logistics

MDPI

Article)

A decision support framework for construction logistics using a pickup and delivery model

József Békési [1], Miklós Krész [2,*] and Ákos Szirányi [3]

[1] University of Szeged; bekesi@inf.u-szeged.hu
[2] University of Szeged; kresz@jgypk.szte.hu
[3] University of Szeged; …
* Correspondence: kresz@jgypk.szte.hu; Tel.: (optional; include country code; if there are multiple corresponding authors, add author initials)

Abstract: In our study, we will overview some of the logistics activities of larger (typically at least 50 operators) construction companies with several sites working on simultaneous projects. We outline some decision support and optimization possibilities. To find a relocation of non-self-propelled machines, we present a specific optimization procedure. The task is modelled as a variant of the so called pickup and delivery problem, which is a well-known mathematical optimization problem. We describe our functional needs in relation to an application software. Such model of construction companies' activities is also justified by the following facts:
- the activities and locations of the resources of the investigated companies are constantly changing,
- the individual construction companies often cooperate with each other and work side-by-side on the same project,
- a comprehensive examination of supply chains is required, eg. to minimize the total cost and environmental pollution.

Keywords: Logistics; Optimization; Pickup and Delivery Problem

Citation: Békési, J.; Krész, M.; Szirányi, Á. A decision support framework for construction logistics using a pickup and delivery model *Logistics* **2021**, *5*, x. https://doi.org/10.3390/xxxxx

Academic Editor: Firstname Lastname

Received: date
Accepted: date
Published: date

1. Introduction

The transfer problem discussed in this paper can be modelled as a variant of the so called pickup and delivery problem (PDP). PDP is a well-known mathematical optimization problem, which has many variants. A detailed survey on several types of the problem is given by Parragh, Doerner, and Hartl [11]. This paper classifies the general problem into subclasses and gives mathematical formulations for each of them. A similar classification scheme is given by Berbeglia et al. [4]

The theoretical models of PDP usually assumes, that the sum of the total requests and the sum of the total supplies is equal. However in real-world problems this ideal assumption is rarely holds. In this paper we introduce a model which handles such practical situations, so we omit these kinds of equilibrium conditions. This gives the specialty of our method. The investigated problem arose at a construction company, that at the same time was working on several projects, at various locations, with different machines that have different functions. Most of the machines were not self-propelled. At the different project locations, machine demand often changed. Maximally satisfying the emerging new machine demand by reallocating idle machines was a common task. Furthermore, it was also a common task to transfer unneeded machinery to the main site and, at times, to transport the dysfunctional machines to the repair workshop. Our aim was to create a method that provides fast and cost-effective transports.

2. Transportation logistics & transportation of machine resources

Logistics is a philosophy and a method that aims to comprehensively organize, control and evaluate supply processes in order to achieve economic and social results. Given that it is an interdisciplinary science, individual subfields can be named and categorized according to several criteria. One of the frequently mentioned subfield is transportation logistics. Most often, this term refers to the different types of transport (railway –waterway – vehicular) of diverse types of goods (e.g. industrial, commercial, agricultural), but there are also some other areas that are least often included in the upper mentioned one. Construction transport logistics is also widely known, generally refers to the transportation of raw and auxiliary materials for construction purposes. In the field of construction logistics, several publications have appeared in recent years (see Lundesjö [15] for an overview). However, there are some areas of construction logistics companies' every day activities that have not been studied in detail in the literature so far, even though, these practical improvements would be important for the effectiveness of companies.

Machinery, trucks and cars operated by construction companies cover a wide range of the technological needs of the performed tasks. Machines can be classified into different machine groups. These groups are formed based on criteria important for companies. Within each determined criterium group individual machines can replace each other. Each machine group differs from all other machine groups by at least one of the company's important criteria.

Project based work is typical, each project's nature, content, duration, machine requirement and location differs. During a project's lifetime - as work progresses - the daily demand for machines changes, and also particularly with line construction (e.g. road construction), the project location is constantly changing as well. The pre-drafted project plan changes often and with necessity during its implementation and daily work due to for example unexpected weather and road conditions, or unexpected failure of machinery. In such cases, the machines and the operators must be able to be re-grouped immediately. In the course of continuous resource allocation activities, especially in cases of unsatisfactory machine operation, the priority of each project should be considered.

3. "Heavy machine transfer problem" (The transportation of heavy machinery)

The daily operational work of construction projects is managed by construction managers. During their daily shifts they continually communicate their machine requirements and information to the controller (see below), which for example can be the following:

- a particular machine should remain on the location for the next working day, and can be further used
- an additional machine in a particular machine group is required for the next working day
- after its daily shift a machine becomes unnecessary for the next working day
- a machine has become unneeded and can be removed immediately or after the daily shift
- a machine has become unneeded and cannot be stored at that location any further
- deficient machine has to be fixed after its daily shift
- deficient machine must be fixed right away

For all projects comprehensively, tasks related to resource allocation are usually carried out by a central logistic manager (hereinafter referred to as the "controller") who is performing operational work, satisfying the construction managers' demand to the largest extent, preferably at a minimum cost, while also minimizing the loss of unsatisfied claims. He runs the company's entire machine park. The organization tasks performed by the controller and construction managers and the frequency and timing of the company's internal delivery tasks vary. The spatial layout of the construction managers and the controller, as well as the information transmitted is shown in Figure 1.

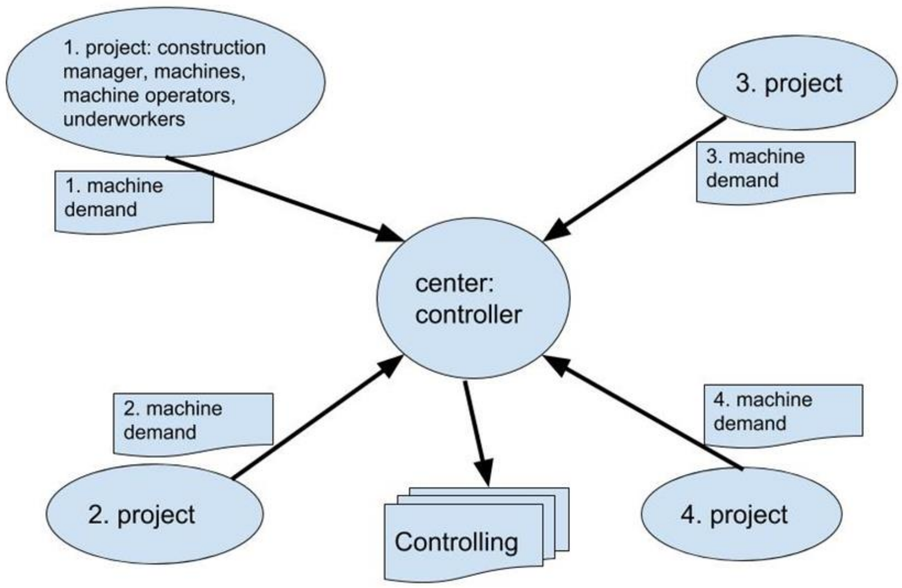

Figure 1. The construction managers are sending their prevailing machine requirements to the controller constantly, and then the controller sends the certain details of the completed command plan to the construction managers.

The relocation and resettlement of non-self-propelled machinery requires shipping with the help of a trailer, and in the case of a trailer a route planning task immediately emerges. Highlighting from the full scope of the task circle, we examine this dual task in our study.

One of the basic tasks of the controller is to set up the schedule of the machines and operators for the beginning of the next working day and, if required, to make changes to this schedule during the day. According to practical experience, 1 main controller can handle the workload of continuous schedule preparing for the maximum amount of 80-100 machines and their needed machine operators - with a relatively tolerable stress load.

The aspects to be considered are very diverse, they are company and partly project-specific, their detailed description would require a separate study. The IT tools and system that support the work of the controller, can be expected to perform decision support and optimization at certain times. The relocation and resettlement of non-self-propelled machinery (hereinafter referred to as "machines"), as well as the route planning of the trailer transporting them is considered to be highly worthy of inspection because it gives a possibility to optimize the costs of the trailer.

Figures 2 and 3 illustrate such a problem with same initial states but with different solutions.

The basic data is the following:

5 working, idle machines (machine supply),

7 machine requirements (machine demand),

8 project locations (P1, P2, ... P6, depot, workshop. Depot and machine repairing workshop(s) is/are also considered project locations.)

In both cases of machine supply and machine demand, the machine groups are marked with different pictograms: hexagon, rhombus, circular sector, rectangle, circle and cross.

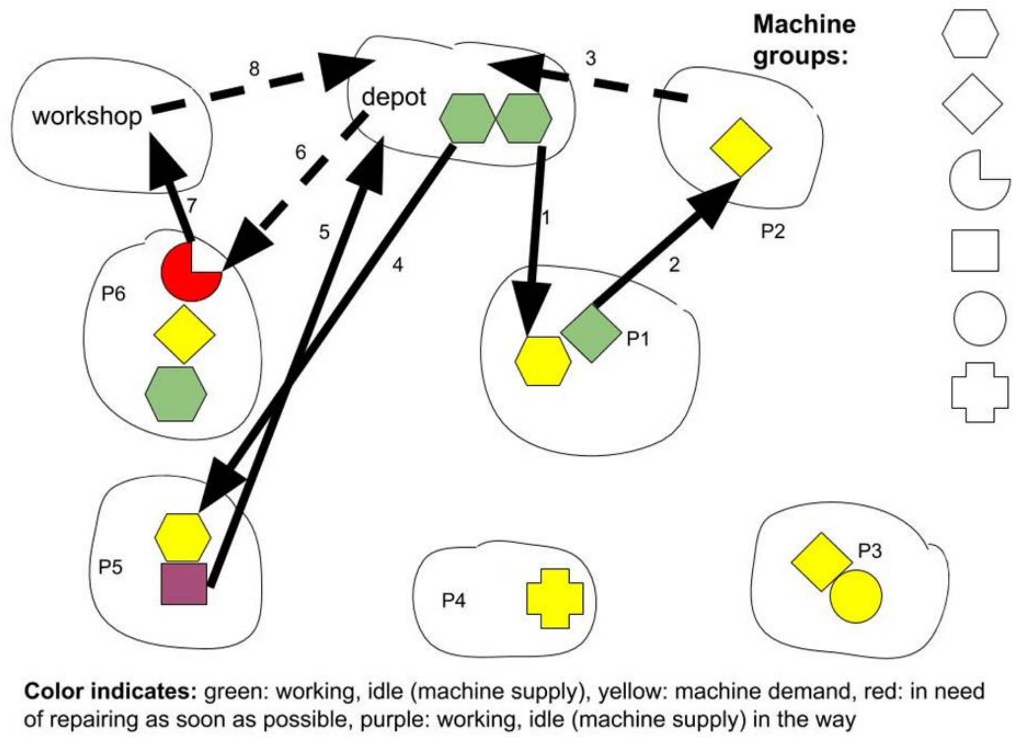

Figure 2. A possible machine resettlement and trailer route.

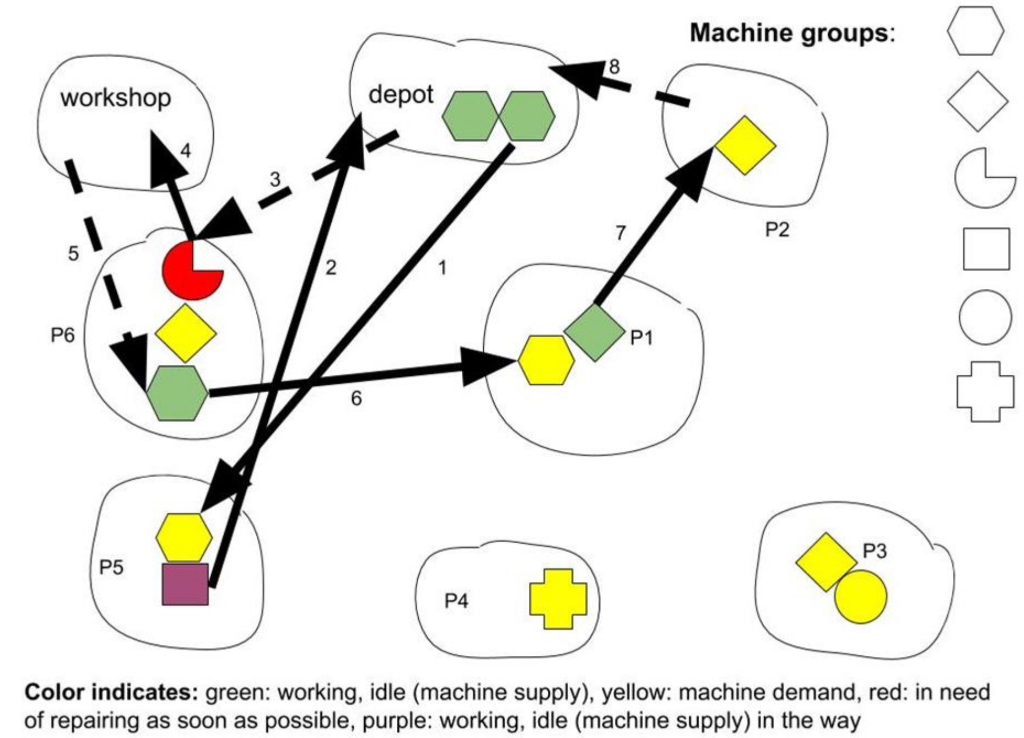

Figure 3. A possible machine resettlement and trailer route.

We indicated three different machine statuses:

- the light green color indicates idle, working machines,

- the pale purple color indicates machines that are idle, working, but are in the way on the certain project location, therefore are needed to be removed as soon as possible,

- the red color indicates machine(s) needed to be delivered to a workshop as soon as possible.

The trailer starts from the depot in both figures, and after satisfying the demand also returns to the depot.

Allocation of resources, i.e. pairing machine supply and demand, that is, satisfying a machine requirement is met by an idle machine - that belongs to a machine group indicated in the machine requirement - being transported to the point of demand with the trailer.

The demand satisfactions (i.e. the trailer's stacked runs) are marked with thick, continuous, black arrows, and the trailer's empty runs are marked with dashed, thick, black arrows. The arrows representing the stacked and empty runs were numbered according to the selected route of the trailer.

The two figures contain pairings that are the same (otherwise not possible), these are the following:

- The machine that is to be repaired as soon as possible was delivered to the workshop.

- The machine that is idle, working, but is in the way on the certain project location was transported to the depot because we did not have any machine requirements for the machines in this machine group.

The other pairings in the two figures are partly different and partly identical.

Concerning the free capacities and machine requirements that are not included in the pairings both figures have in common the following:

- The idle machine (1 piece), which currently is not in demand was left in its previous position in the figure.

- Machine requirements for which no idle machine can be found (2 pieces) remained unsatisfied.

The following can be stated from the figures as well:

- Resource allocation is a pairing task, that in case of the certain machine groups can be either symmetrical or asymmetrical. In case of any machine groups, there may be more machine demand than machine supply, in which case it is impossible to satisfy all machine requirements. In that case, it has to be chosen by the optimum provided by the controller, or in the absence of thereof, provided by the software, which needs are met;

- A reverse case might occur as well: any machine group may have more machine supply than machine demand. In this case, it has to be chosen by the optimum provided by the controller, or in the absence of thereof, provided by the software which machines will be included in the satisfaction of the requirements. The idle machines that are not used based on the controller's decision will either be returned to the main site of the company or will be temporarily left on the project location until a new decision is made; therefore, the said project location becomes a temporary (dynamic) main site.

- The pairings can be executed in different orders (different from the order shown in the figures), which is an NP difficult problem in itself.

- When planning the total cost and running time of the trailer, both the stacked runs and the empty runs have to be considered.

- The maximum number of possible pairings is the minimum number of machine supply and machine demand for each machine group. In our case, in figures 1 and 2, in the case of any pairing, the trainer will have 5 stacked runs (including the transport of the non-working machines to the workshop and the transport of machines in the way to the depot).

In conclusion: the selectable machine supply – demand pairings and the trailer's possible routes are interdependent. We would like to determine the supply-demand pairing and the trailer route that has maximal demand satisfaction, minimal trailer costs, and includes the following initial simplification criteria:

a) If there are more demand than supply in any machine group, we rely on our algorithm to select the requirements that actually will be met. So, the priority between projects is not being considered for now.

b) If there are more supply than demand in any machine group, we would rely on our algorithm to select the machines actually used.

c) If there are more supply than demand in any machine group, the unused, idle machines would be temporarily left at the project location for now.

d) We are not dealing with machines that are unusable and are to be repaired urgently in the workshop.

e) We are not dealing with machines that are usable but are in the way on the current project location.

f) The positions of project locations and distances between them are given and known.

g) The daily time window for each project location is the same, therefore we do not address the time window.

h) The number of trailers is given as basic data, companies aim to solve the task with as few trailers as possible.

i) The capacity of the trailers (load capacity and cargo space) is similar and can only be used to transport one machine at a time.

j) To simplify the costs of the trailer we characterize it with a single number (in our case, with the kilometers traveled).

k) Neither the permissible daily driving and working time of the driver(s), nor the average speed of the vehicle and the time required for loading/unloading is considered.

l) The place of departure and final arrival of the trailers are the main site. The number of trailers and their departure and arrival locations are clarified before the task is completed and will be fixed in the controller's software later on.

4. The mathematical model of the heavy machine transfer problem

The general pickup and delivery problem can be modeled by a directed complete graph $G=(V,E)$, where $V=\{v_1,\dots,v_n\}$ is the set of vertices and $E=\{(v_i,v_j): v_i,v_j \in V, i\neq j\}$ is the set of edges. Here the vertices model the geographical locations of the customers and suppliers and they can be called as request or supply vertices. Each edge $e\in E$ has a non-negative weight or cost c_e, which represents the travelling cost between two vertices. It can be the distance or the travelling time. We are given a set of commodities $P=\{p_1,\dots,p_m\}$. The commodities represent the entities to be transported. In our model they represent the machines. In the general model a commodity vector is assigned to each node. For a given node $v\in V$ and commodity $p\in P$ the commodity value $R(v,p)$ represents the amount of commodity supplied or requested by the given node. For supply nodes $R(v,p)>0$ and for request nodes $R(v,p)<0$. It is common that an equilibrium is assumed, i.e. that the total amount of requests equal to the total amount of supplies. Formally $\sum_{v\in V} R(v,p)=0$ for each $p\in P$. This is a natural assumption, however in practical situations it does not always hold. Sometimes it can happen that the total amount of supplies for a commodity is more than the sum of its requests. Even that can happen that it is less. The transportation can be done by a set of available vehicles $L=\{l_1,\dots,l_k\}$ with capacities $q_1, \dots, q_k$. Starting and finishing points are specified for each vehicle and the aim is to find a set of routes, such that

- each route can be assigned to an available vehicle,
- the load of the vehicle never exceeds its capacity during the route,
- all requests are satisfied,
- the sum of the cost of the designed routes is minimal.

Because of the equilibrium condition on commodities all the requests can only be satisfied if all the supply vertices are visited as well. As we mentioned before the equality of the sum of the total requests and the sum of the total supplies is a reasonable assumption from mathematical point of view, but sometimes it is not practical. In the real-world situation we want to handle the inequality of the two amounts is possible. Recently Ting and Liao introduced such model, which relaxes the constraint that each supply node must be visited. [12] Later the model was extended to the multiple vehicle case by Ting et al in [13]. However these models assume that there is always enough amount of supply to satisfy all the requests. In our case this is not always true.

Berbeglia et al. classified the PDP into three main subclasses, based on the number of origins of the commodities. These are the one to one, one to many to one and the many to many problems. The one to one problems can be called as paired problems, because in this case the origin and the destination of a commodity is exactly given. In case of many to many or unpaired problems more origins and destinations are possible for a commodity. Many variants of these subclasses are investigated in the literature. Here we mention only the swapping problem, which is a specific many to many problem. It was introduced by Anily and Hassin [2]. The swapping problem is a single vehicle PDP, where the capacity of the vehicle is one. This condition corresponds to our requirement, however in our case more vehicles can be used and no equilibrium is assumed on the supply and request values of the commodities. Based on this we can call our problem as Multi Vehicle Selective Swapping Problem (MVSSP). Several papers discussed the swapping problem [1,3,5,6,7,9].

In their survey Parragh, Doerner and Hartl gave mathematical formulations for several variants of the PDP. In the following we give a similar formulation for our real-world problem.

To simplify the formulation, we define a specific bipartite graph G to model the problem. A node will represent a location and a machine group. If a physical location offers or requests more machine groups, then more nodes will be assigned to them. The nodes will be divided into two sets, S and O. S will be the set of supplies and O will be the set of orders. An $s \in S$ will be connected to an $o \in O$ by a directed edge, if their machine groups are equal, which means that the request represented by o can be satisfied from s. As in the general model, we assume that we are given a set of vehicles $L = \{l_1, \dots, l_k\}$ with capacities 1. The set of the departure and arrival locations are given in advance, they will be denoted by D and A. We assign nodes to the elements of D and A as well. The node assigned to vehicle $l \in L$ will be denoted by n_l. We add the nodes of D to S and the nodes of A to O and we denote the new sets by S and O. To represent the possible deadhead trips, we connect each node of O to each node of S, except that we do not connect any arrival and departure node to each other in neither direction. But we connect every departure node to every order node. Using this graph model, the following mathematical programming model can be given.

For the formulation we use the following notations:

$V(G)$: the vertices of G,
$E(G)$: the edges of G,
$E^-(n)$: the set of incoming edges into node n,
$E^+(n)$: the set of outgoing edges from node n,
c_{ij}: the weight of $(i,j) \in E(G)$,
t_{ij}: the travelling time of the vehicle on the way represented by (i,j),

Q^l: the maximal possible working time for vehicle $l \in L$,

M: a large constant, that is larger than the sum of the possible running time of all the vehicles.

We use the following decision variables. For each edge $(i,j) \in E(G)$ and $l \in L$ define $x_{ij}^l = 1$ if the trip between nodes i and j will be executed by vehicle l and $x_{ij}^l = 0$ otherwise. Let $y_j = 1$ if the request $j \in O \backslash A$ is satisfied, otherwise let $y_j = 0$. Finally let T_j^l be the relative arrival time of vehicle l at node j.

The MVSSP can be formulated as the following integer program:

$$\max \; -\mathrm{M} \sum_{k \in O \backslash A} y_k + \sum_{(i,j) \in E(G)} c_{ij} \sum_{l \in L} x_{ij}^l$$

subject to

$$\textstyle\sum_{l \in L} \sum_{(i,j) \in E^-(j)} x_{ij}^l - y_j = 0, \forall\, l \in L, j \in O \backslash A \quad (1)$$

$$\textstyle\sum_{(i,j) \in E^-(j)} x_{ij}^l \le 1, \forall\, l \in L, \text{ where } j \in A \text{ is the node assigned to } l \quad (2)$$

$$\textstyle\sum_{(i,j) \in E^+(i)} x_{ij}^l \le 1, \forall\, l \in L, \text{ where } i \in D \text{ is the node assigned to } l \quad (3)$$

$$\textstyle\sum_{(i,j) \in E^+(i)} x_{ij}^l - \sum_{(j,i) \in E^-(i)} x_{ji}^l = 0, \forall\, l \in L, i \in O \backslash A \cup S \backslash D \quad (4)$$

$$T_j^l \ge (T_i^l + t_{ij}) x_{ij}, \forall\, (i,j) \in E(G), l \in L \quad (5)$$

$$x_{ij}^l \in \{0,1\}, \; \forall\, (i,j) \in E(G), l \in L \quad (6)$$

$$y_j \in \{0,1\}, \forall\, l \in L, j \in O \backslash A \quad (7)$$

$$T_j^l \ge 0, \qquad \forall\, l \in L, j \in V(G) \quad (8)$$

$$T_j^l = 0, \qquad \forall\, l \in L, \text{where } j \in D \text{ is the node assigned to } l \quad (9)$$

$$T_j^l \le Q^l, \forall\, l \in L, \text{where } j \in A \text{ is the node assigned to } l \quad (10)$$

The objective function expresses our aim that first we want to maximize the number of satisfied requests and secondly we want to minimize the total cost of the transport. Constraint (1) ensures that either a request cannot be served or it is served by at most one vehicle. Constraints (1) and (2) mean that each vehicle is used at most once and it departs from its starting location and arrives back to the required place. Constraint (4) is the flow conservation equality, which express that if a vehicle arrives at a location, then it should continue its journey until its end depot. Constraint (5) ensures the consistency of the time variables. Finally Constraint (10) guarantees that a vehicle will not run more than its maximal allowed time. Note that inequality (5) is not linear, but it can be linearized in the same way as in Cordeau's paper [8]. We can use the form

$$T_j^l \ge T_i^l + t_{ij} - N(1 - x_{ij}), \forall\, (i,j) \in E(G), l \in L$$

instead of (5), where N is a constant, that is larger than the largest possible time value.

5. Test results

We generated several test instances. 10 instances were created by a logistic expert. These problems were similar to practical problems. Next we generated three times 10 problems in a random way. The problems of the groups contained 10,15 and 20 orders. The location and the machine group of the orders were generated in a random way using uniform distribution. The supplies of the machines were generated in a similar way. Finally we created three times 10 larger problems with sizes 100,150 and 200. We solved the generated models for each instance using CPLEX. The smaller problems were tested with 1,2 and 3 vehicles, while the larger ones only with 1 vehicle. The next tables lists the running times of the solver for each problem. The solver was started using a time limit of 1200 seconds for each instance.

Table 1. Running times of the practical problems in milliseconds

Problem #	Vehicles	Time

1	1	40
	2	100
2	1	20
	2	45
3	1	50
	2	822
4	1	50
	2	783
5	1	75
	2	10249
6	1	35
	2	130
7	1	45
	2	125
8	1	25
	2	745
9	1	41
	2	90
10	1	1055
	2	210827
Avg	1	143,6
	2	22391,6

Table 2. Running times of the smaller random problems in milliseconds

			Size	
Problem #	**Vehicles**	**10**	**15**	**20**
1	1	20	50	60
	2	135	79649	120
	3	210	1200191	70175
2	1	10	27	47
	2	275	94	125
	3	25977	62427	531
3	1	10	47	31
	2	50	110	123
	3	135	5051	48276
4	1	20	203	47
	2	140	19153	2444
	3	7172	1200043	1200028
5	1	10	149	105
	2	190	2936	2206
	3	10075	785101	1200064
6	1	20	32	78
	2	125	156	110
	3	3865	297	132931
7	1	10	396	47

	2	45	5003	203
	3	155	219285	3900
8	1	41	16	63
	2	440	578	647
	3	41119	168635	1475
9	1	15	47	72
	2	115	312	322
	3	720	7406	1200033
10	1	10	47	133
	2	75	110	118652
	3	520	734	1200248
Avg	1	16,6	101,4	68,3
	2	159	10810,1	12495,2
	3	8994,8	364917	505766,1

Table 3. Running times of the larger random problems in milliseconds

			Size	
Problem #	**Vehicles**	**100**	**150**	**200**
1	1	6251	26559	65815
2	1	8068	12124	44377
3	1	10918	16931	50195
4	1	6088	29568	58634
5	1	7365	17121	41553
6	1	7757	16040	40741
7	1	10540	25239	81613
8	1	5954	21602	81176
9	1	15271	17256	54561
10	1	6979	20947	54159
Avg		8519,1	20338,7	57282,4

With respect to the tables, we can state that with the elaborated algorithm and the CPLEX solver software, tasks with practical needs can be solved with realistic run-time, even in the case of the largest construction companies.

6. Conclusions

In this paper we studied a pickup and delivery model for a specific construction logistic problem. Our aim was to give an exact mathematical model of this daily transportation task. We were able to find the optimal solutions of such instances that can happen in practice. The running times show that the optimal solutions can be found in a relatively short time for such problems.

Supplementary Materials: -

Author Contributions: Conceptualization, X.X. and Y.Y.; methodology, X.X.; software, X.X.; validation, X.X., Y.Y. and Z.Z.; formal analysis, X.X.; investigation, X.X.; resources, X.X.; data curation, X.X.; writing—original draft preparation, X.X.; writing—review and editing, X.X.; visualization, X.X.; supervision, X.X.; project administration, X.X.; funding acquisition, Y.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Research, Development and Innovation Office NKFIH [grant number SNN 129178].

Data Availability Statement: -

Acknowledgments: -

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Anily, S.; Gendreau, M.; Laporte, G. The preemptive swapping problem on a tree. *Networks* **2011**, *58(2)*,83–94, https://doi.org/10.1002/net.20451.
2. Anily, S., Hassin, R. The swapping problem. *Networks* **1992**, *22(4)*, 419-433, https://doi.org/10.1002/net.3230220408.
3. Anily, S.; Pfeffer, A. The uncapacitated swapping problem on a line and on a circle. *Discrete Applied Mathematics* **2013**, *161(4-5)*, 454–465, https://doi.org/10.1016/j.dam.2012.07.002.
4. Berbeglia, G.; Cordeau, J.F.; Gribkovskaia, I.; Laporte, G. Static pickup and delivery problems: A classification scheme and survey. *TOP* **2007**, *15*,1–31, https://doi.org/10.1007/s11750-007-0009-0.
5. Bordenave, C.; Gendreau, M.; Laporte, G. A branch-and-cut algorithm for the nonpreemptive swapping problem. *Naval Research Logistics* **2009**, *56(5)*,478–486, https://doi.org/10.1002/nav.20361.
6. Bordenave, C.; Gendreau, M.; Laporte, G. Heuristics for the mixed swapping problem. *Computers & Operations Research* **2010**, *37(1)*,108–114, https://doi.org/10.1016/j.cor.2009.03.032.
7. Bordenave, C.; Gendreau, M.; Laporte, G. A branch-and-cut algorithm for the preemptive swapping problem. *Networks* **2012**, *59(4)*,387-399, https://doi.org/10.1002/net.20447.
8. Cordeau, J.F. A Branch-and-Cut Algorithm for the Dial-a-Ride Problem. *Operations Research* **2006**, *54(3)*,573-586, https://doi.org/10.1287/opre.1060.0283.
9. Erdogan, G.; Cordeau, J.F.; Laporte, G. A branch-and-cut algorithm for solving the non-preemptive capacitated swapping problem. *Discrete Applied Mathematics* **2010**, *158(15)*,1599–1614, https://doi.org/10.1016/j.dam.2010.05.025.
10. Lundesjö, G. editor. *Supply Chain Management and Logistics in Construction*. *Delivering Tomorrow's Built Environment*. Kogan Page Limited: London, UK , 2016.
11. Parragh, S.N.; Doerner, K.F.; Hartl, R.F. A survey on pickup and delivery models part II: Transportation between pickup and delivery locations. *Journal für Betriebswirtschaft* **2008**, *58*, 81-117, https://doi.org/10.1007/s11301-008-0036-4.
12. Ting, C.K.; Liao, X.L. The selective pickup and delivery problem: Formulation and a memetic algorithm, *Int. J. Production Economics* **2013**, *141*, 199–211, https://doi.org/10.1016/j.ijpe.2012.06.009.
13. Ting, C.K.; Liao, X.L.; Huang, Y.H.; Liaw, R.T. Multi-vehicle selective pickup and delivery using metaheuristic algorithms. *Information Sciences* **2017**, *406-407*, 146-169, https://doi.org/10.1016/j.ins.2017.04.001.