TRANSPORT PROBLEMS 2021 Volume 16 Issue 4
PROBLEMY TRANSPORTU DOI: 10.21307/tp-2021-057

Keywords: vehicles; optimization; warehouse; transceiver points; ramps

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PLANNING AND MODELING OF THE TIME FOR ACCEPTANCE AND STAY OF VEHICLES AT THE LOADING AND DISCHARGING POINTS

Summary. When delivering goods in the warehouses of enterprises, courier and forwarding companies, and for logistics operators, loading and unloading is usually done manually or mechanically. On the other hand, the load can first be placed on the ground next to the vehicle and then accepted in the pile, or a ramp can be used so that it can be delivered directly to the warehouse or vice versa. When there is a ramp, the loading and discharging activity is performed faster and it is much easier. When there are many vehicles serviced on ramps, it is necessary to have a free ramp available. This is often not the case when the warehouse has more ramps and a large exchange of goods. In this case, a time schedule is usually made for the reception and handling of vehicles, which is communicated to carriers and drivers so that there is no unnecessary downtime of vehicles and overloading of points with ramps. There are cases in which the established organization of work cannot be performed due to various force majeure or other reasons, such as delays at border crossings, bans on passing through certain sections, change in the working hours of warehouses, pandemic and other reasons. The vehicles then arrive at the checkpoints at a time that is different from their schedule and have to wait to be serviced. Waiting at the unloading points makes drivers nervous and they become dissatisfied with the working conditions. In this respect, a solution has been proposed based on the working hours and occupancy of the loading and discharging point and the time of arrival of the vehicles at the point, and how to receive the vehicles so that the waiting time between them is the shortest. For this purpose, a partially integer linear optimization model has been created in Matlab, which provides a valid plan with the shortest waiting times for all vehicles. Simulations have been made for different numbers of ramps and vehicles. The results show that the model is suitable for pre-creating a valid plan for the operation of the vehicle warehouse, if any, with a minimum waiting time.

1. INTRODUCTION

When multiple vehicles are serviced in one loading, discharging – or loading- discharging point, it is necessary to follow the order of arrival or the set schedule. This can be done through good organization and strict adherence to working hours. When performing synchronous work between the loading and discharging points and the vehicles, a mathematical apparatus is presented, according to which the calculations specified in [5] should be performed. The specified mathematical apparatus makes it possible to draw up a plan in which the vehicles arriving at the checkpoints will not stagnate, as well as at the checkpoints, and the workers do not wait without work. This is possible when a preliminary organization is made and there is enough load and the vehicles comply with the schedule. However, there are other situations where the vehicles are smaller or the loads are less, as well as cases where each vehicle needs to arrive in a certain time window, or conversely, the vehicle may require a time range, in which it can be serviced. At the same time, the synchronous operation of loading and discharging points and vehicles is related to the planning of carriers. In [6], a mathematical apparatus is presented using which classical problems related to traffic optimization can be solved. Based on the known models, software products have been created that can derive solutions to the above-mentioned tasks as a solution; an example of this is the TransCAD product, which is intended for professional purposes and is suitable for large companies, or a training version, which is prepared for academia [20]. In [16], the author conducted a comparative study, in the ArcGIS environment of TransCAD, between an electric vehicle, a light vehicle and a vehicle and a drone to select suitable transport and parcel delivery routes in Ohio. The results obtained from the study show the usefulness of the software product. When solving such tasks, some special cases arise related to the peculiarities of the load. For example, in [9], the supply of palletized fruits and vegetables from different farms to one point with vehicles was optimized. The study was conducted in the logistics company Gali Group, located in Sicilia, Italy. The Ant Colony Optimization algorithm was used to optimize the mileage and number of vehicles. In solving this task, however, time windows were not taken into account, which is provided for further research. Another case is the transport of containers, which allow the vehicles to stay for a short period at the loading and discharging points and to be serviced quickly. Tasks of a similar type are considered in [18].

Other authors have also addressed the issues of synchronous operation of vehicles and loading and discharging points. With regard to the service of trucks, where there is uncertainty at the time of arrival, a fuzzy queue system of the main flow has been established and the optimal speed of service in a fuzzy environment has been studied. [14]. In [15], the trucks' turnaround time and the utilization rate of the dock yard were taken into account at the same time, and the planning model and the simulation joint optimization method were used to calculate the maximum number of reserved trucks that can be accepted during the period. In general, it can be noted that existing publications on this issue have their limits. Some of them simply analyze the planned arrival of vehicles, others study the optimization of loading/discharging resources and still others study the optimization of loading/discharging processes with current planning on arrival of vehicles, etc. Less time is devoted to solving the set tasks with the different methods.

The application of different methods for optimization and solving problems related to transport modeling and logistics of the vehicle routing problem type with or without constraints of delivery within specified time windows are analyzed in [12]. It is reported that 62% of the suitable methods are meta-heuristics, only in 18% of the cases are exact methods (mathematical programming) used and in 20% of the cases, other methods are used. The analysis helps to more quickly select an appropriate test method. Basically, these are genetic algorithms, ant colony system, simulated annealing and taboo search. However, the time for solving the set tasks with the different methods is not specified. Such tasks are discussed in [7]. It defines the time for solving tasks of the vehicle routing problem type with or without constraints of delivery within specified time windows. Exact results related to solving routing tasks are presented in [12]. It is noteworthy that the genetic algorithm yields the best results, while taboo and Ebola prove to be more efficient algorithms in terms of computational times.

Currently, considering customers' demands for fast delivery, finding the right solutions in a short time period is of great importance. Sometimes, it is related to whether a company will continue its activities or will have to close it.

2. DETERMINATION OF THE SYNCHRONOUS OPERATION OF POINTS AND VEHICLES

2.1. Theoretical bases of synchronous operation of vehicles and loading and discharging points

At cargo handling points, deliveries are made by vehicles that travel long, medium and short routes. In the case of short routes, the organization of work between loading and discharging points and vehicles is rarely disrupted because the random factors that can disrupt the rhythm of work are few and predictable. When in the points are serviced, vehicles arriving from long, medium and short routes, then difficulties often arise in acceptance at the loading and unloading points. On long routes, drivers are exposed to a number of predictable and unpredictable events, such as driving at night, in rain, fog, snow, congestion and other scenarios, which lead to greater fatigue and stress. This creates the preconditions for road accidents [18] and often affects the health of drivers [8], who have seen increased demand in recent years. [13] points out that, on average, of the 8.5 million employed in the transportation, warehousing and utilities super sector in the United States of America, 28% were obese due to reduced physical activity. Mainly, the presence of hypertension was reported in 49% of workers over the age of 65 and 20% in the age group 25-64 years. This shows how risky and dangerous work in this sector is in terms of implications for health. Another important feature is when vehicle drivers arrive at the end points and the rhythm of work is disturbed; they have to wait a long time, move vehicles for short distances for a short time at different lengths of time until they are serviced, the risk of fatigue increases and a desire to sleep arises [10]. In [11], a detailed study was carried out on the problems of vehicle drivers in Australia during the delivery of goods to the final points. It has been found that although there is legislation governing driving and rest times for drivers, often, due to inefficiency in cargo management, their fatigue increases. The results of the study show that to reduce driver fatigue, good communication between drivers, carriers and customers should be ensured when booking, adopting a reservation system for time intervals for receiving and sending goods and ensuring maximum recovery. From what has been considered so far, it is clear that a necessary condition for the proper organization of the movement of vehicles on the route is their synchronous operation with the loading and discharging points. This condition is achieved when the rhythm of operation of the loading and discharging points is equal to the interval of movement of vehicles [5]. The rhythm of operation of point R is the time interval between two laden or unloaded vehicles leaving the station,

$$R = \frac{t_{t(r)}}{X_{t(r)}}, \tag{1}$$

where $t_{t(r)}$ is the time for loading/discharging the vehicle;

$X_{t(r)}$- the number of loading/discharging points at the station.

The condition for synchronous operation is expressed by equality $R = I$, where $I = \frac{t_0}{A_m}$ or

$$\frac{t_{t(r)}}{X_{t(r)}} = \frac{t_0}{A_m}. \tag{2}$$

It follows from equality (2) that the required number of posts $X_{t(r)}$ with a certain number of vehicles A_m, working on the routes

$$X_{t(r)} = \frac{t_{t(r)}A_m}{t_0} \tag{3}$$

or the required number of vehicles is

$$A_m = \frac{t_0 X_{t(r)}}{t_{t(r)}}. \tag{4}$$

If there are several loading and discharging points along the route, in each of which there is a certain number of posts, then, their total number is

$$\sum X = \sum X_t + \sum X_r + \sum X_{t-r}, \tag{5}$$

where $\sum X_t, \sum X_r, \sum X_{t-r}$ are, respectively, the total number of loading, unloading and loading–discharging posts at all points of the route.

n_t, n_r, n_{t-r} denote, respectively, the number of loading, unloading and loading–discharging points along the route; then, the equation for determining the required number of posts at all points on the route in the presence of synchronous operation of loading and discharging points and vehicles acquires the form

$$\sum X = \frac{A_m v_t (t_t n_t + t_r n_r + t_{t-r} n_{t-r})}{l_0 + v_t (t_t n_t + t_r n_r + t_{t-r} n_{t-r})}, \tag{6}$$

where l_0 is the length of one turnover, km; v_t is the technical speed of the vehicle, km / h.

With the specified dependence (6), the required number of posts in all points of the route can be determined in the presence of synchronous operation of the loading and discharging points and the vehicles.

2.2. Violation of the synchronous operation of vehicles and loading and discharging points

The synchronous operation of vehicles and loading and discharging points is disrupted when delays occur in the operation of posts or vehicles, for any reason.

In this case, a violation of the equality $R = I$ occurs, where $R \neq I$.

In cases where $R > I$, the vehicles are waiting to be loaded or unloaded and vice versa; when $R < I$, the vehicles are standing at the points of loading and discharging points, [5].

If the difference $R - I$ is denoted by Δt, then, for $R > I$, the quantity Δt will have a sign "+" and vice versa for $R < I$; Δt will have a sign "-".

The determination of Δt for $R > I$ or $R < I$ at the loading point is performed using the expression $R = t_t / X_t$.

For the travel interval I for a linear reversible route using the mileage in only one direction,Δt is determined by the dependence

$$\Delta t = \frac{t_0}{X_t} - \frac{\frac{l_0}{v_t} + t_{t-r}}{A_m} = \frac{A_m t_t v_t - l_0 X_t - X_t t_{t-r} v_t}{A_m v_t X_t}, \tag{7}$$

where t_{t-r} is the time for loading and discharging at the start and end point, hours.

The dependence for Δt at the discharging point will be

$$\Delta t = \frac{A_m t_r v_r - l_0 X_r - X_r t_{t-r} v_t}{A_m v_t X_r}, \tag{8}$$

The time Δt represents the stay of the second arriving vehicle at the loading or discharging point, respectively, while the first vehicle is considered not to be parked. The length of stay of the n^{-th} arriving vehicle at the loading or discharging point will be

$$\Delta t_n = \Delta t(n-1), \tag{9}$$

where Δt for a loading point is calculated using formula (7) and for a discharging point according to (8).

The total stay $\sum \Delta t_i$ of all vehicles i waiting to be loaded or unloaded is obtained as the sum of the arithmetic progression of the dependence.

For the point of loading

$$\sum \Delta t_i = \frac{A_m t_t v_t - l_0 X_t - X_t t_{t-r} v_t}{A_m v_t X_t} \frac{(n-1)n}{2}. \tag{10}$$

For the point of discharging

$$\sum \Delta t_i = \frac{A_m t_r v_r - l_0 X_r - X_r t_{t-r} v_t}{A_m v_t X_r} \frac{(n-1)n}{2}. \tag{11}$$

The obtained formulas for non-productive stops allow the assumptions that all posts at the checkpoints are evenly loaded, there are no delays in the process of traffic on the route, when maneuvering them and when approaching and leaving the checkpoints and that loading and discharging times are relatively constant. As a rule, these conditions cannot always be fulfilled for a number of random reasons, the impact of which cannot be pre-calculated with functional dependencies. As a result, sometimes, very significant changes occur both in the arrival of vehicles at the checkpoints and in the operation of the individual posts. All this shows that the rhythm of work at the loading and discharging points and the interval of movement of vehicles are random variables. The study of these quantities to reduce delays can be performed by calculation of mathematical statistics.

Specifically, the vehicle-loading and discharging point system can be considered as a queuing system, which consists of a number of service devices (loading and discharging mechanisms), incoming flow of requests (vehicles entering the loading and discharging point) and characteristics of the "behavior" of the requests (vehicles) during service and outbound flow (vehicles leaving the checkpoint), for this can use "queuing theory".

In practice, in the transport and warehousing activity, a number of tasks arise related to ensuring the synchronous operation of vehicles and loading and discharging points. One of the solutions for planning the work is to set requests from the carriers for possible time windows of stay for carrying out loading and discharging works of the vehicles, followed by a serviceability check and an affirmative or negative answer; Fig. 1.

2.3. Mathematical model

To solve the case in question, a simulation will be performed, in which it is assumed that n a number of loading and discharging activities per vehicle (truck) are performed in a given warehouse (if one vehicle performs more loading and discharging activities, it is assumed that these activities are performed by different vehicles, ie, the number of vehicles is equal to the number of activities). Each vehicle can perform this activity on one of the given m number of ramps in a certain time window and with a certain duration of the loading and discharging activity. It is also necessary to take into account the technical time required to leave the previous vehicle that has operated on one ramp and the entry of another on the same ramp (this is the time to "pull" a previous vehicle and enter a new one on the same ramp). The main goal is to find a valid plan in terms of which vehicle, on which ramp and at what time to start loading and discharging activities so that the necessary requirements for time windows of individual vehicles are met and there is no overlap in their activities of one and the same ramp. From a practical point of view, it is appropriate for the time of commencement of loading and discharging activity of each vehicle to be as close as possible to the beginning of its time window and to be in this time window.

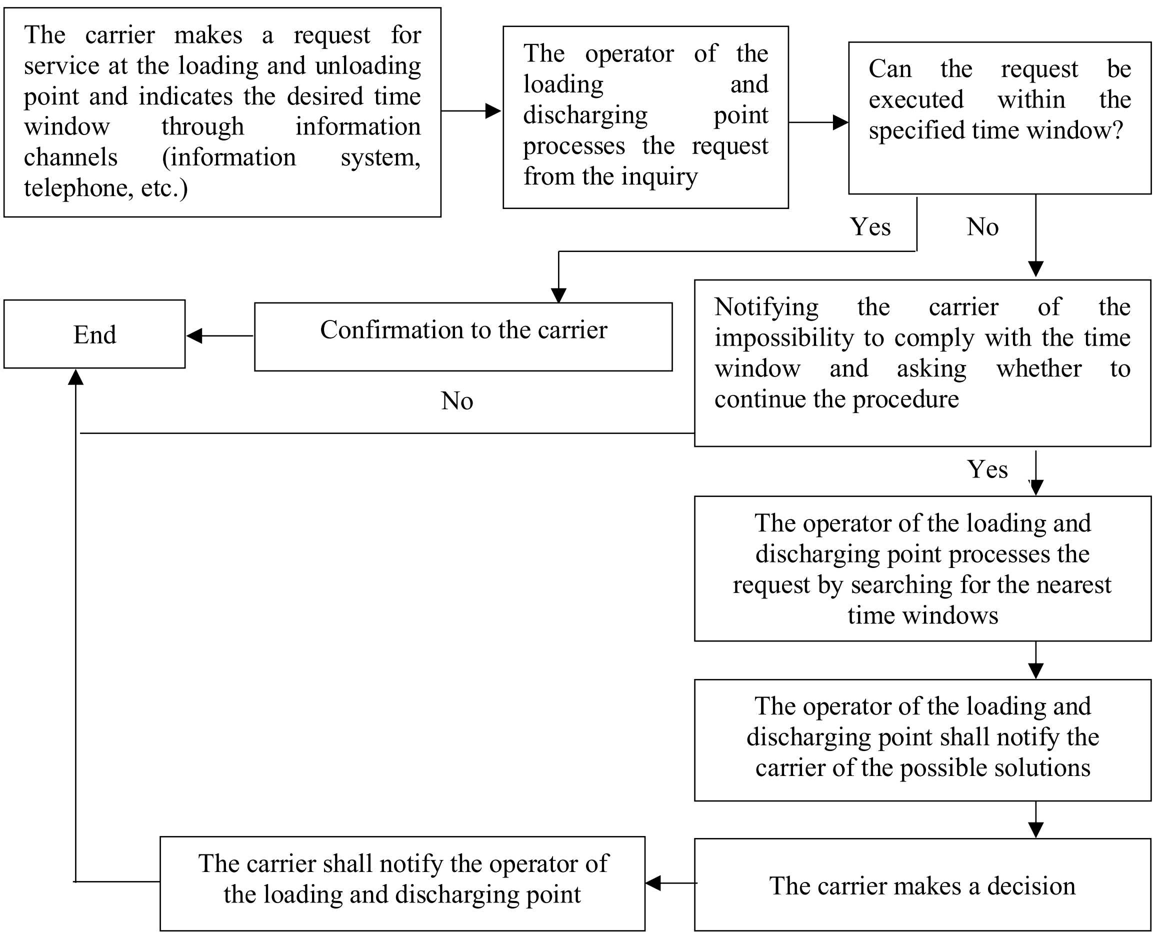

Fig. 1. Scheme for notifying the drivers for acceptance at the point

To compile a mathematical model of the task, the following notations are introduced:
m – the number of ramps;
n – the number of loading and discharging activities (number of vehicles);
t_i^1 – the moment before which it cannot begin i activity, $i = \overline{1,..n}$;
t_i^2 – the moment before which it must have ended i activity, $i = \overline{1,..n}$;
t_i – the duration of i activity, $i = \overline{1,..n}$;

p – the minimum technical time required for the "withdrawal" of the previous vehicle and the entry of the new one on the same ramp;

T_i – the moment it should start i activity (i The vehicle starts loading and discharging activity), $i = \overline{1,..n}$;

$$x_{ir} = \begin{cases} 1, & \text{if } i \quad activity \text{ is performed on } r \quad \text{ramp} \\ 0, & in\ the\ opposite\ case \end{cases} \quad i = \overline{1,..n}, \ r = \overline{1,..m}\,.$$

Until now, the moments are unknown:T_i in which the respective activities should start, as well as the ramps on which to enter - x_{ir}. The problem is modeled as a partially integer optimization problem with an objective function of the sum of the moments of starting the activities to be minimal [6]:

$$\min Z = \sum_{i=1}^{n} T_i\,. \tag{12}$$

The limitations are as follows:

$$t_i^1 \le T_i \le t_i^2, \forall\, i = \overline{1,..n} \qquad 13)$$

$$\sum_{r=1}^{m} x_{ir} = 1, \ \forall\, i = \overline{1,..n}. \tag{14}$$

If two activities are on the same ramp, one of the following two inequalities is satisfied:

$$T_i + t_i + p \le T_j + \left(2 - x_{ir} - x_{jr}\right)M, \forall\, i,j = \overline{1,..n}\,, \forall\, r = \overline{1,..m} \tag{15}$$

$$T_j + t_j + p \le T_i + \left(2 - x_{ir} - x_{jr}\right)M, \forall\, i,j = \overline{1,..n}\,, \forall\, r = \overline{1,..m} \tag{16}$$

$$x_{ir} \in \{0,1\},\ T_i \in \mathbb{R}^+, M \gg 1. \tag{17}$$

Restrictions (13) are imposed to comply with the time window of each activity. Restriction (14) ensures that an activity can be performed exactly on one ramp. Restrictions (15) relate to the fact that if $i^{-\text{та}}$ $and\ j^{-\text{та}}$ activities are to be performed on the same ramp and if $i^{-\text{та}}$ is before $j^{-\text{та}}$activity, then the sum of the moment of activity T_i, the time for this activity t_i and the minimum technical time p must be before the moment T_j of $j^{-\text{та}}$ activity. The interpretation of restriction (16) is analogous only that in this case, $j^{-\text{та}}$ activity precedes $i^{-\text{та}}$. In inequalities (15) and (16), a very large positive number M≫1 is assigned for the value of M. If these two activities are performed on the same ramp, then, the binary variables x_{ir} and x_{jr} would take the value 1 at the same time and the expression $\left(2 - x_{ir} - x_{jr}\right)M$ in (15) and (16) would be canceled, as a result of which these inequalities would become active. If these activities are on different ramps, then at least one of the variables x_{ir}, x_{jr} will be canceled and inequalities (15) and (16) will always be fulfilled, ie, there is no sense in them because the activities are performed on different ramps.

The problem that arises in models (12) - (17) is that if two activities are performed on one ramp, exactly one of the two inequalities, (15) or (16), must be fulfilled for the respective indices. This leads to the non-convexity of the admissible area and the task thus set is not linear. This shortcoming can be remedied by introducing additional unknown binary variables [3]:

$$y_{ij} = \begin{cases} 1, & \text{if } i \quad \text{activity precedes } j \quad \text{activity} \\ 0, & in\ the\ opposite\ case \end{cases} \quad i,j = \overline{1,..n}.$$

Then, inequalities (15) and (16) will be modified as follows:

$$T_i + t_i + p \le T_j + \left(2 - x_{ir} - x_{jr}\right)M + (1 - y_{ij})M, \forall\, i,j = \overline{1,..n}\,, \forall\, r = \overline{1,..m} \tag{18}$$

$$T_j + t_j + p \le T_i + \left(2 - x_{ir} - x_{jr}\right)M + y_{ij}M, \forall\, i,j = \overline{1,..n}\,, \forall\, r = \overline{1,..m} \tag{19}$$

The final model of the task is the following partially integer linear optimization problem:

$$\min Z = \sum_{i=1}^{n} T_i, \tag{20}$$

$$t_i^1 \le T_i \le t_i^2, \forall\, i = \overline{1,..n} \tag{21}$$

$$\sum_{r=1}^{m} x_{ir} = 1, \ \forall\, i = \overline{1,..n} \tag{22}$$

$$T_i + t_i + p \le T_j + \left(2 - x_{ir} - x_{jr}\right)M + (1 - y_{ij})M, \forall\, i,j = \overline{1,..n}\,, \forall\, r = \overline{1,..m} \tag{23}$$

$$T_j + t_j + p \le T_i + \left(2 - x_{ir} - x_{jr}\right)M + y_{ij}M, \forall\, i,j = \overline{1,..n}\,, \forall\, r = \overline{1,..m} \tag{24}$$

$$x_{ir} \in \{0,1\}, y_{ij} \in \{0,1\}, T_i \in \mathbb{R}^+, M \gg 1. \tag{25}$$

Models (10) - (15) represent a partially integer problem; [1, 2, 4] it is known that in the general case, such problems are class NP complete problems (nondeterministic polynomial time). They are very time consuming as they take up a lot of time and memory resources. To solve them, it is not always appropriate to look for accurate algorithms, as the solution will take an unacceptably long time and resource of computational memory. For this purpose, a function that solves problem (10) - (15) is implemented in the Matlab software product. Matlab provides a rich suite of features for solving similar tasks, [21]. Different exact algorithms as well as different heuristic and genetic algorithms can be used [3, 19]. The latter do not always lead to an exact solution, but often yield a result very close to the optimal one. Given that the main goal is to find a valid solution that satisfies constraints (11) - (15) and in this case, objective function (10) is less important, such an option is perfectly acceptable.

The following is a software implementation for solving problem (10) - (15) implemented in the software product Matlab 2017b:

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function nTx=rampi(t,m,p)
M=max(max(t))*10;%M=500;
[n,~]=size(t);
T=zeros(n,1);
x=zeros(n,m);
y=zeros(n,n);
Aeq=[];
beq=[];
for i=1:n
    yy=zeros(n,n);
    yy(i,i)=1;
   Aeq1=zeros(n,m);
   Aeq1(i,:)=1;
   Aeq=[Aeq
       [zeros(1,n) Aeq1(:)' zeros(1,n^2)]
       [zeros(1,n) zeros(n*m,1)' yy(:)']];
beq=[beq;1;0];
end
A=[];b=[];
for i=1:n
for j=i+1:n
T1=zeros(n,1);
        x1=zeros(n,m);
        y2=zeros(n,n);
        y2(i,j)=1;y2(j,i)=1;
A=[A
          T1(:)' x1(:)' y2(:)'];
       b=[b;1];
for r=1:m
           T1=zeros(n,1);
x1=zeros(n,m);
           y1=zeros(n,n);
           b1=[];b2=[];
           T1(i)=1;
           T1(j)=-1;
           x1(i,r)=M;
           x1(j,r)=M;
           y1(i,j)=M;
           A=[A
```

```
                T1(:)' x1(:)' y1(:)'
               -T1(:)' x1(:)' -y1(:)'];
            b1=3*M-t(i,3)-p;
    b2=2*M-t(j,3)-p;
            b=[b
               b1
               b2];
    end
    end
    end
    for i=1:n
    for j=1:i-1
    for r=1:m
            T1=zeros(n,1);
    x1=zeros(n,m);
            y1=zeros(n,n);
            b1=[];b2=[];
            T1(i)=1;
            T1(j)=-1;
            x1(i,r)=M;
            x1(j,r)=M;
            y1(i,j)=M;
            A=[A
               T1(:)' x1(:)' y1(:)'
               -T1(:)' x1(:)' -y1(:)'];
            b1=3*M-t(i,3)-p;
    b2=2*M-t(j,3)-p;
            b=[b
               b1
               b2];
    end
    end
    end
    lb1=t(:,1);
    ub1=t(:,2);
    lb2=zeros(n*m+n^2,1);
    ub2=ones(n*m+n^2,1);
    lb=[lb1;lb2];
    ub=[ub1;ub2];
    f=[ones(n,1)*1;0*ones(n*m,1);zeros(n^2,1)];
    s=n+1:n+m*n+n^2;
    opt=optimoptions('intlinprog','Heuristics','basic','MaxTime',3000);%,'AbsoluteGapTolerance',1e-
3,'ConstraintTolerance',1e-%3,...
    % 'IntegerTolerance',1e-3,'LPOptimalityTolerance',1e-7,'ObjectiveImprovementThreshold',1e-
3,'RelativeGapTolerance',1e-3,...
    % %'CutGeneration','basic','CutMaxIterations',10,'MaxTime',300);
    %'basic'
    %'intermediate'
    % 'advanced'
    % 'rss'
    % 'rins'
    % 'round'
    % 'diving'
```

```
% 'rss-diving'
% 'rins-diving'
% 'round-diving'
% 'none'
[X,Z]=intlinprog(f,[s],A,b,Aeq,beq,lb,ub,[],opt);
%[X,Z]= ga(@(x)0,length(f),A,b,Aeq,beq,lb,ub,[],s)
T=X(1:n);
x=reshape(X(n+1:m*n+n),n,m);
y=reshape(X(m*n+n+1:end),n,n);
x=round(x);
x=x*[1:m]';
y=round(y);
nTx=[[1:n]' T x];
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Input arguments are an array t and in each line are set, respectively, the earliest time in which the activity must have started, the latest time in which the activity must have ended and the time for the activity itself. The next input argument is the number of ramps - m. The last argument is the technical time - p. The output argument is an array, in the rows of which are described, respectively, the number of the activity, the moment at which it should start and the number of the ramp where the activity should be performed.

In the following cases, formally, the time starts from zero and all times are in minutes.

2.4. Simulation results

Two cases have been considered. The first case includes three ramps and eight vehicles, and the second case includes three ramps with eight vehicles.

Case 1: $m = 3$ ramps, six vehicles and technical time for entering and leaving the vehicle from the place of processing of the ramp $p = 5$ are given. Table 1 shows the time windows and the times for performing the activities for the six vehicles.

Table 1

Activities, time windows, and times for carrying out the activities in case 1

Vehicle number/ Activity	A moment after which the activity can be started	A moment before which the activity must have ended	Activity time
1	0	50	30
2	10	68	40
3	5	35	20
4	15	75	40
5	30	55	20
6	25	80	25

The input data areset in Matlab as follows:

```
>>t=[0 50 30
 10 68 40
 5 35 20
15 75 40
30 55 20
25 80 25];
>>m=3;
>>p=5;
```

The function is called:
>>nTx=rampi(t,m,p)

The result from it is:

Vehicle	**Time to start the processing**	**Ramp number**
nTx =		
1.0000	0	3.0000
2.0000	10.0000	1.0000
3.0000	5.0000	2.0000
4.0000	30.0000	2.0000
5.0000	55.0000	1.0000
6.0000	35.0000	3.0000

The solution of the problem shows that a valid plan has been found, in which all vehicles will be serviced and their total waiting time will be the least. The interpretation is as follows: the first activity (vehicle) arrives at the moment $T_1 = 0$ on the third ramp and is processed there. The second activity starts at the moment $T_2 = 10$ on the first ramp, the third activity at the moment $T_3 = 5$ on the second ramp, fourth activity on the second ramp, the fifth activity on the first ramp, the sixth activity on the third ramp, etc.

Case 2. $m = 3$ ramps, eight vehicles and technical time $p = 5$ are given. Table 2 shows the time windows and the times of the activities.

In the second case, there is again a solution to the problem; a valid plan has been found in which all vehicles will be serviced and their total waiting time will be the least. The distribution of vehicles is as follows: the first, sixth and seventh vehicles will be serviced on ramp two. The second and eighth vehicles will be serviced on ramp one. The remaining vehicle numbers three, four and five will be serviced on ramp 3.

Table 2

Activities, time windows, and times for carrying out the activities in case 2

Vehicle number/ Activity	**A moment after which the activity can be started**	**A moment before which the activity must have ended**	**Activity time**
1	5	55	45
2	20	80	45
3	15	55	35
4	40	90	45
5	0	35	20
6	60	95	15
7	45	85	20
8	10	80	20

Solution:

Vehicle	**Time to start the processing**	**Ramp number**
1.0000	5.0000	2.0000
2.0000	35.0000	1.0000
3.0000	25.0000	3.0000
4.0000	65.0000	3.0000
5.0000	0	3.0000
6.0000	80.0000	2.0000
7.0000	55.0000	2.0000
8.0000	10.0000	1.0000

If a situation arises in which a valid plan cannot be found, then, the time for processing the vehicles with the drivers, whose time intervals coincide and should be adjusted, is specified. If this does not happen, they will not be serviced, which sometimes happens in such situations.

3. CONCLUSION

The study found that both in Bulgaria and in the rest of the world, not all companies use professional product programs to compile routes for their vehicles in the presence or absence of time constraints. This necessitates the use of various mathematical models to find solutions in which to find suitable time windows at cargo handling points so that drivers are satisfied in terms of waiting time. For the purposes of such a task, in which ramps are used in the loading and discharging activity, as is the case with courier companies and companies for small consignments in the cities, a mathematical model and algorithm have been compiled to solve such tasks. The results of the study, conducted by simulation in Matlab, show that the model can be used to solve such problems, where, according to the situation, a valid plan is obtained, in which the vehicles with pre-specified time intervals are processed from the end point at total minimum waiting time. In cases where the time intervals of the waiting vehicles are such that a valid plan cannot be drawn up, another solution is sought, in which a compromise should be made between the drivers and the workers in the warehouse, again maintaining the minimum total waiting time for all vehicles.

In the simulation performed with three ramps and eight vehicles, a valid plan and a total minimum waiting time for vehicles were obtained, when ramp one accepts the second and eighth vehicles, ramp two accepts the first, sixth and seventh vehicles and ramp three accepts vehicles with numbers three, four and five.

Acknowledgment

This research received funding from the Ministry of education and science under the National science program “Intelligent animal husbandry”, grant agreement N°Д01-62/18.03.2021.

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Received 18.05.2020; accepted in revised form 02.12.2021