improvement of the goal functions values [%]	0	1,3%	3,0%	8,4%
Computational time [s]	267	55	90	122

Source: own work

As it is shown in tables 4 and 5, the algorithm managed to schedule all of the planned deliveries in 267 seconds. So it needed much less time to complete the task than average planner hired in the company. Generated schedules were also usually better than schedules generated by planners from the goal functions perspective. The optimization conducted in phase 4th of the algorithm resulted in the average improvement of suppliers' schedules by 4,2%.

DISCUSSION

In order to check whether further improvements of the goal functions values are possible, authors assumed that there is a possibility to change the order of suppliers in the scheduling process in the second phase of the algorithm. Additional five computational experiments were conducted for the input data presented in previous chapter. These experiments cover all possible combinations of suppliers order. The algorithm managed to schedule all planned deliveries in each experiment. The detailed results of all six experiments were summarized in table 6.

Table 6. Values of goal functions, improvements in loading schedules after phase 4 optimization and computational time of each of six experiments which were conducted

Tabela 6. Wartości celów funkcji, poprawy w schematach załadunków po przeprowadzeniu optymalizacji z punktu 4 we wszystkich 6 eksperymentach

	Values of the goal functions					Phase 4 average	Computational
Order	Consignee	Supplier 1	Supplier 2	Supplier 3	All suppliers	improvement [%]	Time [s]
S1->S2->S3	320,29	458,57	848,00	504,57	1811,14	4,2%	267
S1->S3->S2	344,29	458,57	894,00	527,43	1880,00	4,7%	300
S2->S1->S3	312,29	508,57	838,00	550,29	1896,86	4,4%	263
S2->S3->S1	344,29	458,57	838,00	512,57	1809,14	4,7%	303
S3->S1->S2	380,29	442,57	874,00	529,14	1845,71	5,8%	338
S3->S2->S1	380,29	486,57	888,00	529,14	1903,71	5,6%	342
					mean	4,9%	302,17

Source: own work

As it is shown in table 6, values of the goal functions may depend on the order of suppliers determined in 2nd phase of the algorithm. The best result on the value of criterion related to consignee's warehouse, i.e. 312,29, is achieved for the following suppliers order: S2 -> S1 -> S3. Comparing this order with the character of input data one may presume that the best result on the value of mentioned criterion may be achieved by ordering suppliers by the minimal time of transport (from the shortest one to the longest one), or by the number of days in which there is no possibility to load the shipment (from the largest number, to the smallest number). However further and more extensive research is needed in order to draw more binding conclusions. On the other hand, the values of the goal functions related to suppliers' schedules may achieve their best values for other suppliers order. E.g. the sum of the suppliers' goal functions achieved the best result in case of S2->S3->S1 order. However at this point it is almost impossible to draw any conclusions about the ordering rules which result in the best values of goal functions related to suppliers' warehouses. This may be related to the fact, that the criterion of minimization of the dispersion of unloadings in consignee's warehouse is considered in the algorithm as more important than the criteria related to suppliers' warehouses. Therefore the optimization of this criterion results in narrowing of the feasible solutions sets for other criteria. It should be also noticed, that in case of each experiment, the computational time was similar and oscillated near 5 minutes value. The average improvement of the goal functions after optimization done in 4th phase of the algorithm was 4,9%. This confirms the necessity of including this phase in the algorithm.

CONCLUSIONS

One of the advantages of the proposed algorithm is the fact that it could be easily implemented in standard spreadsheet software which is available in most companies. So there is no need to purchase specialized software.

The proposed algorithm allows to achieve good results in relatively short time. On the other hand the results of the experiments show a need for further research which may be conducted on two fields. The first direction of the research is related to the need to better recognition of suppliers ordering rules in the 2nd phase of the algorithm. The second direction refers to multiple criteria character of the problem. Usage of multiple criteria analysis or optimization methods may lead to achieve better results, especially in the situations, when suppliers and consignees are equally ranked in the decision process or in the situations, when increasing the stock in transit does not imply much higher cost of the whole logistic process.

REFERENCES

Cha B.C., Moon I.K., Park J.H., 2008. The joint replenishment and delivery scheduling of the one-warehouse, n-retailer system. Transportation Research E, 44, 720-730.

Chen B., Chung-Yee L., 2008. Logistics scheduling with batching and transportation. European Journal of Operational Research, 189, 871-876.

Cheng E. Wang X., 2010. Machine scheduling with job class setup and delivery considerations. Computers & Operations Research, 37, 1123-1128.

Fertsch M., 1996. Terminologia logistyczna - pojęcia i ich definicje (Logistic terminology - terms and their definitions), Instytut Logistyki i Magazynowania, Poznań.

Garcia J.M., Lozano S.. 2005, Production and delivery scheduling problem with time windows. Computers & Industrial Engineering, 48, 733-742.

Grajek M., 2011a. Harmonogramowanie dostaw wyrobów alkoholowych na obszarze Unii Europejskiej (cz.1) (Delivery scheduling of alcohol products in EU area - recognition of the problem part 1), Logistyka, 5, 31-32.

Grajek M., 2011b. Harmonogramowanie dostaw wyrobów alkoholowych na obszarze Unii Europejskiej - rozpoznanie problemu (cz.2) (Delivery scheduling of alcohol products in EU area - recognition of the problem part 2), Logistyka, 6, 38-39.

Grajek M., 2012. Harmonogramowanie dostaw wyrobów alkoholowych na obszarze Unii Europejskiej - rozpoznanie problemu (cz.3) (Delivery scheduling of alcohol products in EU area - recognition of the problem part 3), Logistyka, 1, 37-38.

Grajek M., Żak J., 2012. Konstrukcja i testowanie modelu matematycznego dla problemu harmonogramowania dostaw wyrobów alkoholowych na obszarze Unii Europejskiej (The design and testing of a mathematical model for the problem of delivery scheduling of alcoholic products in the EU), Logistyka, 2, cd 2, 609-622.

Gupta J.N.D., Henning K., Werner F., 1999. Local search heuristic for two-stage flow shop problems with secondary criterion, Otto von Guericke Universität, Magdeburg.

Hall N., Potts Ch., 2005, The Coordination of Scheduling and Batch Deliveries, Annals of Operations Research 135, 41-64.

Herka W., 2004. Harmonogramowanie procesów ciągłych w warunkach niepewności jako wielokryterialny problem decyzyjny (Scheduling of contiunous processes under uncertainty as multiple criteria decision problem), Wydawnictwo Politechniki Częstochowskiej, Informatyka Teoretyczna i Stosowana, 5 (4), 87-102.

Kovalyow M. Cheng E., 2001. Single supplier scheduling for multiple deliveries, Annals of Operations Research 107, 51-63.

Lenstra J.K., Rinnooy Kan A.H.G., 1978. Complexity of scheduling under precedence constraints, Operations Research, 26, 22-35

Lixin T., Hua G., 2009. The coordination of transportation and batching scheduling, Applied Mathematical Modelling, 33, 3854-3862

Tang J., Yung K.L., Kaku I.,Yang J., 2008. The scheduling of deliveries in a production-distribution system with multiple buyers, Annals of Operations Research, 161, 5-23.

Xue D., Wang H., Norrie D.H., 2001. A fuzzy mathematics based optimal delivery scheduling approach, Computers in Industry, 45, 245-259.

Zinder Ya.B., Shkurba V.V., 2001. Scheduling theory. Encyclopaedia of Mathematics, Springer-Verlag, Berlin, Heidelberg, New York.

HEURYSTYCZNE PODEJŚCIE DO PROBLEMU DZIENNEGO HARMONOGRAMOWANIA DOSTAW. STUDIUM PRZYPADKU: HARMONOGRAMOWANIE DOSTAW WYROBÓW ALKOHOLOWYCH W RAMACH WEWNĄTRZWSPÓLNOTOWEJ WYMIANY HANDLOWEJ

STRESZCZENIE. **Wstęp:** Harmonogramowanie dostaw odgrywa znaczącą rolę w działalności przedsiębiorstw funkcjonujących na rynku Unii Europejskiej, w tym tych zajmujących się produkcją i obrotem wyrobami alkoholowymi. Specyfika tejże działalności wymaga uwzględnienia przepisów prawnych, które warunkują szereg wytycznych i ograniczeń w magazynowaniu i przewozach tego rodzaju produktów pomiędzy krajami UE. Jednocześnie problematyka ta jest stosunkowo słabo rozpoznana w literaturze.
Metody: Autorzy zaproponowali heurystyczny algorytm rozwiązywania problemu harmonogramowania tego rodzaju dostaw. W oparciu o dane wejściowe zawierające zapotrzebowanie w dłuższym horyzoncie czasowym oraz przy uwzględnieniu ograniczeń, zaprezentowana procedura pozwala na ustalenie harmonogramu dostaw od jednego lub wielu dostawców do jednego odbiorcy z dokładnością do jednego dnia. Algorytm uwzględnia interesy odbiorcy, dostawców oraz przewoźnika poprzez uwzględnienie ich ograniczeń oraz zastosowanie trzech kryteriów w procesie harmonogramowania, tj.: minimalizacji zapasu w drodze, a także minimalizacji rozrzutu liczby załadunków w magazynach odbiorcy i dostawców.
Wyniki: Zaproponowany algorytm zaimplementowano w arkuszu kalkulacyjnym z dodatkiem solver. Zaaplikowano go do rozwiązania rzeczywistego problemu w jednej z firm importujących wyroby alkoholowe, w której stosowano dotychczas metodę manualnego wypełniania tablic DRP. Rezultaty wskazały na poprawność działania algorytmu i jego wysoką efektywność względem dotychczas stosowanej metody.
Wnioski: Rezultaty wskazały na potrzebę dalszych badań w zakresie wyboru kolejności harmonogramowania dostaw od poszczególnych dostawców, a także na możliwość zastosowania narzędzi wielokryterialnej analizy lub optymalizacji do rozwiązywania tego rodzaju problemów.

Słowa kluczowe: harmonogramowanie dostaw, węwnątrzwspólnotowa wymiana handlowa, import wyrobów alkoholowych, podejście heurystyczne, implementacja w arkuszu kalkulacyjnym, optymalizacja.

DER HEURISTISCHE VERSUCH ZUM PLANUNGSPROBLEM DER TAGESLIEFERZEIT. DER KASUS: LIEFERZEITPLAN VON MONOPOLWAREN IM RAHMEN DES INNERGEMEINSCHAFTICHEN HANDELS

ZUSAMMENFASSUNG. Einleitung: Der Lieferzeitplan spielt eine wichtige Rolle für die auf dem Markt der Europäischen Union funktionierenden Firmen. Er ist besonders bedeutend für die Firmen, die sich mit der Herstellung und dem Umsatz von Monopolwaren beschäftigen. Die Eigentümlichkeit einer solchen Wirtschaftstätigkeit erfordert, dass viele gesetzliche Regelungen beachtet werden müssen, die auch zahlreiche Richtlinien und Beschränkungen in Lagerhaltung und Transport von diesen Produkten in der Europäischen Union bedingen. Man soll hier betonen, dass diese Problematik bisher nur in einem gewissen Maße in der betreffenden Literatur erforscht wurde.

Methoden: Es wird die heuristische Methode für den obengenannten Lieferzeitplan vorgeschlagen. Die Methode ermöglicht die Festsetzung des Lieferzeitplans von einem oder vielen Lieferanten zu einem Empfänger (auf den Tag genau) in Anlehnung an die Eingabedaten, die den Bedarf in längerer Zeit und mit Rücksicht auf die Beschränkungen enthalten. Die Methode berücksichtigt die Interessen sowohl des Lieferanten, des Empfängers als auch des Transporteurs, denn sie beachtet die Beschränkungen und nutzt drei Kriterien, d.h. Minimalisierung des Bestandes, der unterwegs ist, Minimalisierung der Verladungsverteilung und Minimalisierung der Entladung.
Ergebnisse: Die Methode wird in den Kalkulationsbogen, der mit einem Solver ausgerüstet ist, implementiert. Die Methode kann auch in einer Firma, die Monopolwaren importiert, angewendet werden. Früher hat diese Firma die Methode von DRP Matrix-Ausfüllen in Anspruch genommen. Die Ergebnisse haben bewiesen, dass die neue Methode richtiger und besser als die früher benutzte ist.
Fazit: Die Ergebnisse beweisen, dass die weitere Forschung notwendig ist und die Methoden von Multikriterien-Analysen und die betreffende Optimierung in Frage kommen.

Codewörter: Lieferzeitplan, innergemeinschaftlicher Handel, Monopolwarenimport, der heuristische Versuch, Optimierung, Implementierung in den Kalkulationsbogen.

Mariusz Grajek, Paweł Zmuda-Trzebiatowski
Institute of Machines and Motor Vehicles
Poznan University of Technology
3 Piotrowo St, 60-965 Poznan, Poland
e-mail: mariusz.grajek@gmail.com
e-mail: pawel.zmuda-trzebiatowski@put.poznan.pl